LAHAINA GREEN STORMWATER INFRASTRUCTURE DRAINAGE SUPPLEMENT



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EXECUTIVE SUMMARY

The *Lahaina Green Stormwater Infrastructure (GSI) Drainage Supplement* provides a comprehensive update to the 2005 Lahaina Town Drainage Master Plan, integrating nature-based solutions to address stormwater management challenges in the wake of the August 2023 wildfires. Prepared for the Maui County Department of Public Works and the U.S. Environmental Protection Agency, this report outlines a hydrologically driven approach to rebuilding Lahaina with resilience, sustainability, and cultural sensitivity.

Purpose and Scope

The supplement aims to:

- Integrate green stormwater infrastructure (GSI) into Lahaina's drainage system to reduce flooding and improve water quality.
- Update infrastructure mapping and modeling for key drainage areas (Line R and Lines O/D).
- Provide science-based recommendations for hydrologic restoration during redevelopment.

Key Findings

- Lahaina's drainage system is outdated and undersized, contributing to frequent flooding and water quality impairments.
- The 2005 Master Plan's recommendations were not implemented, leaving certain vulnerabilities.
- Modeling shows that widespread GSI implementation could significantly reduce runoff volumes, peak discharge rates, and pollutant loads.
- The Lahaina community is well-positioned to incorporate GSI into rebuilding efforts to achieve water resource, cultural restoration, and climate sustainability goals.

Recommendations

1. **Pilot Projects**: Eight site-specific GSI projects in Drainage Areas R and O/D demonstrate practical applications of bioretention, permeable pavements, tree trenches, and constructed wetlands.
2. **Widespread GSI Integration**: Recommendations are tailored to parcel types—residential, commercial, public, and park areas—with scalable GSI practices.
3. **Policy and Code Enhancements**: Suggestions include enforcing existing stormwater rules, integrating GSI into street design manuals, and adopting a GSI-first approach for public projects.
4. **Modeling Results**: Hydrologic and water quality modeling confirms that GSI can reduce stormwater volumes by up to 90% and pollutant loads by over 80% in some areas.

Implementation Strategy

- Align GSI efforts with concurrent recovery initiatives such as the Lahaina Long-Term Recovery Plan and One Water Strategy.
- Provide technical support and incentives for homeowners and developers.
- Acquire key parcels for public GSI projects and ensure long-term maintenance capacity.

Conclusion

This supplement positions GSI as a cornerstone of Lahaina's recovery and future resilience. By restoring natural hydrology and integrating sustainable stormwater practices, Lahaina can rebuild in a way that honors its cultural heritage, protects its environment, and prepares for climate change.

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1.0 INTRODUCTION

This report is prepared for the United States Environmental Protection Agency (EPA) Office of Community Revitalization under Call Order No. 68HERH24F0399 to support recovery efforts in Lahaina, Maui after the devastating August 2023 wildfires. This report serves as a supplement to the 2005 Lahaina Town Drainage Master Plan (DMP) to guide the Maui County Department of Public Works in how to integrate green stormwater infrastructure (GSI) and nature-based solutions into the stormwater drainage system in Lahaina. The 2005 Master Plan included a host of recommendations for gray infrastructure improvements that largely focused on enlarging pipes and outfalls and creating some additional drainage networks to divert and reroute flows from undersized networks. These recommendations in the 2005 plan were not implemented. The Lahaina wildfires and subsequent reconstruction efforts have renewed County and local interest in improving the drainage system in Lahaina, but with a recognition that green and nature-based stormwater management systems can provide multiple benefits to Lahaina that the more traditional (from an engineering perspective) gray infrastructure approaches typically cannot provide.

This report builds on the 2005 Master Plan, using a HydroCAD hydrologic and hydraulic model to simulate the stormwater flows through the existing Lahaina drainage system and comparing that to a set of recommended improvements that includes GSI. The 'existing' system and land use/land cover conditions evaluated in the analysis represented the conditions just before the August 2023 fire, so that these pre-fire conditions could serve as the point of reference for future improvements. While we know that certain parcels will be redeveloped to conditions that differ from the pre-fire condition, properties generally are permitted to rebuild to at least the pre-fire conditions without additional land use approvals. By means of providing an example for the rest of the Lahaina study area, this report focused drainage modeling and site specific GSI concept examples in two particular drainage areas in the center of the study area. These concepts were then used to apply more general GSI recommendations across the full Drainage Master Plan (DMP) study area based on certain site characteristics and reconstruction/ redevelopment/ conservation opportunities that may present themselves. In addition, the analysis and recommendations consider potential future changes in land use, through reconstruction and finding other opportunities to integrate GSI into the landscape. The analyses and recommendations in this report consider climate change by incorporating greater rainfall design storm volumes as well as by recognizing coastal flood conditions, rising groundwater conditions, and hydrologic restoration opportunities, and by presenting an overall approach to hydrologic restoration through widespread GSI implementation.

1.1 Purpose

This supplement recommends an approach to incorporating GSI into community recovery that carries an overarching goal of restoration. Restoration of the community, restoration of the natural hydrology, restoration of the coastal water quality, and restoration of the cultural connection to the flow of water through the community. Objectives of this effort include:

1. Envision how GSI could be integrated into the stormwater drainage system of Lahaina to both reduce flooding issues and improve water quality. The community has an expressed desire to rebuild a more resilient Lahaina. The 2005 Drainage Master Plan (DMP) focused primarily on expanding the capacity of the piped drainage network to alleviate flooding concerns. A management approach that incorporates GSI also provides opportunities to improve water

quality, restore the area's natural hydrology, and offer additional co-benefits to the community (e.g., biodiversity, cooling, health).

2. Update drainage infrastructure mapping, modeling, and management recommendations from the 2005 DMP within the two largest contributing drainage areas. The original hydrologic and hydraulic modeling for the 2005 Drainage Master Plan was based on existing infrastructure 20 years ago. Since then, drainage infrastructure and hydrologic conditions have changed, which required revisions to drainage mapping and creation of new H&H models. To meet government contract time constraints, we focused our effort within two key drainage lines (Line R and Lines O/D). The results of this work serve as an example for how the DPW could complete mapping and modeling updates to the remaining areas of Lahaina.

3. Provide science-based recommendations for the restoration of hydrology during redevelopment through GSI. There are many competing (and synergistic) objectives for the rebuilding of Lahaina. The recommendations from this report are developed with the perspective that recovery and reconstruction can also work to restore the hydrology in Lahaina, and are provided as reference material to support community redevelopment efforts.

1.2 Guiding Principles

In preparing this plan, we worked to employ the following guiding principles in our work:

Listen to the local community and local practitioners to understand the experience that is lived in Lahaina and integrate those realities into our understanding of existing conditions and the recommendations evaluated and included in this plan.

Reflect the culture of Lahaina in the types of recommendations included in this plan, and the creativity of the vision that we explore in this plan.

Nurture the water system from mauka to makai, with recognition that the land and water throughout the watershed are integral to the health of the community and coastal waters.

Recognize the current status and reality of fire recovery, as both an immense community-altering challenge and an opportunity for restoration.

Simple and effective communication about this plan will serve the community well as it moves toward implementation and restoration.

1.3 Concurrent Planning and Recovery Efforts

This GSI update to the Lahaina Drainage Master Plan was developed concurrently with and with awareness of several other important plans and projects underway. Many of the other efforts are related to the reconstruction efforts following the 2023 Lahaina Wildfire, and some are longer term efforts that were underway when the fire occurred. The wildfire recovery efforts are primarily outlined in the **Lahaina**

Long-Term Recovery Plan (LTRP) (Dec 2024)[1]. This plan outlines the short (1-2 year), mid (3-5 year), and long-term (6+ year) recovery projects planned by Maui County. Several key elements of the recovery plan with particular relevance to the GSI Update to the Lahaina Drainage Master Plan include:

- Rebuilding with Resilience (Section 6.5, LTRP Recovery Principles) includes embedding resilient design into adaptations strategies and projects.
- Project: Asset Management and Acquisitions Program (Short-term)
- Project: Infrastructure Assessment and Improvement Studies (Short-term)
- Project: Affordable Rental Housing Program (Short-term)
- Project: Street Connectivity and Extensions (Mid-term)
- Project: Stormwater Resilience and Flood Risk Management (Mid-term)
- Project: Community Facilities (Mid-term)
- Project: Wai and Watershed Planning (Mid-term)
- Rebuild the West-Maui Senior Center (Mid-term)
- Project: Creation of a Cultural Corridor and Restoration of the Moku'ula and Loko o Mokuhinia Complex (Long-term)

Lahaina Affordable Housing Programs, which will include purchasing properties and constructing public affordable housing for residents of Lahaina.

Lahaina Royal Complex Plan[2], which aims to restore Lahaina's natural wetland coastal ecosystem and cultural historical sites as part of a significant effort to restore, honor and protect culturally significantly sites within a cultural corridor in Lahaina. The focus of this plan includes, in particular, the potential restoration of Malu'ulu o Lele Park to a culturally significant wetland system.

Lahaina Watershed Flood Risk Management Project[3], which focuses on the design of a flood diversion system consisting of berms and detention basins mauka of Honoapiilani Highway and discharging to nearshore coastal waters south of Kaua'ula Stream.

One Water Strategy for Lahaina, described in the 2025 Maui State of the County address[4] as "a coordinated water management plan that takes a holistic approach to managing drinking water, wastewater and stormwater, while addressing post-fire recovery challenges and ensuring Lahaina's long-term sustainability."

1.4 Green Stormwater Infrastructure (GSI)

Green stormwater infrastructure uses filtration, infiltration, and evapotranspiration to treat and soak up rainwater where it falls. It can deliver multiple environmental, social, and economic benefits beyond stormwater management alone. Terms such as nature-based solutions, green infrastructure, and low-impact development are also used to describe GSI installations, and there is overlap between these concepts. When GSI systems are thoughtfully designed to achieve site-specific or broader community

[1] Online portal of the Lahaina Long-Term Recovery Plan (December 2024), which is a living document to track and guide recovery efforts of the County of Maui. https://www.mauirecovers.org/lahaina
[2] https://www.mauirecovers.org/recover/lahaina-royal-complex
[3] https://www.mauirecovers.org/recover/stormwater-resilience-and-flood-risk-management
[4] Maui County Press Release, March 7, 2025: https://www.mauicounty.gov/CivicAlerts.aspx?AID=16233

objectives, they can provide cleaner air and water, protect against flooding and excessive heat exposure, maintain groundwater levels, provide diverse habitat, and create beautiful green spaces for all to enjoy. [5] Individual GSI options are usually referred to in local regulations and design guides as GSI best management practices (BMPs), but EPA references tend to use the term stormwater control measures (SCMs). For the purpose of this supplement, we use both acronyms depending on the context, but with the same meaning.

GSI SCMs generally fall into four main categories: rainwater harvesting, filters, infiltration, and constructed wetlands. The specific SCMs proposed throughout this supplement are described in **Table 1** and presented in **Figure 1** and **Figure 2.**

It can be challenging to retrofit dense urban areas with GSI due to space limitations, existing infrastructure, lack of easements, construction costs, and limited maintenance capacity. Redevelopment, infill, road repaving, and utility upgrades offer the best opportunities to provide better stormwater management. It is not difficult to rethink how parking lots and other hardscapes can minimize runoff, envision how parks and community open space can become multi-functional landscapes, and reimagine how collectively, individual homeowners can contribute to more sustainable neighborhoods.

While the use of GSI is not yet widespread on Maui or in Lahaina, there has been a significant effort to support its use. There are several helpful Hawaii and other island-specific reference guides available that further describe the practices and provide technical guidance on selection, design, and maintenance. Information on construction and maintenance costs, pollutant removal performance, salt and wind tolerant native Hawaiian trees, and sizing procedures to provide water quality treatment or manage runoff volume can be found in these manuals. This Supplement to the Lahaina DMP refers to different types of GSI practices that can be used to manage stormwater in the study area. More detailed information on these practices can be found in the following references:

> **The Low Impact Development Practitioner's Guide for Hawaii (December 2023).** Hawaii Office of Planning and Sustainable Development, Coastal Zone Management Program. https://files.hawaii.gov/dbedt/op/czm/ormp/ormp_implementation/2023LIDPractitionersGuide.pdf
>
> This document is geared toward improving water quality in receiving waters, and provides guidance on how to incorporate a number of LID practices (also known as GSI practices) into new development and redevelopment projects. Practices presented include infiltration basins, rain gardens, permeable pavers, green roofs, tree box and planter boxes, rainwater harvesting practices, and others. This manual contains more Hawaii-specific images of practices installed in the ground than the Hawaii DOT manual includes.

[5] Excerpted from https://www.epa.gov/green-infrastructure/about-green-infrastructure.

Table 1. Summary of Proposed GSI SCMs by Category

GSI Category	Icon	SCM Name	Description
RAINWATER HARVESTING		**Rain Barrels**	Used to capture and store rainwater from roofs and downspouts for subsequent reuse, primarily for watering of vegetation.
		**Cisterns**	Used to capture and store rainwater from roofs and downspouts for subsequent reuse. Typically, significantly larger than rain barrels. Can be installed above-ground or subsurface.
INFILTRATION		**Native Tree/ Vegetation Planting**	Provide habitat while also enhancing evapotranspiration, infiltration, and healthy soils that together intercept rainfall and reduce storm water runoff. Native vegetation is adapted to the local climate and ecosystem.
		**Permeable Pavements**	Consists of pavement or interlocking paver blocks designed to allow storm water to infiltrate through voids in the pavement surface into an underlying stone layer. Includes porous asphalt, pervious concrete, and permeable pavers.
		**Underground Infiltration Chambers**	A subsurface storm water storage facility (a structural chamber or an excavated pit backfilled with a coarse stone aggregate) that receives and temporarily stores stormwater runoff, before slowly discharging through infiltration into the naturally permeable soil below.
		**Infiltration Basins**	A relatively large, shallow grass surface depression where storm water runoff collects and infiltrates into the underlying soil matrix.
FILTERS		**Tree Trenches**	Also known as a "tree box," this is a system of trees connected by an underground infiltration structure. On the surface, it looks like a row of ordinary street trees, but underground there is a system to manage incoming runoff, provides irrigation, and infiltrate into the ground.
		**Bioretention**	Vegetated depressions where runoff is directed through vegetation and designed soil mixtures for infiltration and treatment. Soil mix may include a combination of sand, organic matter, soil, or other media. May include *bioswales* that convey flow from one location to another.
		**Bioretention with Underdrains**	Vegetated systems with an underdrain system that collects the treated water and coneys it to the enclosed drainage system. *Stormwater planters* are a type of bioretention that function similarly but are installed above ground, as an elevated bioretention in a box.
WET-LANDS		**Constructed Wetlands/Loi Kalo**	Stormwater treatment systems that use natural processes of wetland vegetation, soils, and their associated microbial assemblages to remove pollutants, create wildlife habitat, and restore natural hydrology.

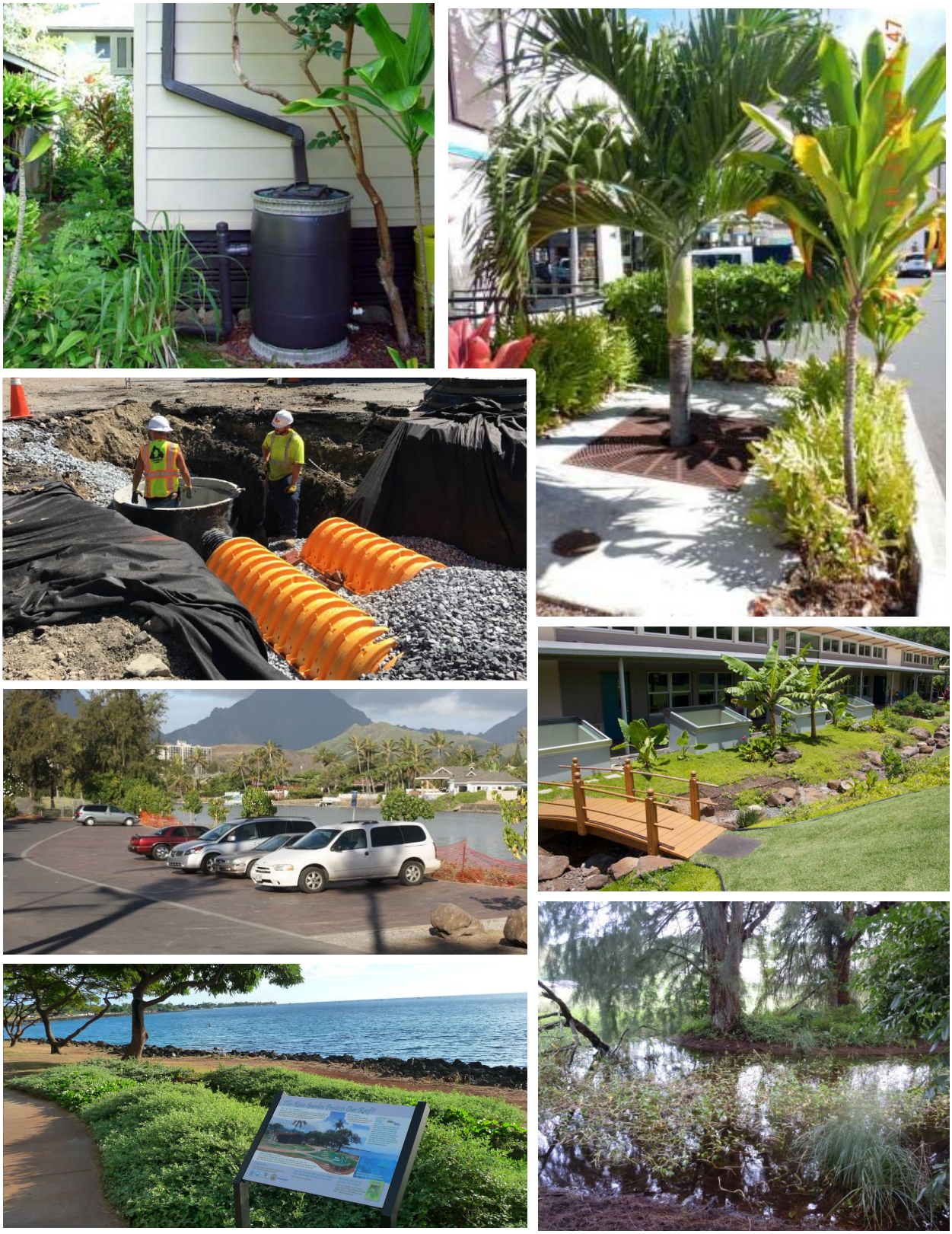


Figure 1. Example GSI SCMs.

From top left to bottom right: Residential rain barrel (Honolulu Board of Water Supply); Tree filter at market in Kahala, O'ahu (Bowers + Kubota Consulting); Underground chambers for infiltration or reuse at Boston school (Horsley Witten); Permeable brick pavers for parking at Kailua Beach Park (Hui o Ko'olaupoko); Infiltration trench at Punahou School (City and County of Honolulu); Infiltration basin at Ala Wai Golf Course (Bowers + Kubota Consulting); Bioretention raingarden at Wahikuli Wayside Park (Tova Calendar). Constructed stormwater wetland in the CNMI (Horsley Witten).



Figure 2. Renderings of GSI Practices from Honokowai.
These illustrate how GSI practices for filtering pollutants out of runoff can blend into the urban landscape.

Storm Water Post-Construction Best Management Practices Manual (February 2022). Hawaii State Department of Transportation, Highways Division, Storm Water Management Program. https://hdot.cdn.prismic.io/hdot/04d59dc7-5681-4965-a21c-e153bfa0e197_2022+Storm+Water+Post-Construction+Best+Management+Practices+Manual.pdf

This document uses the terminology Low Impact Development practices (LID Practices) instead of GSI terminology used in this document. Appendix A contains descriptions, images and example designs for details for 13 LID practices, including many of the practices recommended here, such as rainwater harvesting in rain barrels and cisterns, permeable pavements, infiltration basins, tree trenches, bioretention, bioretention with underdrains, constructed wetland, and tree box filters.

Website: Green Infrastructure for Stormwater Management (2018). Prepared and hosted by Hawaii's Sea Grant's Center for Smart Building and Community Design (SBCD) at the University of Hawaii, this website provides various information, tools, and resources about GSI practices in the context of Hawaii. https://seagrant.soest.hawaii.edu/sbcd-stormwater-practices/

Stormwater BMP Guide for New and Redevelopment for the City and County of Honolulu (July 2017). Prepared by the City and County of Honolulu Department of Planning and Permitting. https://www.honolulu.gov/swq/wp-content/uploads/sites/32/2023/10/SW_BMP_Guide_REVISED_July_2017.pdf

This guide provides planning and design guidelines to support implementation of the Honolulu City and County Rules Relating to Water Quality, which require that new development and redevelopment projects integrate Low Impact Development (LID) strategies and treatment practices to reduce pollution from storm water runoff.

Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID (February 2014). NOAA Coral Reef Conservation Program. Prepared by: Horsley Witten Group, Inc. and Center for Watershed Protection. https://www.coris.noaa.gov/activities/stormwater_lid/

This guide is intended to inspire practitioners to advance the application of LID practices (also known as GSI practices) in Hawaii, CNMI, Guam, American Samoa, USVI, and Puerto Rico by showing that it has been done before, and by outlining the steps to be successful. Practices discussed in the guide include bioretention practices, rainwater harvesting, and permeable pavement, among others.

Hawaii Rainwater Catchment Guide (2020). College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. This guide provides detailed information on structures and best management practices for rainwater harvesting for potable and non-potable reuse. https://www.ctahr.hawaii.edu/hawaiirain/guidelines.html

There are site-specific constraints, community preference, and climate-related factors that will likely influence GSI implementation. Site constraints are described for individual practices in most of the guidance manuals listed above. For example, the HDOT manual limits infiltration practices where soil permeability is low (<0.5 in/hr); groundwater levels are within 3 ft of the surface; if the practice is too close to septic systems or buildings (<35 ft), or property lines and roads (<10 ft); or if subsoils are

contaminated. High groundwater is generally found makai of the highway in Lahaina, which could limit the use of infiltration practices close to the shoreline and encourage the use of filtering practices with underdrains or practices that tap groundwater to maintain permanent pools, such as wetlands. There may be archeological or cultural resources in the vicinity that must be protected, or the site may be within existing or future hazard zones (e.g., sea level rise, flood zone), which may be space prohibitive. Practices with permanent pools may be undesirable due to community concerns related to stagnant water and mosquitos. Alternatively, community interest in increased use of native plants, shade canopy, and fire suppression may shape how vegetated GSI practices are landscaped.

The 2023 Hawaii LID Guide identifies several climate adaptation considerations for GSI to accommodate sea level and groundwater rise, coastal erosion, and coastal flooding, including use of:

- flood-resistant materials and anti-floatation designs for structures subject to inundation or high water tables,
- structures or overflow devices that promote rapid drainage,
- special additives to make concrete more resistant to corrosion, as well as stainless steel, plastic, or coated reinforcing bars,
- careful selection of salt, wind, and inundation tolerant vegetation, and
- berms and other protective measures to withstand wave action.

Table 2. Summary of GSI SCMs (Land Use Application, Pollutant Removal, and Maintenance)

GSI	SCM Name	Prime Land Use Application[1]	Pollutant Removal[2] Nutrients, Sediment, Pathogens			Maintenance[3]
	**Rain Barrels & Cisterns**	R, C, P Need a clear use for harvested runoff (irrigation, toilet flushing).	H	H	H	L
	**Native Tree/ Vegetation Planting**	R, C, T, P Great way to meet Hawaii native tree percentage requirements	--	--	--	L Less maintenance than non-native species; arborist to direct care & pruning
	**Permeable Pavements**	R, C, T (limited), P Common application for driveways and parking lots	H Lower for TN	H	H	M Less if designed to only manage what rains on it; may need to vacuum or sweep
	**Underground Infiltration Chambers**	R (multi-family), C, T, P May be most effective in areas mauka of highway	H Lower for TN	H	H	M include pretreatment; vactor truck and jet for flushing
	**Infiltration Basins and trenches**	R, C, T (limited), P Require space, mostly applied-maulka of highway	H Lower for TN	H	H	M include pretreatment; vactor truck and jet for flushing
	**Tree Trenches**	C, T, P Great in parking lots and along streets.	M	H	M	L arborist to direct care & pruning

GSI	SCM Name	Prime Land Use Application[1]	Pollutant Removal[2] Nutrients, Sediment, Pathogens			Maintenance[3]
	**Bioretention**	R, C, T, P Includes bioswales and simple raingardens.	H Lower for TN	H	H	M Landscape maintenance based species used
	**Bioretention with Underdrains**	*C, T, P* Use maki of highway, areas with limited infiltration, or where overflows can be tied into existing drain pipes.	M	H	H	M
	**Constructed Wetlands/Loi Kalo**	C, T, P Require larger spaces.	M	H	M	L Inspect to ensure biota flourishing and topographic diversity

[1] Most commonly applied in **R**esidential, **C**ommercial, **T**ransportation/Roads, and **P**arks (adapted from HDOT, 2023)
[2] **H**igh, **M**edium, or **L**ow removal effectiveness for three pollutants of concern sediment, nitrogen, and bacteria (Table 4.6 in 2023 Hawaii LID Practitioners Guide). Not shown are trash, metals, oil and grease, pesticides, and organics.
[3] **H**igh, **M**edium, or **L**ow maintenance needs based primarily on Table 4.7 in the Hawaii LID Practitioners Guide.

Practice selection and key design elements may also be determined based on the BMP's effectiveness of removing pollutants of concern, like sediment and nutrients, as well as consideration related to anticipated maintenance requirements. Table **2** includes general pollutant removal and maintenance information for various practices. The Maui development and subdivision permits include a breakdown of maintenance tasks for various GSI practices. Table 5.5 in the 2017 Honolulu BMP manual summarizes annual costs and annual labor hours for maintaining various BMPs. These costs are based on stateside estimates from 2012.

2.0 STUDY AREA CHARACTERISTICS

2.1 Lahaina Drainage Master Plan Area

The Lahaina moku[6] is located on the western slopes of the West Maui mountains on the mokupuni[7] of Maui. The Lahaina moku contains at least 10 ahupua'a[8]. The 2005 Lahaina Town Drainage Master Plan (DMP) focused on an 860 acre[9] study area (**Figure 3**) that drains to the ocean through direct drainage discharge outfalls as well as north and south into the Kahoma and Kaua'ula streams via overland flow and drainage discharges outfalls. The makai edge of the study area was determined largely by a diversion berm that aims to divert runoff from the upper slopes of the ahupua'a. For this report, the 2005 DMP

[6] Hawaiian word for island land division.
[7] Hawaiian word for island.
[8] Hawaiian word for an island land subdivision, similar in boundaries to a watershed area between mountain ridges.
[9] Note: The 2005 DMP contained a discrepancy between the areas depicted in the study area maps versus the narrative. The analysis represented in the GSI Supplement here reflects the information developed through GIS mapping that replicated the 2005 DMP study area boundary.

drainage area boundaries were replicated in GIS and then revised and updated by HW to incorporate changes associated with major changes to the land development landscape that have occurred since 2005, including primarily the Lahaina Bypass, two new residential developments adjacent to Kahoma Stream (Kahoma Villages and Komo Mai Street), and new condominiums and other structures on the south/east side of the study area. The updated drainage areas within the Lahaina DMP area are presented in **Figure 5** and form a basis for the understanding of drainage flow for this GSI Supplement.



Figure 3. Lahaina DMP Study Area

On the north side of Lahaina Town, the Kahoma Stream extends from the upper reaches of the West Maui mountains down through Lahaina Town and into the Pacific Ocean. One tributary to the Kahoma Stream, the Kanaha Stream, also comes from the West Maui mountains and joins the Kahoma Stream mauka of the Lahaina Bypass. Kahoma Stream is a vegetated channel until a point just makai of the Lahaina Bypass Road, at which point the stream is straightened and enters a reinforced concrete channel.

On the south side of Lahaina, the Kaua'ula Stream extends from the upper reaches of the West Maui mountains down through Lahaina, discharging into the Pacific Ocean at a reinforced concrete channel at the southern end of Lahaina. Most of Kaua'ula stream is vegetated channel except for the reinforced concrete section makai of Honoapi'ilani Highway.

Land uses in the study area consists largely of developed area, as well as smaller areas of grasslands (primarily fallow agricultural lands), forest and scrub/shrub areas (**Table 3**). The latest available land use or land cover mapping data for this study area is the National Oceanographic and Atmospheric Administration (NOAA) 2011 C-CAP Land Cover data, and this was used for this analysis to represent the land cover conditions just prior to the 2023 Lahaina wildfires (**Figure 4**).

Table 3. Land Uses within the Study Area (NOAA C-CAP, 2011)

Land Use	2011 Area (ac)
Barren Land	26
Cultivated Crops	3
Developed, High Intensity	380
Developed, Open Space	182
Evergreen Forest	83
Grassland	124
Open Water	5
Palustrine Emergency Wetland	18
Scrub/Shrub	40
Unconsolidated Shore	4
Total	**864**

The Drainage System

Stormwater drainage infrastructure within the study area is primarily comprised of short, limited-capacity culverts, catch basins, drain manholes, and pipe networks within Lahaina Town that outlet to streams and the ocean (Belt Collins, 2005). According to the 2005 DMP, there were 16 distinct major outfalls that discharged from the drainage network into the ocean, Kahoma Stream, and Kaua'ula Stream. Each of these outfalls was designated by a letter, and the drainage networks contributing to each outfall were delineated. These networks were modeled for the 2005 DMP using StormCAD to evaluate the capacity of the drainage system to each outfall to convey the runoff generated from the contributing area.

For this report, the drainage networks and tributary drainage areas were reviewed and recreated in HydroCAD. The drainage areas were revised or updated based on more recent information provided by Maui County representing land use changes and new developments that have occurred since 2005. In

addition, HW made further minor revisions to the drainage network and drainage area mapping based on observations during our May 2025 site visit. The revised drainage area map that served as a basis for analysis in this report is presented in **Figure 5** below.

In addition to the drainage infrastructure described above, a temporary flood diversion system was constructed in 1997 on the former Pioneer Sugar Mill property in response to a major flood event. In 2003, the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) formalized that temporary floodway diversion system to capture flow from runoff mauka of Lahaina and direct it to Kaua'ula Stream on the southern side of Lahaina. The diversion system included three basins to store and attenuate runoff. Portions of the system, although not the entire project, were sized to retain the 25-year storm. The diversion channel was maintained by volunteers. A permanent diversion channel, mauka of the current temporary system, has been under construction in stages starting after 2005, and is described in greater detail below.

Drainage Concerns

Lahaina has experienced at least 26 serious floods since 1879, the largest of which occurred as a result of a 21.7-inch rain event in 1960. In January 2002, a major storm event caused temporary flood control measures at the former Pioneer Sugar Mill property mauka of the Highway to fail, resulting in significant ponding on Wainee and Prisons Streets (in addition to Front Street and Malu'ulu o Lele Park). Prior to the mill's closure in 1999, cultivation of the mill property reduced the runoff that flowed down to Lahaina Town. Since then, the land has lain fallow, and runoff volumes have increased.

The 2005 Lahaina Town Drainage Master Plan identified drainage problems across the study area. The extent of the existing drainage pipe and ditch systems in Lahaina Town is limited, resulting in ponding of runoff in low spots and surface flow across roadways and through lots. One low spot, Malu'ulu o Lele Park, was formerly a fishpond and wetland that were integral to the historic Lahaina Royal Complex. The natural drainageway in this location has caused frequent flooding of nearby housing structures. A second low spot exists along most of Front Street. Areas of known flooding that were identified in the 2005 Lahaina Town Drainage Master Plan are shown below in **Figure 6**.

Figure 4. Land Cover



Figure 5. Lahaina DMP Drainage Areas (Updated from the 2005 DMP)

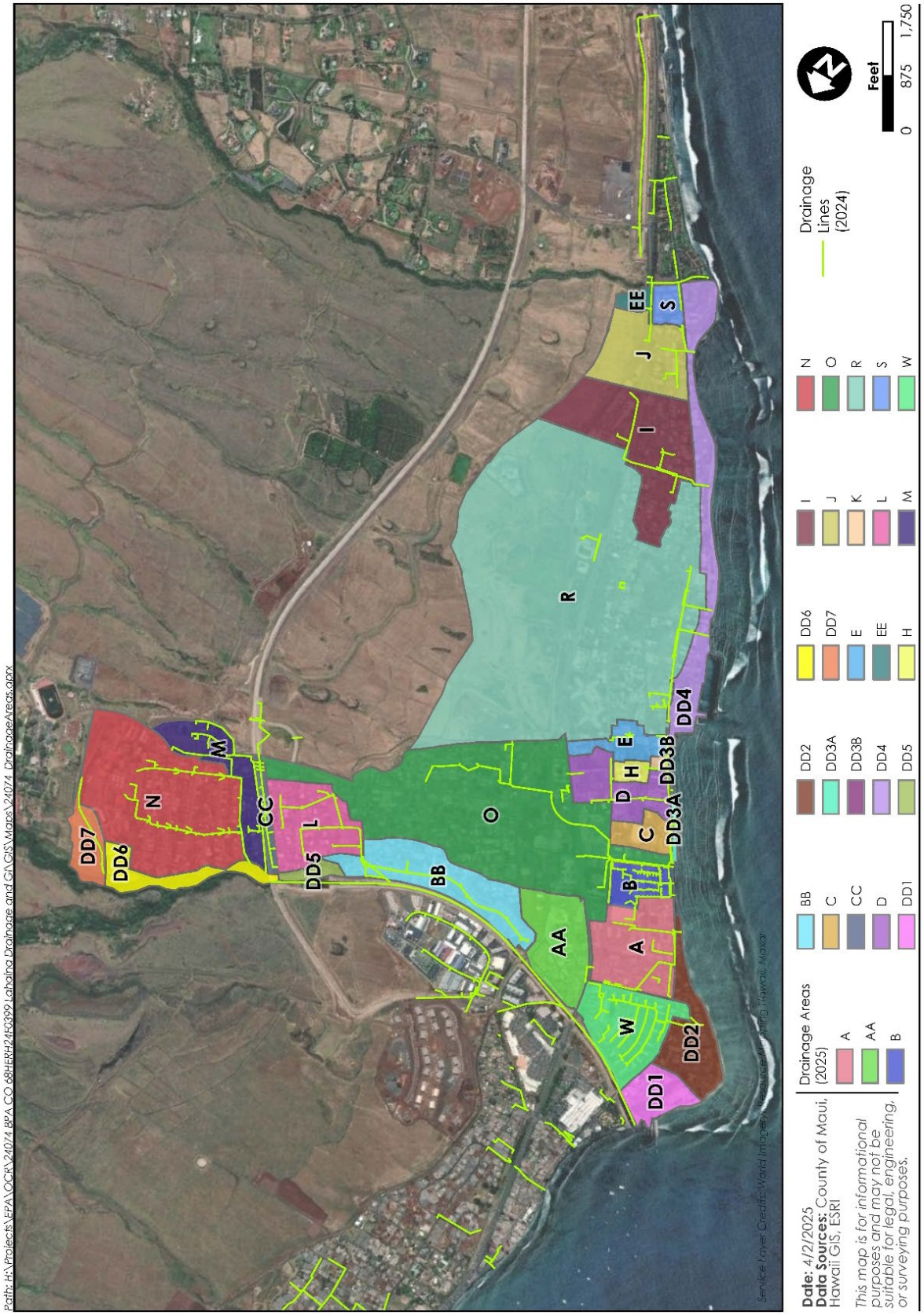


Figure 6. Critical Areas for Drainage Improvement, as presented in the 2005 Master Plan



2.2 Lahaina Water Quality Issues

The health of marine and inland waters is intrinsically tied to the people and places of West Maui. Coral reefs and coastal waters provide food, recreational opportunities, cultural connections, and economic vitality to local communities. These benefits are threatened by degraded water quality, habitat loss, and the altered hydrology characteristic of the urban and agriculturally-modified landscape. The Hawaii Department of Health classifies Lahaina Beach, Lahaina Harbor, and the Kahoma, Lahaina and Kauaula nearshore as being impaired for one or more parameters, including turbidity, total suspended solids, nitrogen (NO3 +NO2, NH4), and/or Chlorophyll a (DOH, 2024). Hui O Ka Wai Ola, Surfrider, University of Hawaii, County of Maui Office of Recovery and others have conducted additional monitoring at seven stream and outfall discharges along the Lahaina shoreline. Their results indicate a consistently high level of turbidity above water quality standards, primarily derived from stream inputs and resuspension (**Figure 7)**. They also note that there is a relatively lower level of nitrogen input from legacy agricultural sources compared to other locations in West Maui. They recommend ensuring that erosion control, revegetation, and wetland restoration efforts are supported during the rebuilding process, which integrates well with GSI approaches.

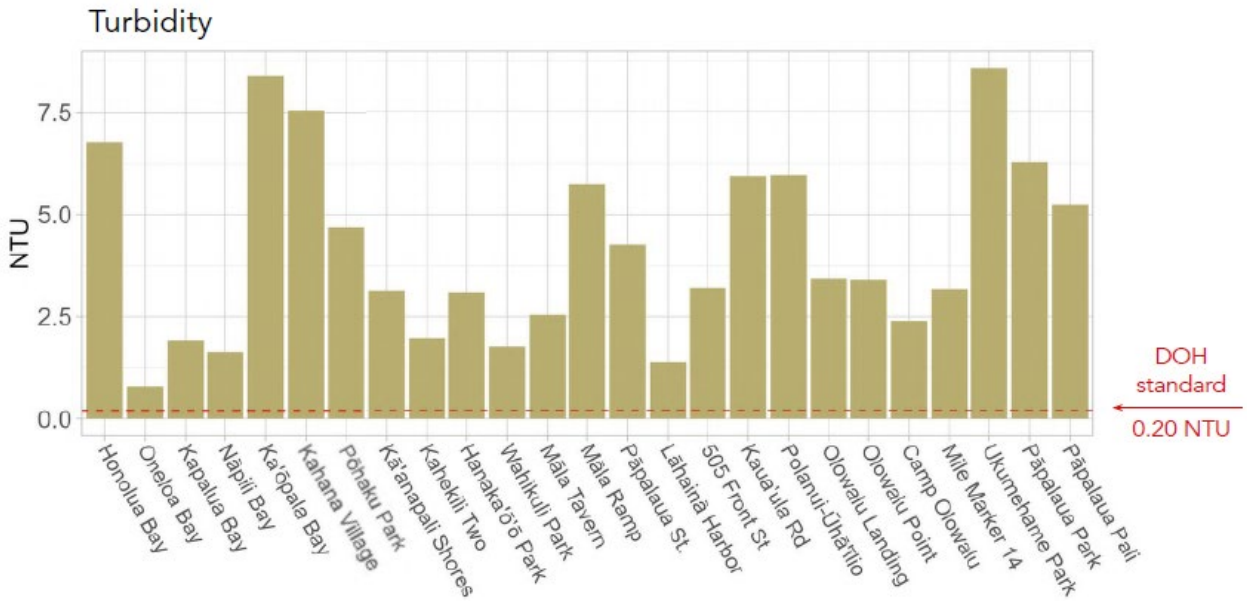


Figure 7. Excerpt from Hui O Ka Wai Ola's Coastal Water Quality Report (2023)[10] showing turbidity results in West Maui

2.3 Drainage Line R

Additional drainage problems identified by the Department of Public Works and Environmental Management (DPWEM) within the 2005 Lahaina Town Drainage Master Plan include:

[10] https://www.huiokawaiola.com/uploads/8/6/5/2/86526856/hokwo_water_quality_report_2016-2023.pdf

- The grated inlet at 505 Front Street is slow to drain, sometimes causing flooding in the underground parking lot located there. The 18-inch outlet from this inlet is buried under beach sand.
- The box culvert and channel along King Kamehameha III School is often clogged with sand at its outlet.
- The sides and bottom of the channel along Malu'ulu-o-Lele Park are deteriorating. Water is frequently stagnant and develops an odor. Many driveways cross the channel.
- Several areas identified by DPWEM as frequently inundated.
- Frequent clogging of all drain lines that discharge into the ocean.
- Seaweed is frequently trapped in drain lines, creating a rotten smell that occurs over time.

Public input gathered for the 2005 Lahaina Town Drainage Master Plan identified the following additional drainage problems:

- The drainage ditch adjacent to Malu'ulu o Lele Park is constantly filled with water. Outlets from the ditch to the ocean are plugged with sand.
- The open area north of the Aquatic Center is often used as a parking area for annual events including "Taste of Lahaina." The area has become compacted, resulting in increased runoff. The retention basin adjacent to the area has become partially filled to provide additional parking space, reducing storage capacity.
- Several areas of severe flooding including Wainee Street near Lahaina Hongwanji Church and the intersection of Shaw Street and Front Street.

The 2005 DMP proposed a number of structural drainage improvements within the Line R network. These improvements, presented in **Table 4** below, have not been implemented and therefore continue to be considered potential improvements to the system. Yellow shading indicates a recommended upgrade to an existing drain line. Green shading indicates a recommended new drain line. Red shading indicates a recommendation to abandon a drain line.

Table 4. Line R structural drainage improvements proposed in the 2005 DMP[11]

Street Name/ Pipe Line	Existing Configuration	Proposed Configuration
Outfall Easement	Double 8′ x 4′ Box (Outfall R to Front St)	Triple 12′ x 4′ Box (R2 Outfall to Front St)
Front Street	4′ x 2.5′ Box (Outfall Easement to Kamehameha Iki Park); 12″ (Kamehameha Iki Park to Sewage Pump Station); 4′ x 1.5′ Box Kamehameha Iki Park to Shaw St)	Double 6′ x 4′ Box (Outfall Easement to Kamehameha Iki Park); Double 6′ x 3′ Box (Kamehameha Iki Park to Sewage Pump Station); Double 7′ x 3′ Box (Kamehameha Iki Park to Shaw St)
Mokuhinia Place	24″ (Front St to Luakini St)	Double 10′ x 4′ Box (Front St to Luakini St)
Luakini Street	24″ (Mokuhinia Pl to Wainee St St)	Double 10′ x 4′ Box (Mokuhinia Pl to Wainee St St)

[11] These proposed improvements were not implemented, as of June 2025.

Street Name/ Pipe Line	Existing Configuration	Proposed Configuration
Wainee Street	24" (Prison St to Maui Islander)	Double 8' x 4' Box (Prison St to Luakini St); 42", abandon Prison St line (Prison St to Maui Islander); Double 10' x 4' Box (Luakini St to Punana Leo O Lahaina); Double 48" (Punana Leo O Lahaina to Shaw St)
Prison Street	(None)	Double 8' x 4' Box (Wainee Street to 24" Culvert from Honopiilani Hwy)
Punana Leo O Lahaina Easement	(None)	Double 10' x 4' Box (Wainee Street to Double 24" Culvert from Honopiilani Hwy)
R1 Outfall Easement	(None)	8' x 4' Box (Outfall R1 to Front St)
Prison St	24" (Front St to Wainee St)	8' x 4' Box (Front St to 133 Prison St); 6' x 4' Box (133 Prison St to Luakini St)
Luakini St	(None)	6' x 3' Box (Prison St to 626 Luakini St)

2.4 Drainage Line O/D

Additional drainage problems identified by the Department of Public Works and Environmental Management (DPWEM) within the 2005 Lahaina Town Drainage Master Plan include:

Line D

- Identified by DPWEM as frequently inundated along Front Street.

Line O

- Lahainaluna Road: run-on from Lahainaluna School. Runoff is diverted to Bishop Estate property, which was undeveloped as of 2005. Runoff also flows onto Kahula Place and through private property to the Paunau Street drainage system; onto the Pioneer Mill Office property; and onto Honoapi'ilani Highway during large storms.
- DPW made a grass swale to address flooding on Kelawea Street, directing more runoff onto Lahainaluna Road.
- The hydrodynamic separator at Ka'anapali Development stopped functioning. The separator was originally installed to divert floodwater from the mill yard. Berms were constructed to capture and retain runoff on the mill site.
- Identified by DPWEM as frequently inundated along Front Street.

Lines O & D

- Frequent clogging of all drain lines that discharge into the ocean.
- Seaweed is frequently trapped in drain lines, creating a rotten smell that occurs over time.

The 2005 DMP proposed a number of structural drainage improvements within the Line O/D network. These are presented in **Table 5** below. These improvements have not been implemented and therefore remain as potential improvements to the system. Yellow shading indicates a recommended upgrade to an

existing drain line. Green shading indicates a recommended new drain line. Red shading indicates a recommendation to abandon a drain line.

Table 5. Line O/D structural drainage improvements proposed in the 2005 DMP[12]

Street Name/ Pipe Line	Existing Configuration	Proposed Configuration
Papalaua Street	18" (Outfall O to Front St); 24" and 30" (Front St to Wainee St)	7' x 4' Box (Outfall O to Front St); 6' x 4' Box (Front St to Wainee St)
Honoapiilani Highway @ Lahaina Clinic	24" Culvert to Graded Swale	24" Pipe to Wainee St Line
Wainee Street	36" (Papalaua St to Lahaina Square); Unknown Ø (Lahaina Square Trunk Line)	48" (Papalaua St to Lahaina Square); 18" (Lahaina Square Trunk Line)
Wainee Street	(None)	60" (Lahainaluna Rd to Panaewa Pl); 40" (Panaewa Pl to Sacred Hearts Church)
Panaewa Place	(None)	60" (Wainee St to Honoapiilani Hwy); 48" (Honoapiilani Hwy to 24" Culvert from David Malo Apartments)
Lahaina Square	36" (Lahaina Square to Honoapiilani Hwy); 24" (Honoapiilani Hwy to Mill St)	48" (Lahaina Square to Honoapiilani Hwy); 48" (Honoapiilani Hwy to Mill St)
Off Pauoa Street Property	30"	54" (Lahainaluna Rd to Property); 48" (at existing pipe to Pauoa St); Abandon in place existing pipe; 42", connect inflow from existing 18" line (along property boundary);
Lahainaluna Road	5' x 3' Box (Outfall D to Front St); 5' x 2.5' Box (Front St to 802 Front St)	10' x 6' Box (Outfall D to Front St); 10' x 6' Box (Front St to Honoapiilani Hwy); 72" (Honoapiilani Hwy to Kuhua St); 60" (Kuhua St to Kelawea St)
Luakini Street	(None)	30" (Lahainaluna Rd to Panaewa St)
Kuhua Street	(None)	36" (Lahainaluna Rd to end)

3.0 RECOMMENDATIONS

We developed a set of recommendations for the County of Maui to better manage stormwater runoff through the use of GSI. The 2005 Lahaina Master Plan identified a series of recommendations to address pipe network capacity to essentially allow water to be captured and conveyed through the drainage system more efficiently, with the goal of alleviating localized drainage problems. Because those recommendations were largely unimplemented, we incorporated the 2005 Master Plan recommendations here. In addition, this GSI Supplement to the Drainage Master Plan introduces a variety of pilot projects and more widespread applications of GSI throughout the Master Plan Study Area. The pilot project recommendations are site specific GSI implementation concepts for individual intersections, roadway sections, or groups of parcels that address specific localized drainage problems and/or take advantage of opportunities on the ground that were identified during the May 2025 site visit. In addition to pilot projects, we developed recommendations for how GSI could be implemented more broadly across the Study Area, based on the type of land use and the hydrologic setting within the Study Area. For these

[12] These proposed improvements were not implemented, as of June 2025.

broad-based GSI recommendations, we provide a suite of SCMs that are suitable for implementation in different areas, so that these SCMs can be integrated into the rebuilding process in Lahaina on the part of both the County of Maui and private landowners. We also examined the existing land use and stormwater management code in the County of Maui and developed a set of simple recommendations related to codes that would augment the effective implementation of GSI and improve overall stormwater management in the Study Area.

3.1 Pilot Projects

Pilot projects were developed to address localized flood challenges as well as to take advantage of opportunities in both Drainage Area R and Drainage Area O/D. **Figure 8** provides a reference map of the locations of each of these pilot projects, which are described in more detail in subsequent sections below.



Figure 8. GSI Pilot Project Locations

3.1.1 Drainage Area R

Figure 13 shows the proposed pipe upgrades as identified in the 2005 DMP as well as the proposed pilot projects that were evaluated in the model. Pipe upgrades identified in the 2005 DMP are detailed above in **Table 4**. The proposed pilot projects in Drainage Area R include the following:

Pilot Project R-1: Aquatic Center Basin Retrofit

A sediment forebay and bioretention area are installed at the downgradient end of the Lahaina Aquatic Center parking lot. Runoff is directed to these practices before overflowing to the existing stormwater basin north of the Aquatic Center. The basin, which exhibits very low infiltration rates,

is excavated deeper and converted to a constructed stormwater wetland, providing improved pollutant removal capacity and ecological habitat. See **Figure 9.**

Pilot Project R-2: Lahaina Recreation Center

On the downgradient side of Shaw Street and the driveway to the Lahaina Recreation Center parking area, a bioswale is installed to infiltrate runoff and convey excess stormwater to two bioretention areas near the driveway entrance. Elsewhere in the parking lot, grass areas that could be used as overflow parking are retrofitted with permeable pavers that allow runoff to infiltrate while preventing compaction of soils from parked vehicles. See **Figure 10.**

Pilot Project R-3: Prison Street Public Parking

The Prison Street Public Parking lot is retrofitted with permeable asphalt over a stone reservoir to store and infiltrate runoff. Excess stormwater that cannot infiltrate is captured by underdrains and directed toward a series of two constructed stormwater wetlands adjacent to the parking lot. This project area overlaps with the historic footprint of wetlands in Lahaina, and can be integral to the hydrologic restoration under consideration for the Royal Complex. The creation of stormwater wetlands in this location could be linked to efforts both north and south of this site to create an integrated network of wetlands that could help to provide the groundwater, surface water and vegetated microbiome that is envisioned in efforts to restore the culturally significant wetland features in the Royal Complex. This wetland and other opportunities could help restore the natural hydrology of the area. See **Figure 11.** See also the GSI handouts in Attachment A for discussion of potential locations for constructed wetlands and hydrologic restoration.

Pilot Project R-4: Front Street at Mokuhinia

Adjacent to Pilot Project R-3, street-side GSI such as tree trenches and bioretention areas are installed along Front Street to capture, treat, and infiltrate runoff. Excess stormwater overflows to the existing drainage line along Front Street. See **Figure 12.**

These pilot projects are summarized below in **Table 6**.



Figure 9. Schematic of Pilot Project R-1



Figure 10. Schematic of Pilot Project R-2



Figure 11. Schematic of Pilot Project R-3

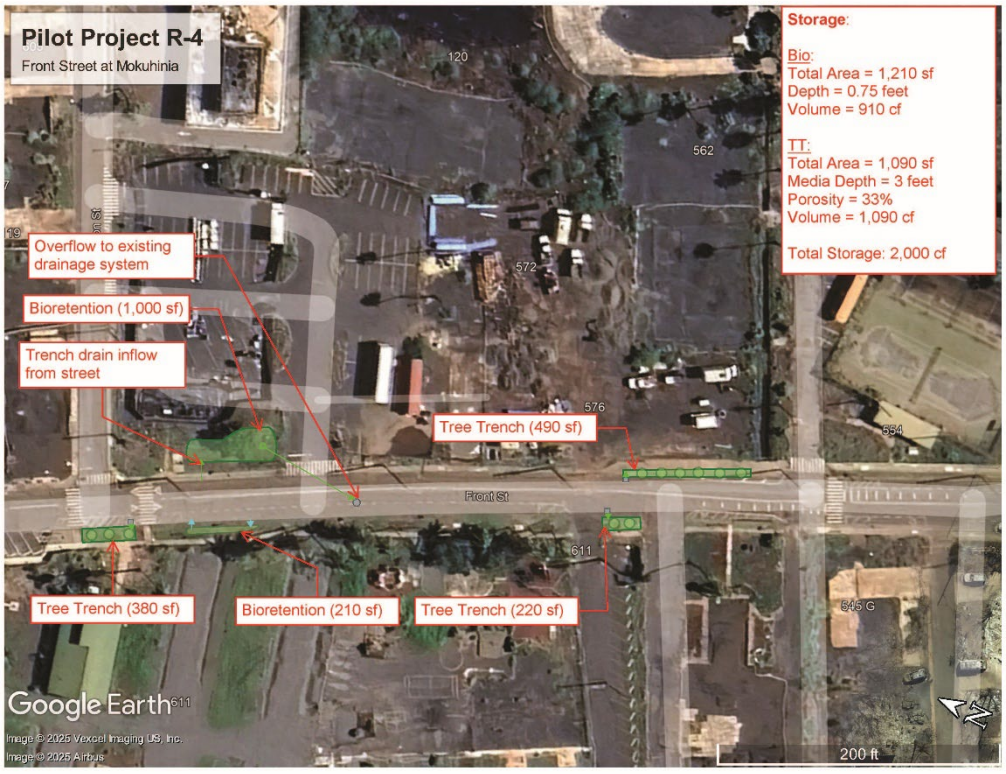


Figure 12. Schematic of Pilot Project R-4

Table 6. Summary of Proposed Pilot Projects in Drainage Area R

Drainage Area	Site ID	Type(s) of Pilot Projects	Site Name	Proposed GSI	Total Storage (cf)
DA R	R-1	Public	Aquatic Center Basin Retrofit	Add pretreatment to basin (forebay and bioretention), retrofit basin as constructed wetland	85,050
	R-2	Public	Lahaina Recreation Center	Bioretentions and Permeable Parking	3,990
	R-3	Public (Parking)	Prison Street Public Parking	Permeable Parking, Constructed Stormwater Wetland, Restored Natural Wetland/Hydrologic Connection	116,300
	R-4	Public ROW (Commercial)	Front Street at Mokuhinia	Tree Trenches and Bioretentions	2,000

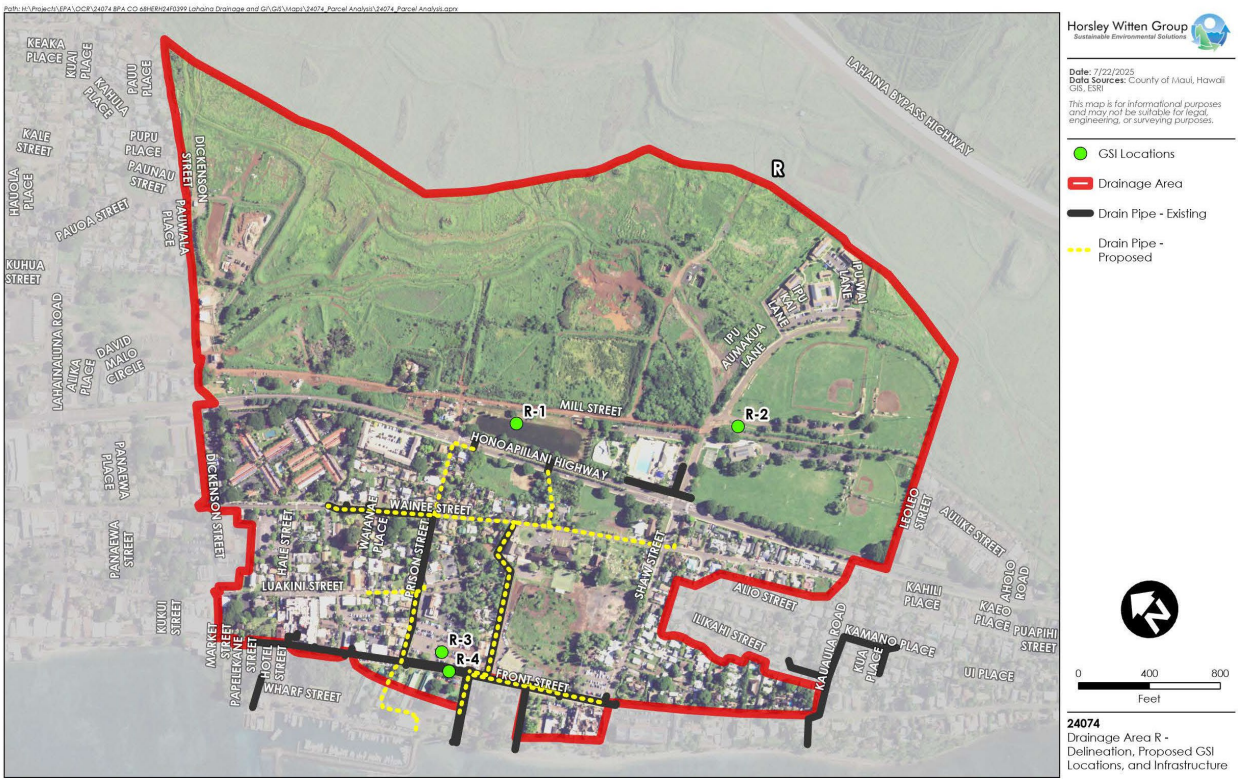


Figure 13. Proposed GSI Pilot Projects and Infrastructure – Drainage Area R

3.1.2 Drainage Area O/D

Figure 19 shows the proposed pipe upgrades as identified in the 2005 DMP as well as the proposed pilot projects that were evaluated in the model. Pipe upgrades identified in the 2005 DMP are detailed above in **Table 5** The proposed pilot projects in Drainage Area O/D include the following:

Pilot Project O-1: Kelawea Street
Street-side GSI such as bioretention areas and tree trenches are installed along Kelawea Street to capture, treat, and infiltrate runoff. Excess stormwater overflows to the gutter line of the road and continues as runoff to downgradient portions of the watershed. See **Figure 14.**

Pilot Project O-2: West Maui Senior Center
Stormwater from Drainage Line O/D is diverted from an existing catch basin on Lahainaluna Road toward a system of subsurface infiltration chambers, which store, treat, and infiltrate runoff. Excess flow continues to a forebay and bioretention area for additional storage and treatment before overflowing to the existing drainage line. Elsewhere on the West Maui Senior Center property, runoff from the parking lot and driveway of the senior center is captured in a bioretention, and overflow is directed to the existing drainage line. See **Figure 15**.

Pilot Project O-3: David Malo Circle Apartments
Three bioretention areas are installed at existing landscaped areas at low points between the apartments on David Malo Circle. The bioretention areas are connected to each other via overflow pipes, and excess runoff is directed to the existing drainage system which exits the site and flows under Honoapiilani Highway. See **Figure 16**.

Pilot Project O-4: Papalaua Street and Front Street
Two tree trenches are installed along Front Street near the intersection with Papalaua Street. The tree trenches are located in sidewalks and plazas that are wider than needed for pedestrian circulation under existing conditions, providing treatment and storage for runoff in addition to the added cobenefit of shade and greenery, without impeding foot traffic. See **Figure 17**.

Pilot Project O-5: Lahainaluna Road and Front Street
Three tree trenches are installed along Front Street near the intersection with Lahainaluna Road. Tree trenches are located at existing bumpouts in the road, such as tree planters or wider sections of sidewalk. The tree trenches will reduce flooding issues and provide treatment to run off without reducing parking capacity or pedestrian circulation. See **Figure 18**.

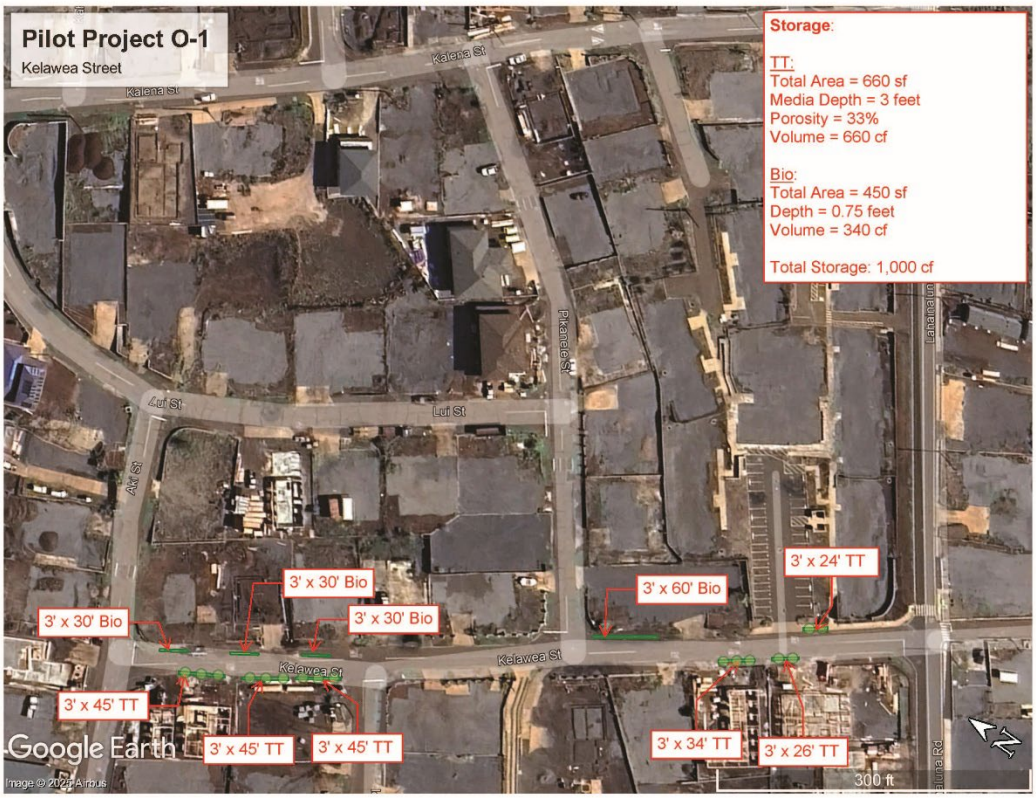


Figure 14. Schematic of Pilot Project O-1.

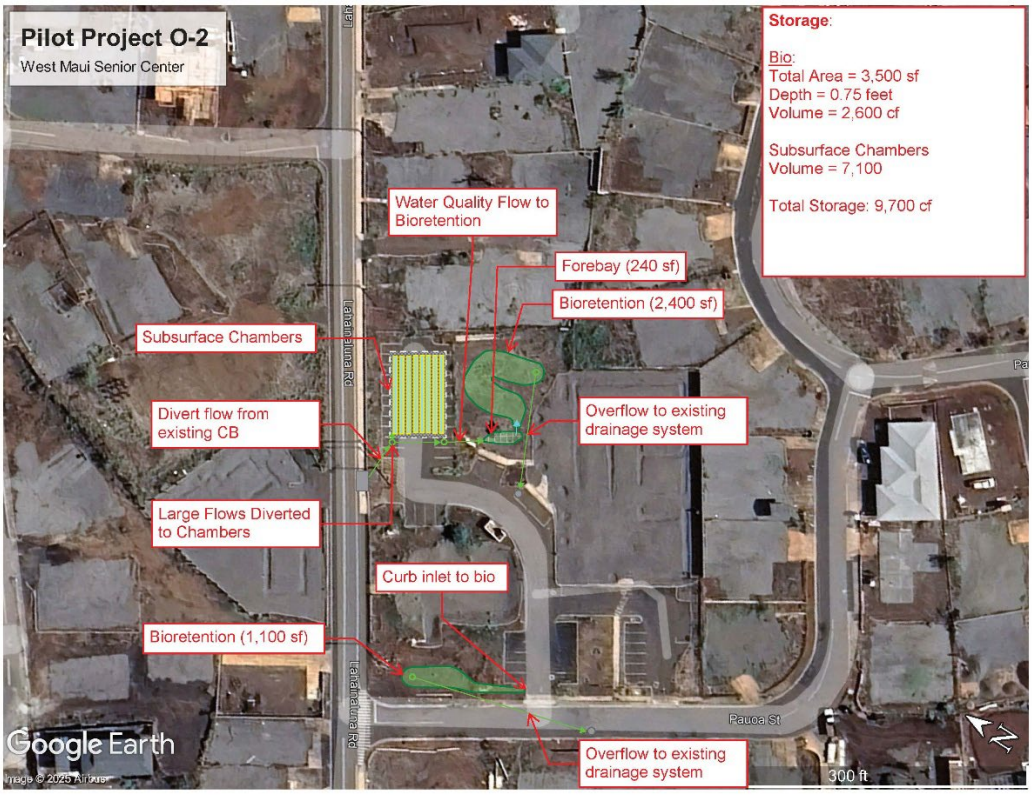


Figure 15. Schematic of Pilot Project O-2.



Figure 16. Schematic of Pilot Project O-3.

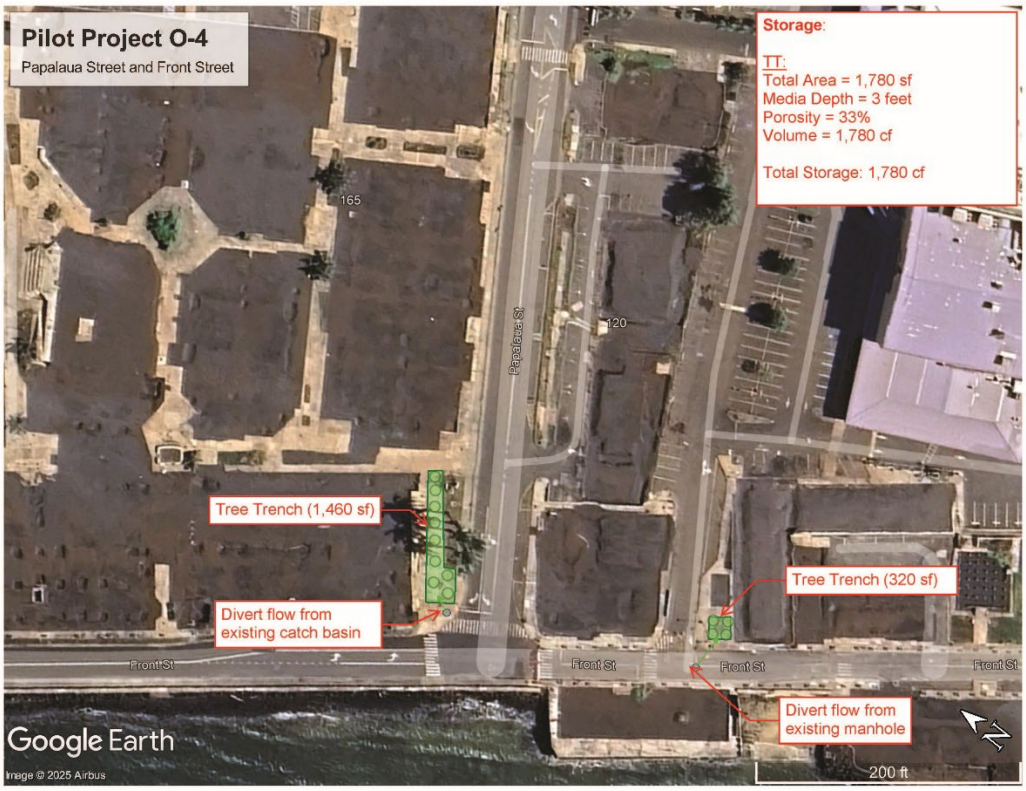


Figure 17. Schematic of Pilot Project O-4.

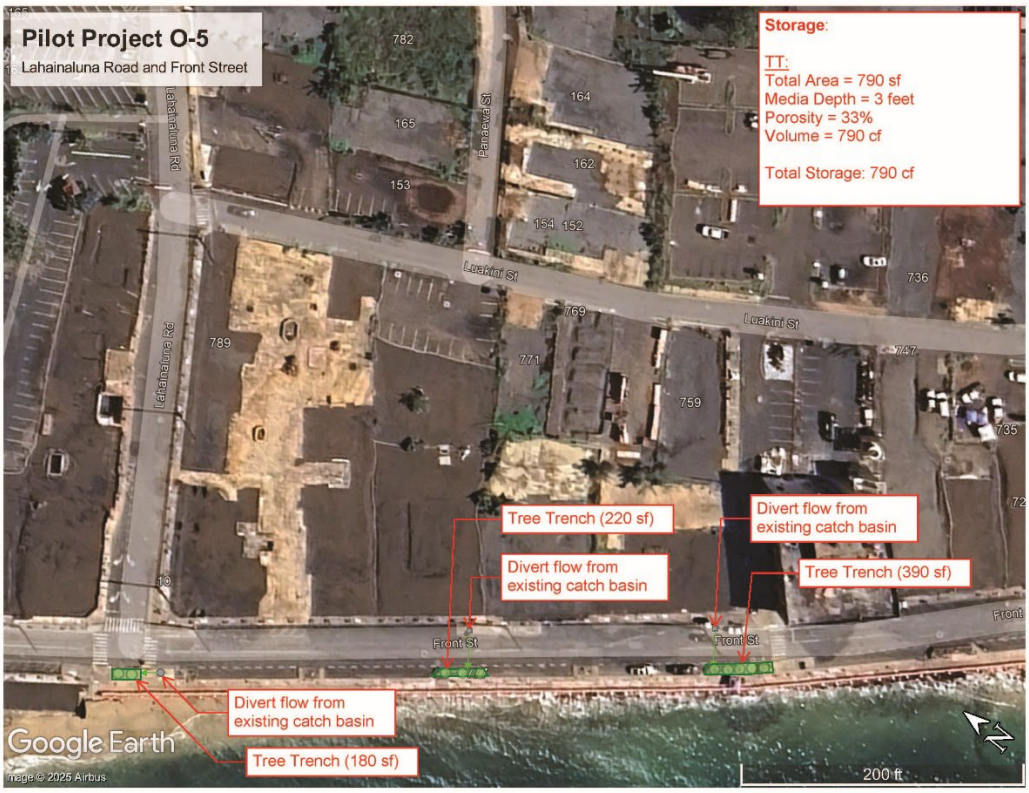


Figure 18. Schematic of Pilot Project O-5.

These pilot projects are summarized below in **Table 7**.

Table 7. Summary of Proposed Pilot Projects in Drainage Area O/D

Drainage Area	Site ID	Type(s) of Pilot Projects	Site Name	Proposed GSI	Total Storage (cf)
DA O/D	O-1	Public ROW (Neighborhood)	Kelawea Street	Tree Trenches and Bioretentions	1,000
	O-2	Public	West Maui Senior Center	Bioretentions and Subsurface Chambers	9,700
	O-3	Public	David Malo Circle Apartments	Bioretentions	1,260
	O-4	Public ROW (Commercial)	Papalaua Street and Front Street	Tree Trenches	1,780
	O-5	Waterfront	Lahainaluna Road and Front Street	Tree Trenches	790

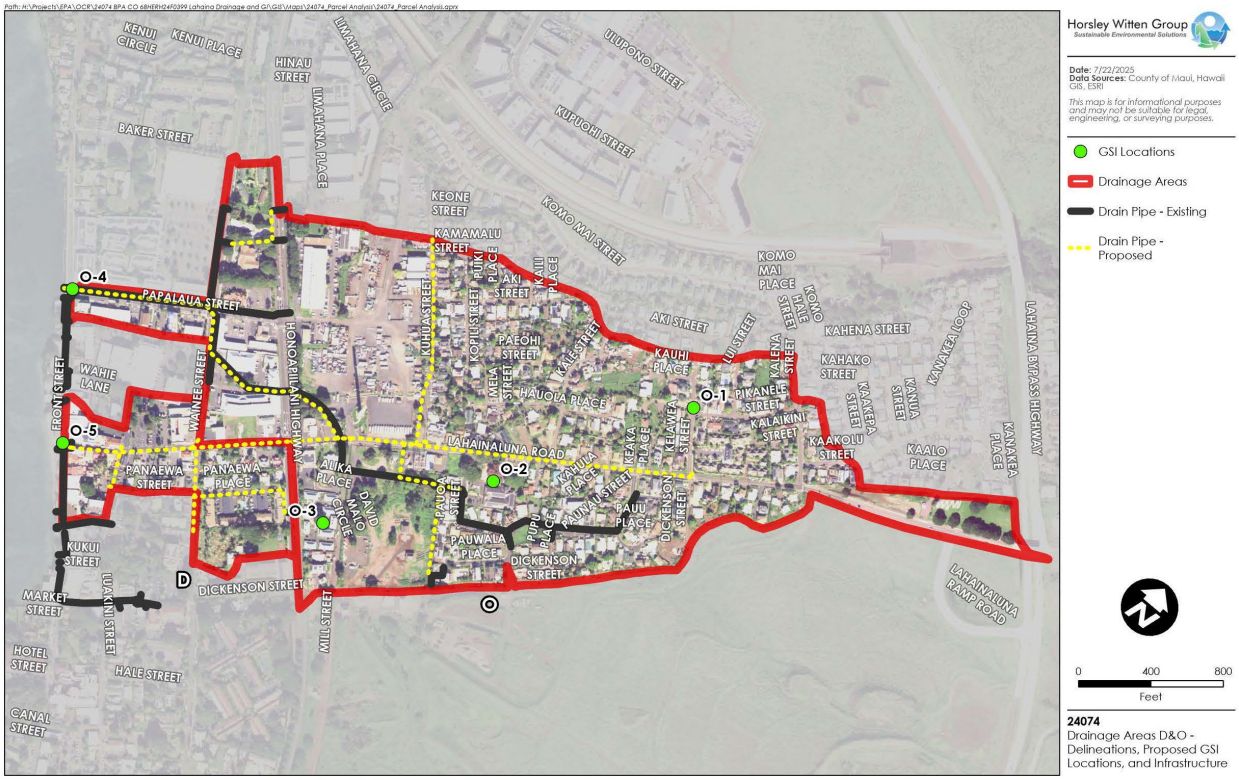


Figure 19. Proposed GSI Pilot Projects and Infrastructure – Drainage Area O/D

3.2 Widespread Application of GSI across Drainage Master Plan Area

While the pilot projects and infrastructure upgrades modeled above give a sense of GSI water quality and quantity impacts at specific identified locations, the real benefit of GSI will come when it is implemented on a widespread basis as an assumed component of rebuilding. To estimate this throughout our focus drainage areas (R and O/D) as well as the entire study area, we divided the study area by "Rebuilding Categories." These categories were developed based on field observations, discussions with various agencies, and how the redevelopment is generally permitted and regulated.

- Residential: Using pre-fire parcel and zoning information, we identified low-, medium- and high-density single family residential lots in the study area. We understand that homeowners are allowed to rebuild their homes through a more streamlined permitting process without requirements for stormwater improvements. However, we also understand that the community is very interested in mālama ʻāina and may be interested in "Building Back Greener" if they knew how to incorporate small-scale GSI. A map showing the general location of single-family residential parcels, which comprises this rebuilding category, is shown below as **Figure 24.**

  Based on the above, **we assumed that 20% of residential lots that were impacted in the fires would choose to implement GSI as they rebuild**. The GSI practices that were applied to these areas included rainbarrels/cisterns to capture rooftop runoff, replacement of lawn or hardened yard areas with fire-safe vegetation to improve infiltration, and use of permeable materials for driveways. An illustration of these GSI opportunities is included in **Figure 20**.

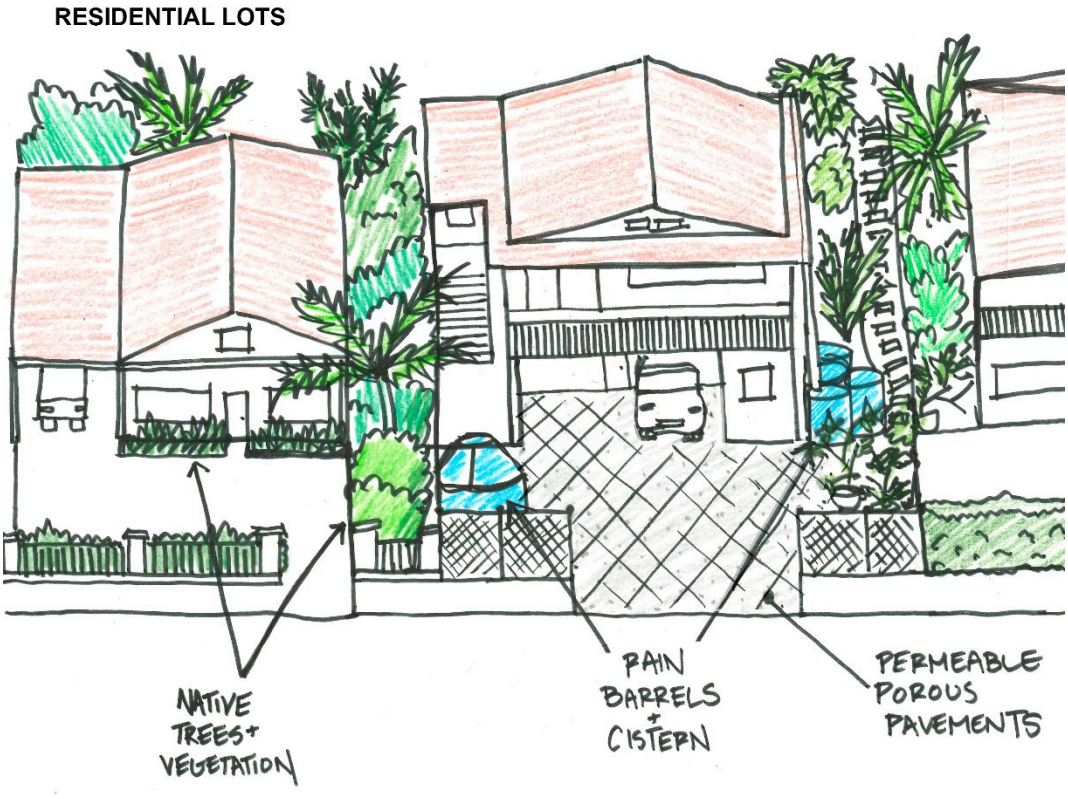


Figure 20. GSI Opportunities on Residential Lots

- Commercial – Small (<1acre lots) and Large (≥1 acre lots): This category lumps different land uses (commercial, hotels, multi-family apartments/condos, etc.) together based on similar development style (large buildings with parking lots) and permitting requirements. Based on our discussions and review of the development code, we understand that there is more flexibility in the stormwater requirements for the smaller lots depending on their location and specific land use, whereas the larger lots are subject to full compliance with the County of Maui Storm Water Rules as they rebuild. The commercial lots were further divided into two sections, those mauka and those makai of Honopiilani Highway. It was assumed that all lots mauka of the highway could infiltrate stormwater, while those makai would be more likely to encounter high groundwater, which would make it difficult to infiltrate significant volumes of stormwater. Although this is not the exact case for every particular commercial parcel in these two areas, it is a reasonable assumption for purposes of modeling and is supported by field observations and discussion with the local experts. A map showing the general location of commercial parcels, comprising this rebuilding category, is shown below as **Figure 25**.

  Based on this information, **we assumed that 50% of the smaller commercial lots will be managing their runoff vs. 100% of the larger lots**. The GSI practices that we assumed for small lots mauka of the highway include tree trenches, permeable pavement, bioretentions, while makai small lots include tree trenches, permeable pavement, and bioretentions with underdrains. The GSI practices assumed for mauka large lots include tree trenches, permeable pavement, bioretentions, and larger infiltration practices such as infiltration basins or underground chambers. We assumed that makai large lots would implement the same practices as small lots – tree trenches, permeable pavement, and bioretentions with underdrains. An illustration of these GSI opportunities is included in **Figure 21**.

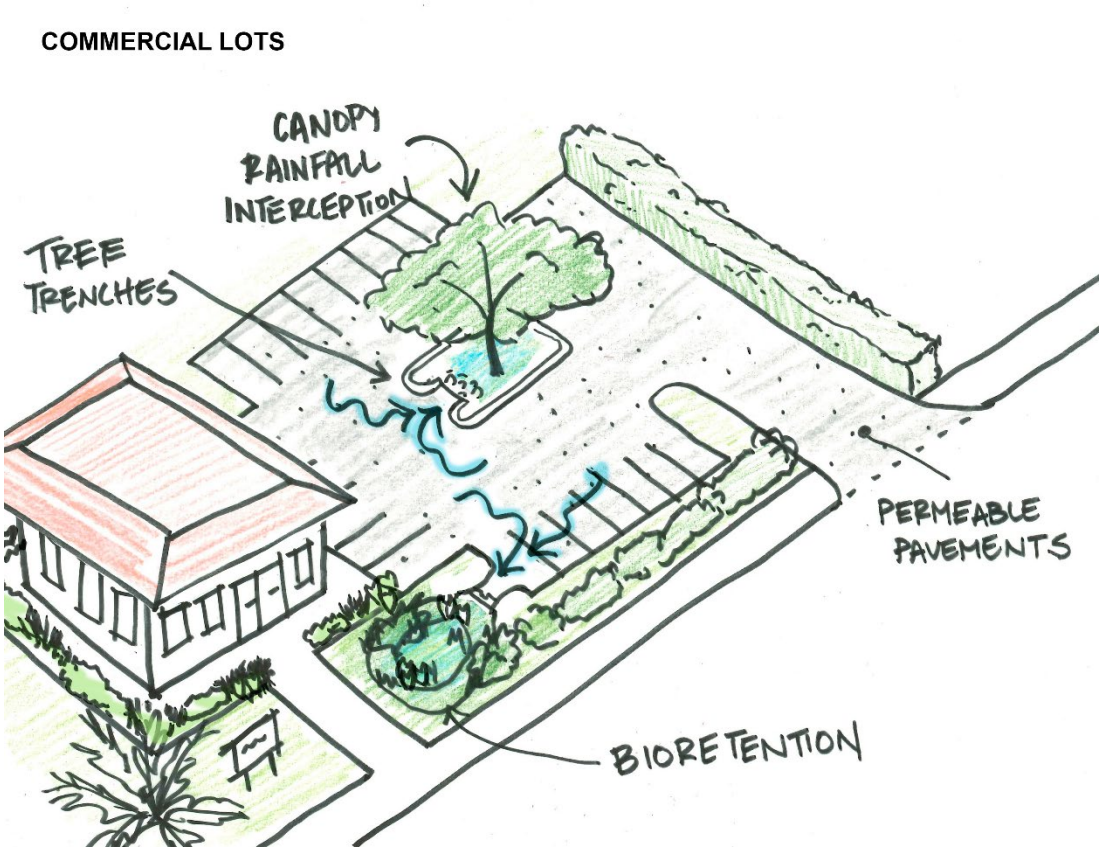


Figure 21. GSI Opportunities on Commercial Lots

- Public – Public Parcels and Rights-of-way (ROWs): For this category, we looked at publicly owned parcel and parcels that were identified as possible future public lots as a result of acquisition. We assumed that, **as these public parcels were rebuilt, they would ALL be designed to manage stormwater with GSI**. The infiltration capacity of these public parcels was evaluated based on their location mauka or makai of the highway, as discussed above. We also looked at the publicly owned ROWs in the study area. We assumed that **20% of public ROWs would be retrofitted or reconstructed with integrated GSI** to better manage stormwater from the ROW. A map showing the general locations of public and potential public parcels and ROWs, comprising this rebuilding category, is shown below as **Figure 26**.

  The GSI practices that we assumed for mauka public lots include tree trenches, permeable pavement, bioretentions, and larger infiltration practices such as infiltration basins or underground chambers. For makai public lots, we assumed tree trenches, permeable pavement and bioretentions with underdrains. For mauka public ROWs, we assumed tree trenches, permeable pavement, bioretentions, while makai ROWs include tree trenches, permeable pavement, and bioretentions with underdrains. An illustration of these GSI opportunities is included in **Figure 22**.

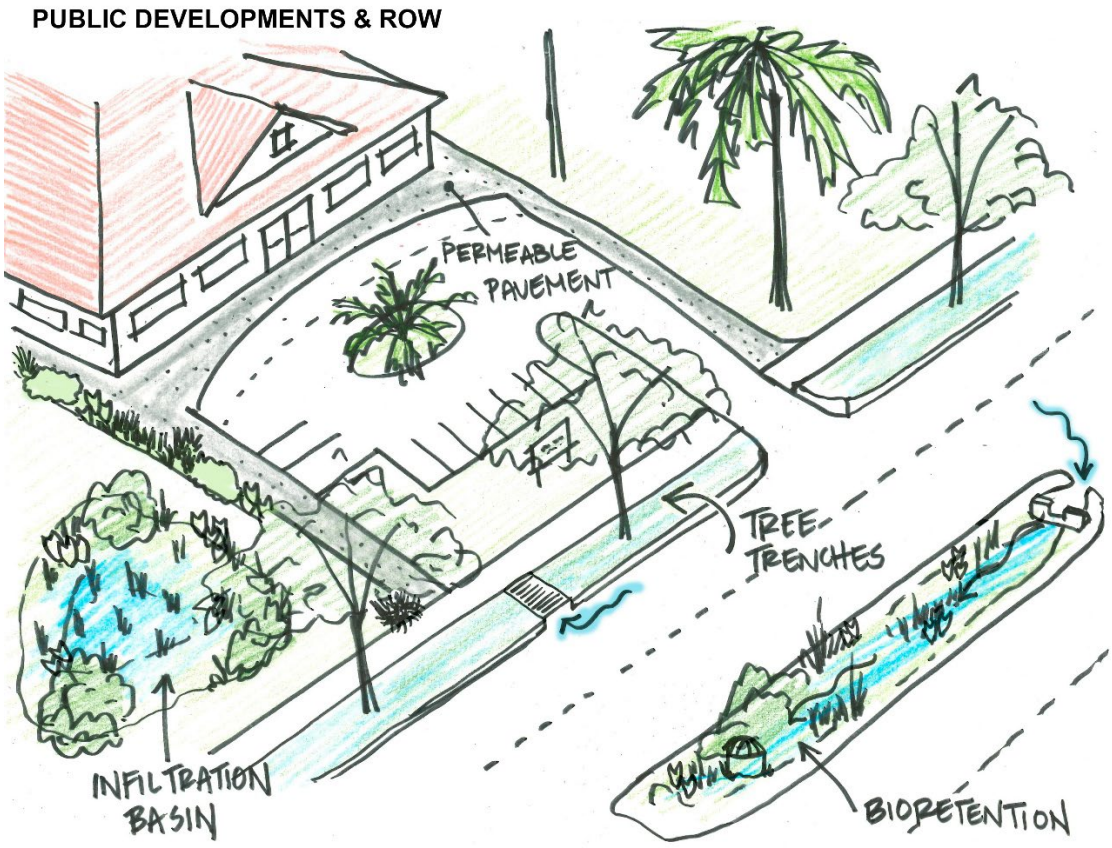


Figure 22. GSI Opportunities on Public Lots and ROWs

- Constructed Wetlands/Park Areas: For this category, we looked at large areas known to have shallow groundwater or springs that are either publicly owned, could possibly become public, and those in historic areas. We assumed that these areas could become parks with constructed wetlands for reconnecting the historic hydrology throughout Lahaina. An illustrated map showing these opportunities to integrate constructed wetlands into parks and open spaces and reconnect the hydrology in the Study Area is included in **Figure 23**.

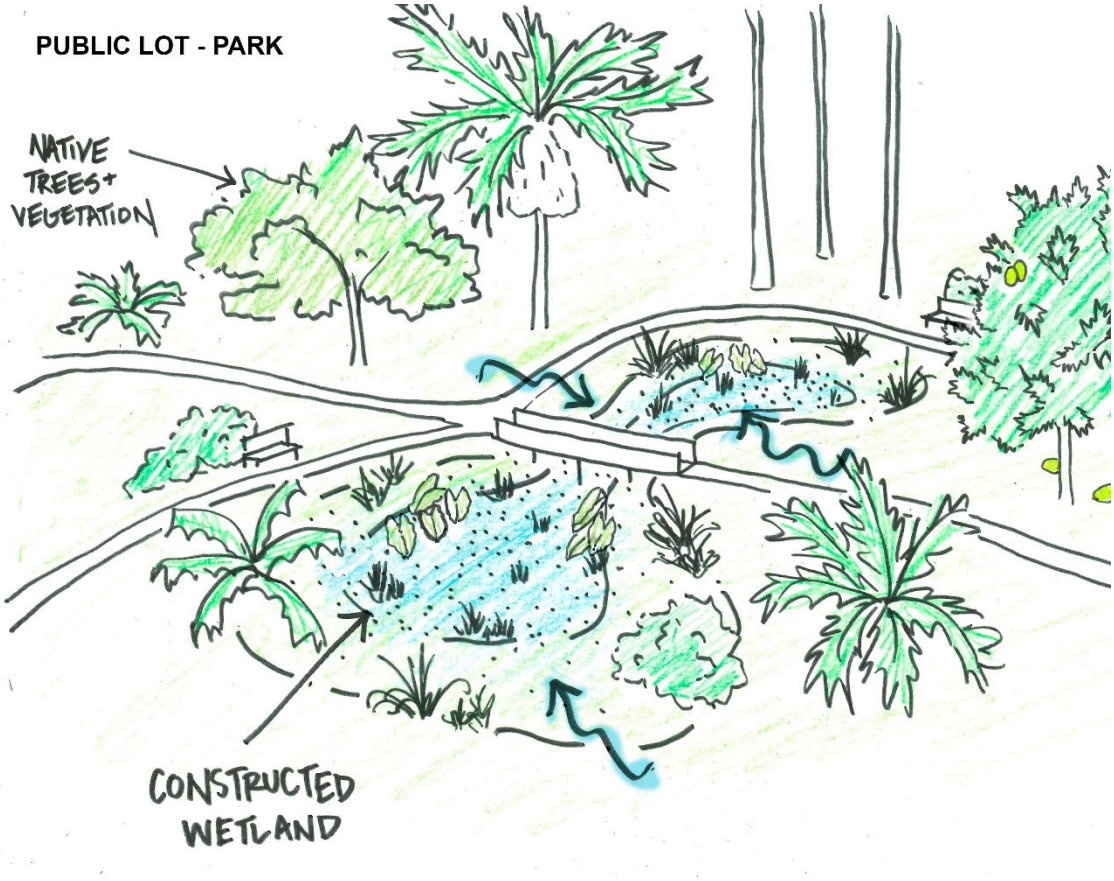


Figure 23. GSI Opportunities for Constructed Wetlands Integrated with Parks

These Rebuilding Categories and the assumed GSI practices are summarized below in **Table 8.** A map showing the parcels within all Rebuilding Categories is shown below as **Figure 27**.

Table 8. Summary of Recommended Widespread GSI based on Rebuilding Category

Parcel Category	Description	GSI Implementation Rate	Proposed GSI
RESIDENTIAL	Single-family Residential Lots	20%	
COMMERCIAL*	Lots ≥ 1 acre - Mauka	100%	
	Lots ≥ 1 acre - Makai	100%	
	Lots < 1 acre - Mauka	50%	
	Lots < 1 acre - Makai	50%	
PUBLIC	Developments - Mauka	100%	
	Developments - Makai	100%	
	ROWs - Mauka	20%	
	ROWs - Makai	20%	
CONSTRUCTED WETLANDS/ PARKS	Large-scale constructed wetlands on public lands or future easements	100%	

**For the purposes of this report, "commercial" includes multi-family residential (apartments, condos) and hotels since the lot layouts are assumed to be similar – large buildings with extensive parking. In addition, these land use categories are similarly grouped in the Storm Water Rule requirements defining the level of design needed for permitting.*



Figure 24. Rebuilding Categories – Residential



Date: 7/29/2025
Data Sources: County of Maui, Hawaii GIS, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Figure 25. Rebuilding Categories – Commercial



Date: 7/29/2025
Data Sources: County of Maui, Hawaii GIS, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Project Boundary
- Constructed Wetlands
- Public
- Public - Right of Way

Figure 26. Rebuilding Categories – Public

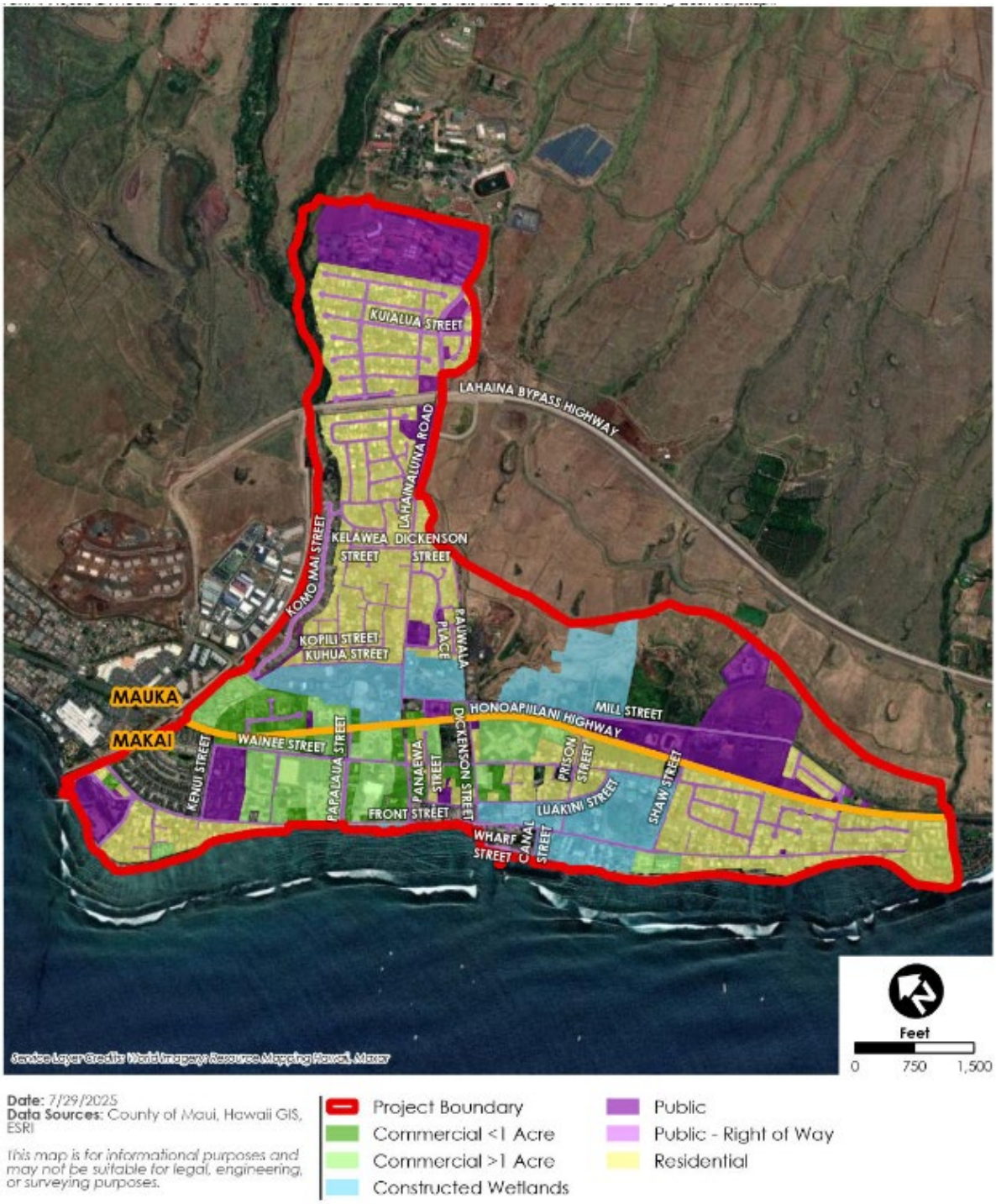


Figure 27. GSI Plan Parcel Classifications

3.3 Development Code/Policy Recommendations (non-structural)

Maui County code is structured to provide the County, through the development review process, with the ability to protect water resources from storm water pollution. The methods for reducing pollution in stormwater include reducing sources of pollution that get entrained in stormwater runoff, reducing the generation of stormwater runoff, and removing pollutants from stormwater before they reach the receiving waters.

Stormwater Management in Development Codes

Maui County currently regulates stormwater in new development and redevelopment through the building permit process (for single-family residential, multi-family residential, business, commercial, industrial, or any non-single family residential projects) or the subdivision approval process (major or minor subdivisions). The stormwater management rules are located in The Rules for the Design of Storm Water Treatment Best Management Practices, which were adopted by the Department of Public Works to guide enforcement of the Subdivision[13] and Building Code[14] requirements.

The rules generally set up three categories or levels of permitting and associated stormwater management implementation, based on the type of project and size of the stormwater impact from the project. In general, very small projects are exempt, minor projects are required to complete Form A (single-family residential) or Form B (business, commercial, multi-family, industrial, or any non-single-family residential) describing the stormwater management approach, and major projects must submit Form A or B as applicable along with engineering design documentation supporting compliance with the Storm Water Rules. Minor projects are those that disturb under an acre and major projects are those that disturb an acre of more. Exempt projects include single-family residential projects in which the total impervious area is less than 5,000 square feet, and remodels and reconstruction, etc., where the cost of work over a 12-month period does not exceed 50% of the replacement value of the existing structure before work is started.

Forms A and B must be signed by the property owner and include what is essentially a set of GSI best management practices for small sites not much different from anything included in the pilot projects developed in this plan. Specifically, they say:

> "To the maximum extent feasible, runoff from paved areas and other impervious surfaces, roof drains, and other onsite drainage systems shall not be allowed to directly drain into the street, gutter, storm drain, or drainage ditch, or any stream, creek, or other body of water. Rather runoff shall first be filtered, infiltrated, or detained onsite by directing runoff to vegetated areas, gravel or sand pits, retention ponds, vegetated swales, tree wells, planter areas, porous pavements, or other water quality treatment devices."

In addition, they require the property owner to certify that the stormwater practices will be property maintained over time. The Form B is more intensive than Form A, as it is for projects other than single family projects, and requires that specific treatment control measures be

[13] Section 18.20.135 of the Maui County Code.
[14] Section 16.26B.3900 of the Maui County Code.

identified and accompanying maintenance check sheets be attached to the form. The check sheets are provided by County of Maui as part of the Forms, and describe the maintenance requirements and frequency for each of the pre-identified stormwater practices. Maui County reviews the forms and at that time has an opportunity to make recommendations to project owners about the selection of stormwater management practices or to specify additional requirements to improve the management of stormwater and reduce pollutants in stormwater originating at the site.

For major projects (those that disturb more than 1 acre), an engineered stamped stormwater management design plan and accompanying drainage calculations are required to be submitted, demonstrating compliance with the Storm Water Rules. In addition, a maintenance plan and certification by the project owner that the long-term maintenance will be implemented is also required.

Table 9 summarizes the stormwater permitting categories and associated requirements based on the type and size of a project under the County of Maui Storm Water Rules.

Table 9. Project Categories and Requirements in the County of Maui Storm Water Rules

Project Type	Definition	Requirements
EXEMPT	Single-family residential with < 5,000 sq ft impervious area Remodels/reconstruction where cost is less than 50% of structure replacement value (within 12 months)	
MINOR	Disturbs < 1 acre	**SINGLE FAMILY RESIDENTIAL (SFR):** Form A Agree to general use of GSI BMPs appropriate for small sites Property owner signatory certifying general ongoing maintenance of BMPs **COMMERCIAL, BUSINESS, INDUSTRIAL, MULTI-FAMILY, NON-SFR:** Form B Identify which stormwater BMPs will be used onsite (from a checklist) Property owner signatory certifying specific ongoing maintenance schedule
MAJOR	Disturbs ≥ 1 acre	**ALL PROJECTS:** Form A or B (as applicable from above) Engineered, stamped stormwater design plans Drainage calculations and documentation to support compliance with Storm Water Rules Detailed long-term maintenance plan Property owner signatory certifying specific ongoing maintenance schedule

Recommendations:

- Uphold the existing standards for stormwater management and guide project proponents in how to implement GSI within the project, for small residential projects all the way to very large projects.
- Strive to ensure that BMPs are effectively maintained over the long-term, through education, enforcement, and technical assistance.

The County has in place a set of Storm Water Rules and permitting processes that are reasonable to promote the effective management of stormwater from new development and redevelopment in Lahaina. The challenge, which is common to many (perhaps most) municipalities, is enforcing the standards. This applies to both the permit approval process, when relief can be granted to project applicants, and the enforcement of long-term maintenance at a site. It is difficult to track stormwater maintenance on private property but is increasingly understood to be important for a municipality to be able to maintain a functioning, effective stormwater management system.

Road and Parking Design:

The Maui County Street Design Manual (December 2018)[15] provides guidance for street design for streets with varying traffic demand and services, including arterials, parkways, collectors and minor streets. This manual provides guidance on typical cross sections for different classifications of streets, in terms of lane width, parking lane width, sidewalks and areas for street trees and plantings. The guidance provided with regard to drainage is very simple and general:

> *"Curb and gutter may be required in some areas based on County Code or as a condition of development. Where a specific stormwater management system is not required, either curb and gutter or drainage swales may be used, provided that the stormwater management system meets other County standard requirements."*

A similar general statement applies to parking, which may or may not be allowed on street in a given area.

Recommendation:

- Incorporate stormwater management using GSI into the street design manual, directly and/or by reference to other guidance manuals.

The Maui County Street Design Manual could aim to more clearly link with stormwater management design to explicitly allow for and promote the use of GSI within the roadway right of way cross section, which extends out to beyond the sidewalks. Areas within traffic calming bump outs as well as vegetated areas along sidewalks could be considered for bioretention, tree box filters or planters. Incorporating these elements into the Street Design Manual would bring these design elements into the forefront of street design rather than being an after-thought or a potential source of design conflict.

[15] https://www.mauicounty.gov/DocumentCenter/View/115295/COM-Street-Design-Manual---December-2018

Lead by Example on Public Properties

The County of Maui, through various departments, owns property and undertakes land development and conservation projects. Purposes for these projects range widely, and include affordable housing, parks and recreation, senior and community centers, schools, historical preservation and restoration, and more. Each of these properties is an opportunity for the County to lead by example and implement GSI on the site to effectively manage stormwater onsite and reduce the contribution of runoff and pollutants into the drainage system. As fire recovery continues in Lahaina, the County of Maui is undertaking various projects that involve the acquisition of land for different purposes. As the design plans are initiated for the next iteration or use of each property, the County could actively work to incorporate GSI to the maximum extent possible. Inevitably, each department that is partnering on a given project will have varying priorities for using the site. However, everybody benefits from a concerted broad scale effort to mimic and restore the natural hydrology in the region.

Recommendation:

- Adopt a GSI policy to guide site design and engineering for all County of Maui public projects.

Limit the percent impervious cover on a site

The County of Maui Zoning Code limits the percent impervious cover on a residential lot (for residential dwellings constructed under building permits applied for after January 1, 2023). **Table 10** below presents the minimum lot area, maximum impervious area and associated minimum non-impervious area for each of the three main residential Districts. By limiting the impervious area on individual sites and encouraging vegetation and GSI practices on the remaining portions of the property, the stormwater runoff generated by these properties can be significantly reduced. It can be challenging to ask individual property owners to reduce the amount of impervious area on their property once it is developed. However, for properties that are newly rebuilding, the County has an opportunity to work with property owners to meet that 65% impervious cover limit. The standards that are already in place in Maui can serve to reduce the stormwater generated from the large areas of residential development in Lahaina (in Zones R-1, R-2, and R-3) (**Figure 28**) compared to conditions prior the 2023 fire.

Table 10. Development Standards for Residential Lots in County of Maui Zoning

Development Standards	R-1	R-2	R-3
Minimum lot area (sf)	6,000 sf	7,500 sf	10,000 sf
Maximum impervious area[16] (65%)	3,900 sf	4,875 sf	6,500 sf
Minimum non-impervious area (35%)	2,100 sf	2,625 sf	3,500 sf

(Source: County of Maui Zoning Code, Section 19.08.040, July 2025)

[16] For dwellings constructed under building permits applied for after January 1, 2023.

Recommendation:

- The County has an existing standard of 65% as the maximum impervious area on a residential parcel in the R-1, R-2 and R-3 zones. This standard, which went into effect in January 2023 in the Zoning Code, can be effective in reducing the stormwater runoff generated from these properties, promoting infiltration of stormwater close to where the rain falls, and helping to mimic natural water cycle in the area. This recommendation encourages the County to uphold this impervious cover limit and work with landowners to implement GSI such as rain barrels, cisterns, permeable pavement, and increased vegetation.

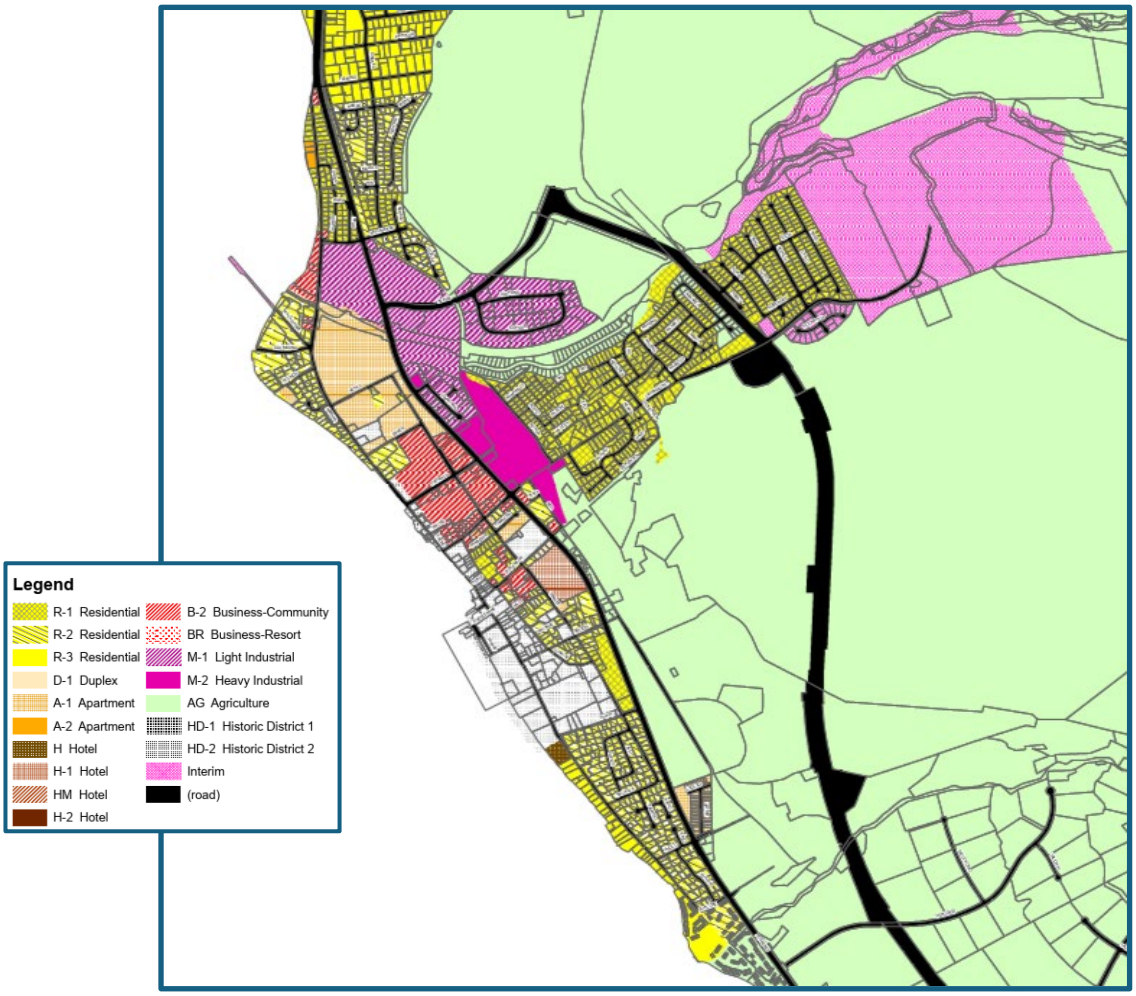


Figure 28. Lahaina Zoning Districts - Excerpt of the Zoning Map from the County of Maui (July 2025)

Increase the Water Quality Treatment Volume

The County of Maui Stormwater Rules (adopted in 2012) require that "the design storm for detention based water quality systems is a one-inch storm" (Section 15-111-5(a)(1)(B)). The one-inch water quality volume is a typical number used throughout the country to generally represent the 90th percentile storm depth, so that water quality treatment would be provided for all storms up to the 90th percentile in size. In other words, all storms up to the 90th percentile event would be captured and treated, and anything in

excess of 1 inch would bypass treatment. However, this understanding was based on a certain statistical history of storm intensity and precipitation depth, both of which are shifting with climate change. With changing rainfall patterns, the 90th percentile storm calculation is a bit of a moving target. . The one-inch water quality volume is outdated and potentially not based on local data. A rainfall analysis conducted by Dr. Neil Berg in 2012 and presented in the manual titled, Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID (February 2014), the 90th percentile storm event in Lahaina was 1.7 inches. An increase in the water quality volume will allow practices to capture and treat runoff from a larger and more intense rainfall event. The modeling analysis in this report evaluated a 24-hour rainfall depth of 1.5 inches rather than one inch to present a more conservative assessment of the water quality treatment that could be provided in the study area.

Recommendation:

- We recommend that, in order to capture and treat stormwater runoff from increasingly intense rainfall events resulting from climate change, the County could institute a larger water quality volume.

4.0 ASSESSMENT METHODS AND MODELING RESULTS

The recommendations above for GSI pilot projects as well as widespread implementation of GSI throughout the study area were evaluated using a combination of drainage system modeling and water quality modeling. The drainage system modeling reveals the benefits that can be achieved by GSI implementation in reducing stormwater flow volumes in each network of the drainage system. The water quality modeling provides an assessment of the pollutant load reductions that can be achieved by GSI implementation, thereby reducing the amount of stormwater pollutants that reach the ocean.

For both the drainage modeling and water quality analysis, we analyzed four general scenarios of stormwater management conditions to compare the effectiveness of each approach to the pre-fire conditions.

The four scenarios analyzed are as follows:

1. The pre-fire conditions (This is the Baseline 'existing conditions' scenario.)
2. The pre-fire conditions plus the implementation of infrastructure improvements recommended in the 2005 Drainage Master Plan
3. The pre-fire conditions plus the 2005 Drainage Master Plan improvements plus the pilot projects recommended in this document.
4. The pre-fire conditions plus the 2005 Drainage Master Plan improvements plus the pilot projects recommended in this document plus the widespread implementation of GSI on public and private properties in the study area.

Due to project resource limitations, we were not able to test each of the individual infrastructure upgrades proposed in the 2005 DMP. Therefore, Scenario 2 reflects conditions if all of the recommendations are implemented. Scenarios 3 and 4 are inclusive of the earlier scenarios.

The methods and results from these assessments are presented in this section, and are described in more detail in the modeling report included in **Attachment C**.

4.1 Drainage System Modeling

4.1.1 Methods

The 2005 Lahaina Town Drainage Master Plan used StormCAD software. This program uses a combination of the Rational and NRCS TR-55 Methods to estimate peak discharge rates for 10- and 50-year, 24-hour storm events and 1-hour storm events and then uses the Manning Equation to model the capacity of the pipes to convey the discharged flow. Then, recommendations were developed to resize (mostly enlarge) pipes and add new connections to ensure that the drainage system had sufficient capacity to carry the design storm flows.

The StormCAD model was comprised of 134 tributary drainage areas, each representing a discrete drainage area to a catch basin or waterbody. The model evaluated existing and proposed drainage conditions at 15 drain lines (A-E, H-K, M-O, R1, R2, and S). Drainage areas less than 100 acres were evaluated using a 50-year precipitation recurrence interval; drainage areas more than 100 acres used a 100-year precipitation recurrence interval.

This update to the 2005 Lahaina Drainage Master Plan used the existing drainage infrastructure information provided in the 2005 plan as a basis for recreating a model of the drainage system. However, instead of using StormCAD, the modeling in this update used HydroCAD, which is based on the NRCS TR-55 method. The benefit of using HydroCAD is that the model could incorporate conveyance elements of the drainage system, such as pipes and outfalls, as well as integrate storage and infiltration processes into the model throughout the system to reflect the function of GSI. This modeling approach allows the user to evaluate the impacts of infiltration and detention through GSI to reduce peak discharge rates and volumes.

The Lahaina Hydrologic/Hydraulic and Water Quality Modelling Summary provided in Attachment C contains a full description of the methods and assumptions used in the development of the HydroCAD models.

4.1.2 Results

The tables below present the volumes and peak flows modeled for each of the Outfalls in Drainage Areas R and D/O for various storm sizes and four different scenarios. The results make it clear that widespread implementation of GSI is potentially highly effective in improving stormwater management in the study area.

HW modeled the gray infrastructure drainage improvements proposed in the 2005 Drainage Master Plan. The gray stormwater infrastructure serves to reduce flooding on roadways and to safely convey flows from large storms. However, gray stormwater infrastructure does not reduce peak flows, reduce volumes, or provide water quality treatment.

HW evaluated the impacts of each pilot project on total runoff volume and peak discharge rate based on the contributing drainage area and outflow point of each pilot project for the 1.5-inch Water Quality storm. For smaller storms, the pilot projects are effective at reducing flowrates from Scenario 2 as well as

providing water quality treatment for the sites. Pilot Projects R-1 and R-2 both demonstrated significant reduction of flows and volumes. These pilot projects are located on public parcels and are not located in burn areas. HW recommends starting with these projects. However, gray infrastructure improvements are tied into these pilot projects to prevent flooding of pilot projects downstream.

The Lahaina Hydrologic/Hydraulic and Water Quality Modelling Summary provided in Attachment C contains an in-depth discussion of the HydroCAD modelling results.

Table 11. Modeled Runoff Volume Reduction – Drainage Area R

Drainage Area R				
Scenario	**Volume Discharged (ac-ft)** ***(% Reduction from Scenario 2)***			
	Water Quality Storm	**1-year 24-hour**	**25-year 24-hour**	**100-year 24-hour**
1. Pre-Fire Condition	8.1	16.6	85.6	148.1
2. Pre-Fire Condition plus 2005 Drainage Improvements	8.1	16.6	87.5	138.8
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	5.7 *(30%)*	12.2 *(26%)*	84.5 *(4%)*	134.0 *(3%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	3.2 *(61%)*	8.7 *(48%)*	79.3 *(9%)*	128.8 *(7%)*

Table 12. Modeled Peak Discharge Rate Reduction – Outfall R1

Outfall R1				
Scenario	**Peak Discharge (cfs)** ***(% Reduction from Scenario 2)***			
	Water Quality Storm	**1-year 24-hour**	**25-year 24-hour**	**100-year 24-hour**
1. Pre-Fire Condition	Outfall R1 was recommended in the 2005 DMP, and did not exist pre-fire.			
2. Pre-Fire Condition plus 2005 Drainage Improvements	25.3	32.8	66.2	70.8
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	25.2 *(0%)*	32.8 *(0%)*	66.2 *(0%)*	70.7 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	23.2 *(8%)*	32.7 *(0%)*	66.1 *(0%)*	70.6 *(0%)*

Table 13. Modeled Peak Discharge Rate Reduction – Outfall R2

Outfall R2				
	Peak Discharge (cfs) *(% Reduction from Scenario 2)*			
Scenario	Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	86.1	126.4	957.0	1,685.4
2. Pre-Fire Condition plus 2005 Drainage Improvements	60.8	130.7	953.5	1,516.0
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	50.5 *(17%)*	111.0 *(15%)*	604.6 *(37%)*	1,498.6 *(4%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	4.3 *(93%)*	66.2 *(49%)*	497.8 *(48%)*	1,477.4 *(3%)*

Table 14. Modeled Runoff Volume Reduction – Drainage Area O/D

Drainage Area O/D				
	Volume Discharged (ac-ft) *(% Reduction from Scenario 2)*			
Scenario	Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	16.4	17.8	71.5	102.3
2. Pre-Fire Condition plus 2005 Drainage Improvements	9.9	19.3	78.5	112.3
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	9.6 *(3%)*	18.9 *(2%)*	77.9 *(1%)*	111.8 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	4.1 *(59%)*	13.1 *(32%)*	71.6 *(9%)*	105.4 *(6%)*

Table 15. Modeled Peak Discharge Reduction – Outfall O

Outfall O				
Scenario	Peak Discharge (cfs) *(% Reduction from Scenario 2)*			
	Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	99.9	193.1	735.9	1,036.9
2. Pre-Fire Condition plus 2005 Drainage Improvements	71.0	137.1	482.2	673.2
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	70.4 *(1%)*	135.5 *(1%)*	482.0 *(0%)*	672.9 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	42.2 *(41%)*	134.4 *(2%)*	480.0 *(0%)*	670.2 *(0%)*

Table 16. Modeled Peak Discharge Reduction – Outfall D

Outfall D				
Scenario	Peak Discharge (cfs) *(% Reduction from Scenario 2)*			
	Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	20.1	36.0	126.2	175.8
2. Pre-Fire Condition plus 2005 Drainage Improvements*	59.3	113.0	466.2	661.5
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects*	57.3 *(3%)*	109.7 *(3%)*	465.8 *(0%)*	660.9 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	18.9 *(64%)*	108.2 *(4%)*	462.2 *(1%)*	656.4 *(1%)*

*Significant increase in proposed flow to Outfall D is due to diversion of portions of Drain Line O to Drain Line D

4.2 Water Quality Modeling

4.2.1 Methods

One of the major benefits of implementing GSI is the ability of GSI to reduce the load of pollutants in stormwater discharges to receiving waters. GSI can improve the water quality in coastal waters, and has been shown to reduce nitrogen, phosphorus, suspended sediments, and bacteria in stormwater discharges. In coastal areas such as Lahaina where coral reefs and recreational uses are increasingly at risk from these pollutants, widespread as well as targeted GSI implementation can truly make a difference.

Water quality treatment in stormwater management is achieved by capturing and treating a specified volume of runoff generated at the beginning of a rain event. This 'first flush' of stormwater runoff generally picks up and carries a significant portion of the pollutants that are transported in each rain event. Therefore, if this 'first flush' of runoff is directed through a green infrastructure SCM that is sized for that volume, the pollutant load from each storm event will be significantly removed from the stormwater flows that reach the ocean. In the County of Maui, the Storm Water Treatment Rules call for stormwater water quality treatment SCMs to be designed to capture and treat the first 1 inch of rainfall. Therefore, the Pilot Projects were designed to maximize the treatment volume that was possible at each site, to meet or exceed the 1-inch treatment depth if possible. The application of widespread GSI across the Study Area assumed that the SCMs would be sized to meet the 1-inch treatment depth.

In addition to modeling the impacts of GSI on peak runoff rates and volumes, this update to the 2005 Lahaina Drainage Master Plan evaluated the impacts of GSI on water quality. To do so, HW developed a spreadsheet-based model to estimate existing pollutant loading rates for four pollutants – total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and fecal coliform bacteria (FC) – across the study area, the Line O and R drainage areas, and the smaller contributing drainage areas to each of the pilot projects. Existing pollutant loading rates were used as a baseline from which to measure the impacts of proposed pilot projects and more wide-spread recommendations.

4.2.2 Results

The individual pilot projects show a significant potential to remove pollutants of concern, with almost all pilot projects estimated to achieve pollutant reduction of 90% or greater. The predicted annual load reductions and percent reductions provided by each pilot project are listed below for Drainage Area R (**Table 17**) and Drainage Area O/D (**Table 18**).

Table 17. Modeled Pollutant Load Reduction from Pilot Projects in Drainage Area R

Site ID	Proposed Annual Load Reduction *(% Reduction)*			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
R-1 Aquatic Center Basin Retrofit	262.8 (100%)	38.6 (100%)	12,555 (100%)	4,215 (100%)
R-2 Lahaina Recreation Center	17.0 (100%)	2.6 (99%)	765.9 (100%)	669.6 (98%)
R-3 Prison Street Public Parking	12.2 (100%)	1.8 (100%)	412.7 (100%)	413.0 (100%)
R-4 Front Street at Mokuhinia	3.4 (99%)	0.5 (94%	97.0 (100%)	125.1 (94%)

Table 18. Modeled Pollutant Load Reduction from Pilot Projects in Drainage Area O/D

Site ID	Proposed Annual Load Reduction *(% Reduction)*			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
O-1 Kelawea Street	17.0 (92%)	2.1 (77%)	433.3 (94%)	629.8 (73%
O-2 West Maui Senior Center	11.2 (100%)	1.7 (100%)	403.7 (100%)	425.2 (100%)
O-3 David Malo Circle Apartments	4.1 (99%)	0.6 (96%)	111.9 (100%)	168.0 (98%)
O-4 Papalaua Street and Front Street	5.0 (92%)	0.6 (74%)	116.5 (93%)	164.7 (67%)
O-5 Lahainaluna Road and Front Street	2.2 (85%)	0.3 (68%)	52.3 (82%)	63.5 (56%)

When these pilot projects were combined with more widespread implementation of GSI across the focus Drainage Areas and the full Study Area as a whole, the model showed the following positive results:

- Drainage Area R showed a reduction in TN, TP and TSS above 90% and an 83% reduction in FC.
- Drainage Area O/D showed a reduction in TN of 65%, TP of 59%, TSS of 82% and FC of 64%.
- The full Study Area showed a reduction in TN of 69%, TP of 64%, TSS of 84%, and FC of 65%.

These results as well as the approach to this modeling are more fully presented in the Modeling Memorandum included in Attachment 3.

Water quality benefits for the various stormwater management scenarios examined are summarized below for Drainage Area R (**Table 19**), Drainage Area O (**Table 20**), and the study area (**Table 21**).

Table 19. Modeled Pollutant Load Reduction for Drainage Area R

Scenario	Proposed Remaining Annual Loading *(% Reduction)*			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
1. Pre-Fire Condition*	380.8 *(0%)*	53.3 (0%)	14,158 *(0%)*	13,340 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	85.4 *(78%)*	9.9 (82%)	327.0 *(98%)*	7,918 *(41%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	32.7 *(91%)*	4.1 (92%)	85.9 *(99%)*	2,807 *(79%)*

*Equivalent to existing pollutant loading for all study areas.

Table 20. Modeled Pollutant Load Reduction for Drainage Area O/D

Scenario	Proposed Remaining Annual Loading *(% Reduction)*			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
1. Pre-Fire Condition*	510.2 *(0%)*	70.0 *(0%)*	16,653 *(0%)*	19,475 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	470.7 *(8%)*	64.7 *(7%)*	15,536 *(7%)*	18,024 *(7%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	225.1 *(56%)*	33.9 *(51%)*	5,514 *(67%)*	8,358 *(57%)*

*Equivalent to existing pollutant loading for all study areas.

Table 21. Modeled Pollutant Load Reduction for Study Area

Scenario	Proposed Remaining Annual Loading *(% Reduction)*			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
1. Pre-Fire Condition*	2,138 *(0%)*	292.6 *(0%)*	72,164 *(0%)*	79,215 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	1803 *(16%)*	244.0 *(17%)*	57,215 *(21%)*	72,342 *(9%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	875.0 *(59%)*	127.6 *(56%)*	21,770 *(70%)*	34,245 *(57%)*

*Equivalent to existing pollutant loading for all study areas.

5.0 DISCUSSION AND NEXT STEPS

5.1 Benefits of GSI Improvements

The implementation of GSI improvements recommended in this supplement is a critical part of the sustainable rebuilding of Lahaina. This approach helps to reduce localized flooding issues by reducing runoff volumes, slowing, and then infiltrating runoff near its source. In addition, GSI as envisioned in this report supports a regional greening and restoration of the regional hydrology in the Lahaina area, which is directly compatible with local climate resilience goals as well as the local vision for restoring the Royal Complex. Historic accounts of the area refer to a localized microclimate created by springs, wetlands, lo'i kalo, and breadfruit groves. This environment helped to keep water local, and both depended upon and supported a unique hydrologic system. Lahaina was home to a system of emergent wetlands at the base of the West Maui mountains fed by both high groundwater and mountain flows. The traditional gray drainage infrastructure in Lahaina together with the large flood control projects at Kahoma Stream and the temporary diversion berm, serve important public safety purposes, but also short circuit the natural hydrology in Lahaina.

This GSI Supplement supports an incremental approach to reconnecting and resupplying that hydrology while maintaining the public safety benefits achieved to date. A holistic integration of GSI throughout the study area will also provide co-benefits such as help to restore natural hydrologic flow paths, maintain important groundwater resources, improve habitat and biodiversity, reduce heat island effects, improve air quality, improve recreational opportunities, and in general, improve the quality of life for those who live, work, and visit Lahaina. This GSI will also be a critical component of making Lahaina more resilient to the impacts from our changing climate.

The models presented in this report clearly support the benefits of GSI implementation by documenting the pollutant removal potential and the reductions in stormwater peak flows and volumes. What cannot be demonstrated in these models, but is demonstrated visually in the GSI Implementation handouts and the pilot project summary sheets, are the other benefits to the landscape and the community. GSI is an approach to stormwater management that reflects the Hawaiian cultural values of caring for the land and water from mauka to makai and cultivating a connection to the local native flora. A lack of GSI approaches in stormwater management is counter to these cultural values and will continue to contribute to the drying of the natural system in Lahaina as rainwater is essentially carried directly and rapidly out to sea.

5.2 Implementation

Implementation of these recommendations will not be easy nor fast. However, there are a few strategies that will help create a successful GSI implementation plan.

5.2.1 Coordination with Existing Initiatives

As described above, there are several large initiatives that are now or soon to be underway. The GSI messaging should be consistently incorporated across these efforts so as not to create confusion. The GSI that is recommended in this document can be integrated into projects undertaken through the many other ongoing efforts in Lahaina.

The Long-Term Recovery Plan includes several projects that can and should consider GSI opportunities as they are implemented. For example, as the Senior Center reconstruction plans proceed, consider the site layout and whether there are opportunities to integrate GSI that can serve not just the Senior Center but the contributing drainage area to the Senior Center (See **Pilot Project O-2**). As plans for affordable housing proceed, consider which properties could serve a dual purpose of improving localized drainage issues by integrating GSI to address the housing project itself and keep runoff onsite, but also to manage runoff from adjacent areas. Any public property is an opportunity to lead by example on GSI. Any plans for road extensions and improvements should certainly incorporate GSI into the design.

This GSI Supplement lays important groundwork for the hydrologic restoration that would be needed to support the Lahaina Royal Complex Plan. In particular, we direct you to the concept in **Attachment A** for widespread implementation of constructed and restored wetlands on larger parcels that may be currently in transition following the fire and the potential to interconnect the hydrology across the study area. Success with this approach requires land use planning beyond a parcel-by-parcel engineering and design approach. It also requires that this planning should take place in the near term to be able to consider opportunities that may exist only for a limited time. This type of regional hydrologic restoration can help shape the plans and opportunities for the Lahaina Royal Complex restoration.

The ongoing effort to design, fund and construct a flood diversion berm to reduce flood impacts in Lahaina will ultimately alter (or continue to alter) the hydrology in Lahaina. While the diversion berm is aiming to divert flows from large flood flows for public safety purposes, it also diverts the flows from smaller storms that are vital to supporting the hydrology, groundwater, wetlands, and vegetation in Lahaina. We recommend that the diversion berm project incorporate mechanisms to allow low flows to pass through at strategic locations, which can also support the hydrologic restoration efforts that feed into the Lahaina Royal Complex Plan.

And finally, the One Water Strategy for Lahaina that has been initiated in 2025 will consider stormwater flows within the holistic approach to water management. Stormwater runoff is a resource, and an important element within the cycle of water through the developed landscape, along with drinking water, irrigation water, and wastewater. The use of GSI as described in this document supports rainwater reuse, the infiltration of water into the ground, as well as the use of vegetation to cycle water and moisture back into the air and soil. This GSI Supplement to the Lahaina DMP should be integrated into the One Water Strategy.

5.2.2 Bridging the Technical Gap

While the community may be very interested in the GSI concept, not many local homeowners and developers are fluent in these designs. A local champion and/or group can help to effectively disseminate information on this topic. Lahaina and West Maui are home to many groups and individuals that are actively involved in protecting the environment, conserving the cultural historic landscape in Lahaina, and supporting efforts around affordable housing and rebuilding. County of Maui DPW could benefit from the community connections, trust, knowledge, and enthusiasm of these local champions to carry the torch for GSI.

In support of this effort, the handouts in **Attachment A** can be used to communicate with the public to help visualize and understand the GSI practices and approaches that might be appropriate for different types of properties.

5.2.3 Creating Incentives

Incentive programs should be developed to encourage homeowners and local businesses to build back greener. Building on the sense of pride and cultural connection that those in Lahaina feel for the land, an incentive program can provide property owners with a sort of stamp of approval or environmental sensitivity for integrating GSI practices within their property. For commercial properties, this can contribute to marketing efforts, to demonstrate that the business is a responsible land-owner. Properties that are building or rebuilding are already required to obtain building permit and stormwater approval, and this certification could be associated with that process, with support from a local organization such as the Chamber of Commerce for signage, marketing, and celebratory events.

5.2.4 Obtaining Additional Public Properties or Easements

Some of the lands identified in this supplement are not yet publicly owned but are in key locations for reconnecting natural hydrology and managing stormwater. These areas should be pursued for purchase or easements. The potential hydrologic benefit of each redevelopment project should be evaluated during land acquisition. Effort should be made to manage stormwater from each redevelopment project and to restore natural hydrology where feasible. Parking is another important issue throughout Lahaina, and GSI

recommendations can be integrated with this parking. Archaeological concerns will need to be carefully assessed throughout these areas. The proposed gray infrastructure improvements are extensive, and focus should be put on implementing these improvements during the rebuilding process to allow for more opportunity to obtain easements.

5.2.5 Operations and Maintenance

Operations and maintenance (O&M) needs to be a key consideration for GSI design and implementation, particularly for GSI implemented on public properties or in the public ROW. GSI designs should be specifically adjusted for the maintenance capabilities and equipment of the responsible parties. Public GSI would fall under the responsibility of Maui County DPW, which already has staff and equipment limitations for the drainage needs in Lahaina. Designs need to be simple, with easy-to-access pretreatment components where most of the maintenance will be required. For example, pretreatment practices could include sediment forebays (shovels and bucket attachments), deep sump catch basins (clam shells), and permeable pavement surfaces (vacuum sweepers). Vegetation components should be maintained by staff with plant expertise. For public GSI, this work could be assigned to other departments such as Maui County Parks and Recreation.

Maintenance of the outfalls and channels that discharge into the ocean will also be key to a sustainable drainage system for Lahaina, particularly as climate change brings rising sea levels and higher intensity wave action. Tide gates should be installed on outfalls to prevent ocean water and associated sediment from entering and clogging the pipe network. Maintaining open channels is an important piece of restoring the historic hydrology in Lahaina, but these need to be designed so DPW can easily access sand plugs with their equipment during storm events as needed.

5.3 Next Steps

This GSI Supplement to the Lahaina DMP provides a variety of recommendations for stormwater improvements, and it is not a simple affair to determine exactly where or how to begin. The following simplified next steps aim to provide a straightforward way for the County of Maui, particularly the DPW, to think about next steps:

- Find a local champion and begin spreading the word about GSI.
- Further spread the word about GSI by sharing the handouts with property owners during permitting and development consultations.
- Bring this GSI report to the attention of the West Maui Senior Center and affordable housing project teams to begin to consider GSI in the design plans as early as possible.
- Bring this GSI report to the attention of the Lahaina Royal Complex project committee to begin to consider opportunities for GSI and wetland restoration within the larger scale hydrologic restoration as early as possible.
- Review this work with land development permit and enforcement team to highlight the importance of integrating GSI into requirements, reducing waivers to these requirements, and strengthening public education and enforcement.
- Select public projects where the County can integrate GSI and highlight it through signage, public education, and public outreach, to lead by example and celebrate successes.

ATTACHMENT A: GSI HANDOUTS

BUILDING BACK GREENER:

RESIDENTIAL LOTS

The August 2023 wildfires were devastating for Lahaina, particularly for the families who lost everything. As those families rebuild or when other families make adjustments to their single-family homes, there are simple, small-scale ways that they could show their *mālama ʻāina* along the way.

Green stormwater infrastructure (GSI) is just another phrase for caring for the land to protect and preserve the water. If families can do these small things at their homes, together, they can have a big impact!

- **Help clean runoff before it gets to the ocean and coral reefs**
- **Reduce localized flooding problems**
- **Cool neighborhoods with fire resistant plants and trees**
- **Save $$ on energy and water costs**

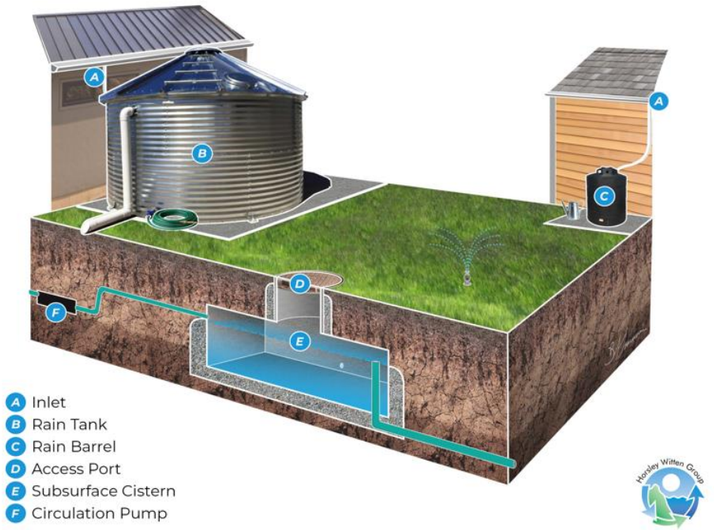
Examples on the back







Rain garden with native plants - HWG

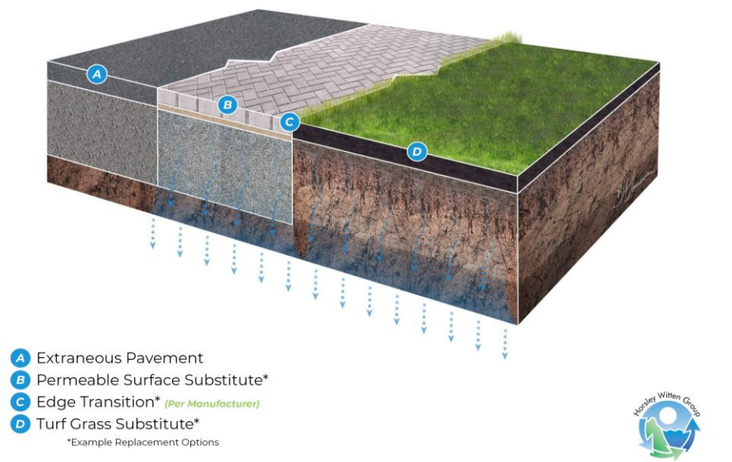


Rainwater Harvesting Schematic - HWG

RESIDENTIAL GSI: HOMEOWNER RESOURCES

Homeowners looking to get inspired on how they can ***green*** their homes while beautifying their properties can refer to the following documents:

- Hawai‘i State Rain Garden Manual https://www.huihawaii.org/rain-gardens.html
- 2020 Guidelines on Rainwater Catchment Systems for Hawai‘i https://www.ctahr.hawaii.edu/hawaiirain/Library/Guides&Manuals/HI_Guidelines_2020.pdf
- HI 2023 LID guide https://planning.hawaii.gov/czm/initiatives/low-impact-development/
- UH Sea Grant GSI Guide https://seagrant.soest.hawaii.edu/sbcd-stormwater-practices/



Pavement Reduction Schematic - HWG

BUILDING BACK GREENER:

COMMERCIAL LOTS

The devastating August 2023 wildfires greatly impacted businesses as well as hotels and multi-family apartment complexes throughout downtown Lahaina. These types of properties share similar site layouts, typically with large buildings and parking lots, and are grouped together as “Commercial” properties. As these owners rebuild, they need to meet stormwater requirements, but can also go above and beyond to show the community their *mālama ʻāina*.

Green stormwater infrastructure (GSI) comes in many shapes and sizes, with an option for every site! In general, we recommend that **mauka sites** incorporate infiltration practices to reduce stormwater volumes while **makai sites**, which may have high groundwater that limits infiltration, focus on cleaning the water before it gets to the ocean.

Residents and tourists alike will appreciate these efforts to help green Lahaina!

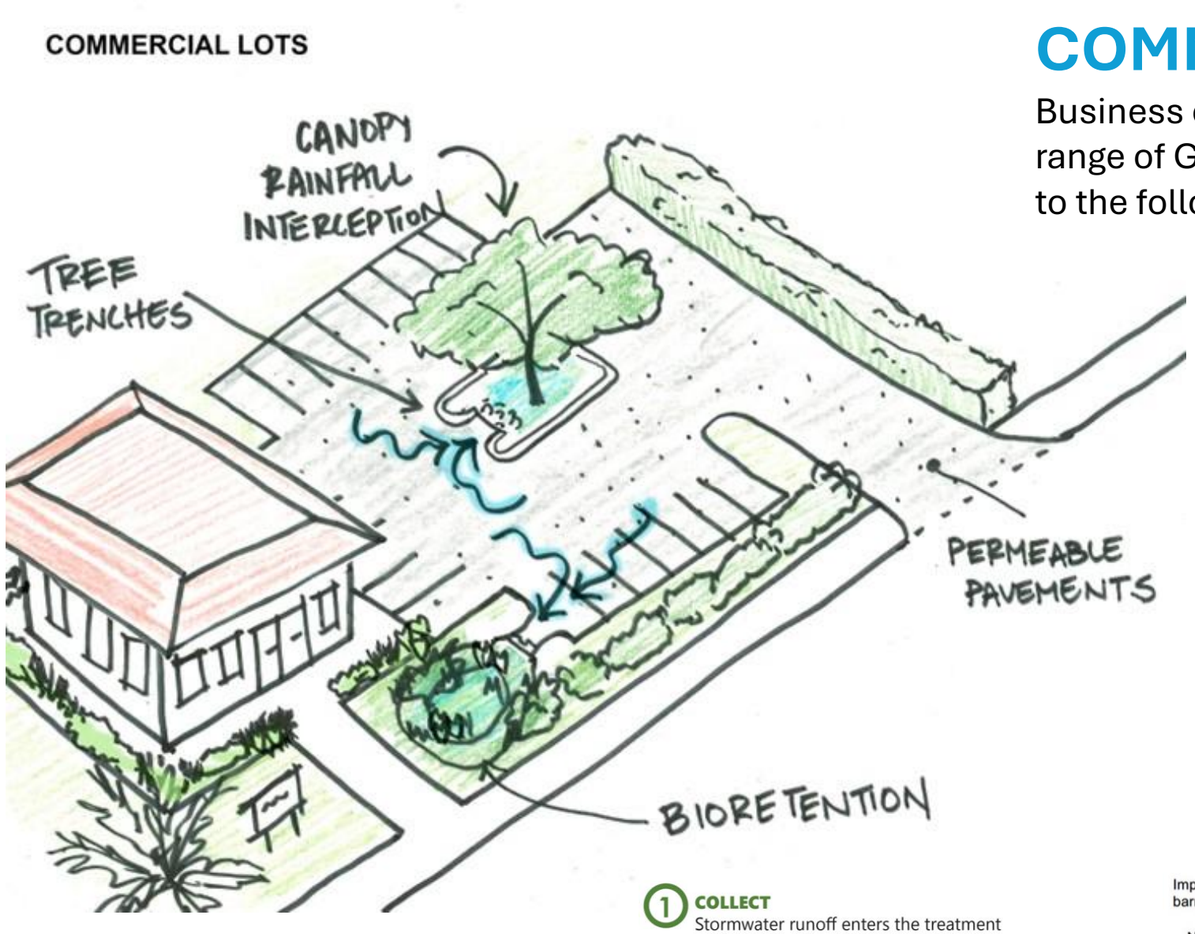
Examples on the back

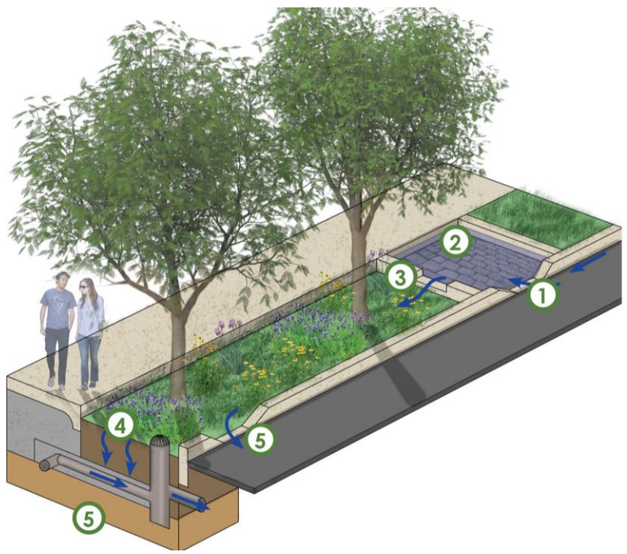


COMMERCIAL GSI: DEVELOPER RESOURCES

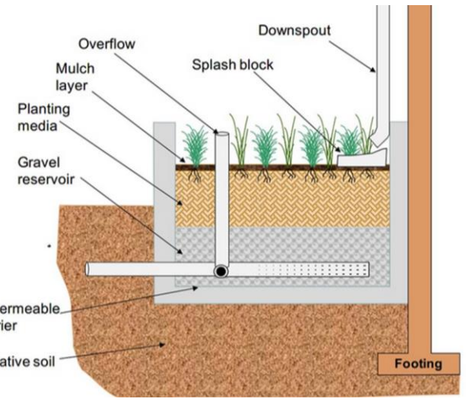
Business owners and developers interested in finding design guidance and details for a range of GSI that reduce costs and pollution while beautifying their properties can refer to the following documents:

- Storm Water BMP Guide For New and Redevelopment for the City and County of Honolulu, 2017 www.honolulu.gov/swq/info-resources/construction-design/
- HDOT Stormwater Post Construction Best Management Practices Manual, 2022 www.stormwaterhawaii.com/wp-content/uploads/2022/07/PC-BMP-Manual_220718-FULL.pdf
- HI 2023 LID guide planning.hawaii.gov/czm/initiatives/low-impact-development/
- Stormwater Management in Pacific and Caribbean Islands: A practitioner's guide to implementing LID, 2014 www.coris.noaa.gov/activities/stormwater_lid/

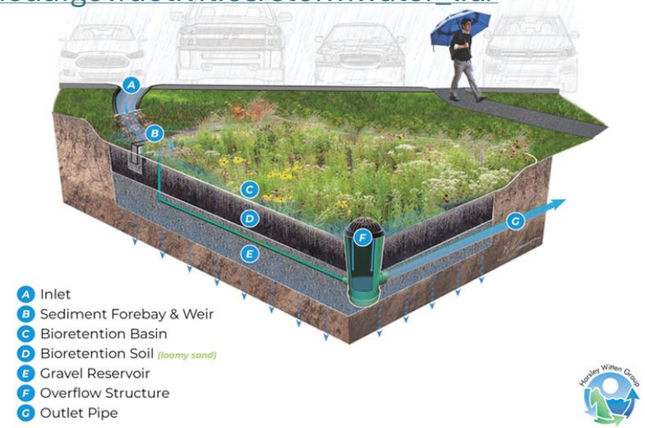




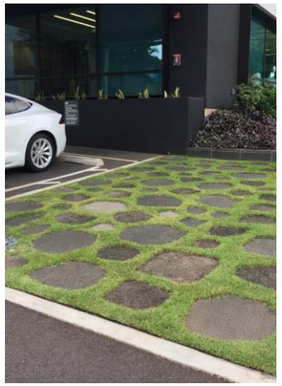
Surface Tree Trench Schematic - HWG



Stormwater Planter (*type of underdrained bioretention used for downspouts*) – Lousiana Stormwater BMP Guidance Tool, 2010



Bioretention with Underdrain Schematic - HWG





Permeable Pavements in Honolulu – UH Sea Grant



Parking Lot Bioretention in Guam - HWG

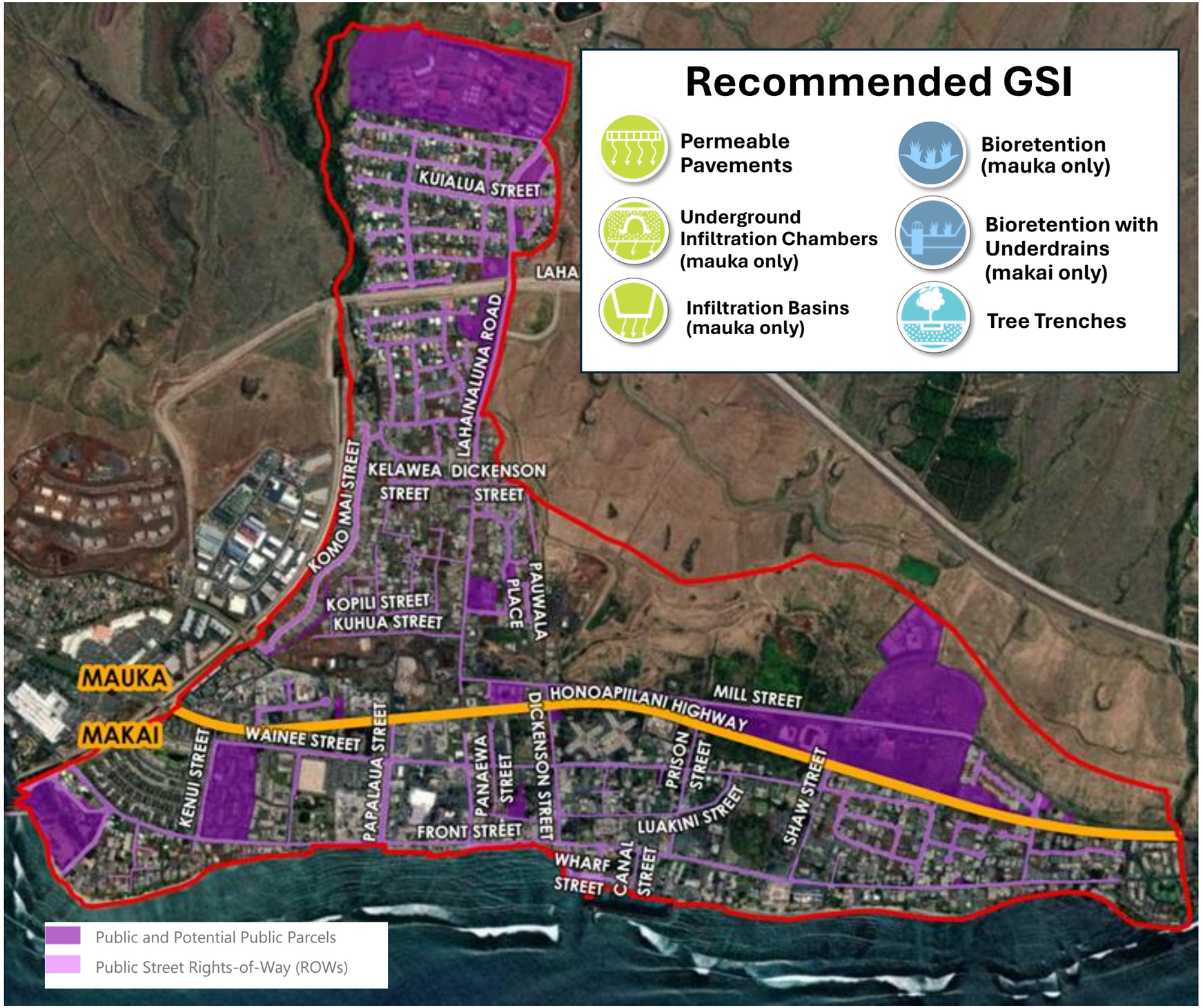
BUILDING BACK GREENER:

PUBLIC PARCELS AND STREETS

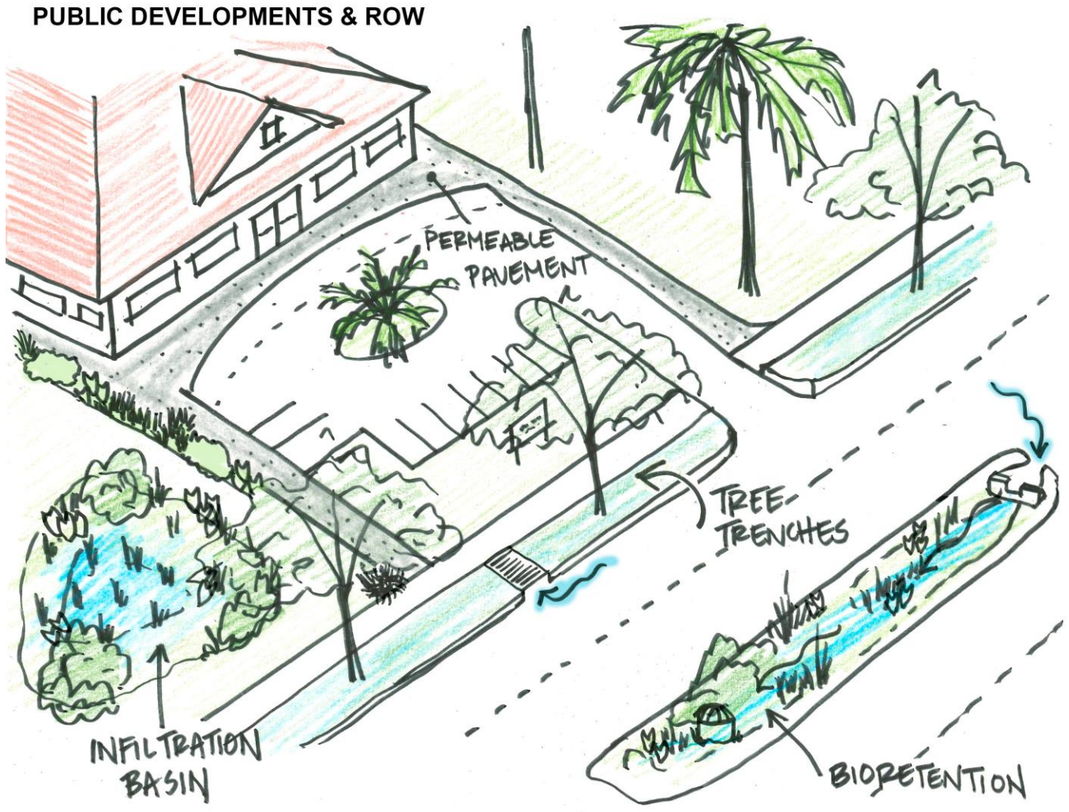
After the August 2023 wildfire disaster, public spaces in Lahaina have an even more important role – to provide support and stability for a rebuilding community. These spaces can also serve as ***inspiration*** to residents and developers on how to build back more resilient with sustainable development practices – to build back greener.

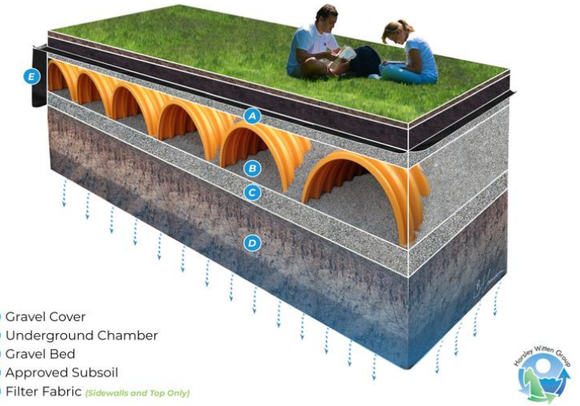
Green stormwater infrastructure (GSI) should be integrated throughout public parcels, with more infiltration incorporated at **mauka sites** than **makai sites**, which may have high groundwater that limits infiltration. As streets are disturbed for replacing and upgrading utilities, GSI should be integrated into the rights-of-way (ROW) as well. GSI in public spaces can:

- **Improve coastal water quality**
- **Reduce localized flooding**
- **Restore groundwater levels**
- **Save $$ on energy and water costs**
- **Build resiliency to climate impacts**
- **Lower urban heat island effects**
- **Improve quality of life**



*Examples on the back





Underground Infiltration Chamber Schematic - HWG



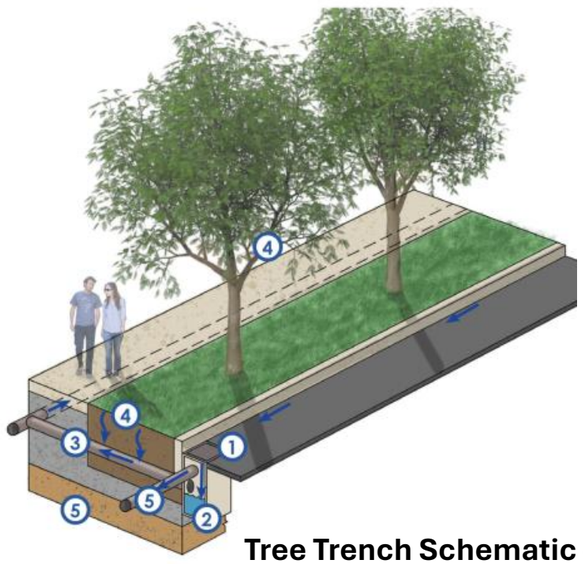
Permeable Paver Installation at Kailua Beach Park, Oahu – photo from HOK, in Pacific Island LID Guide (HWG, 2014)



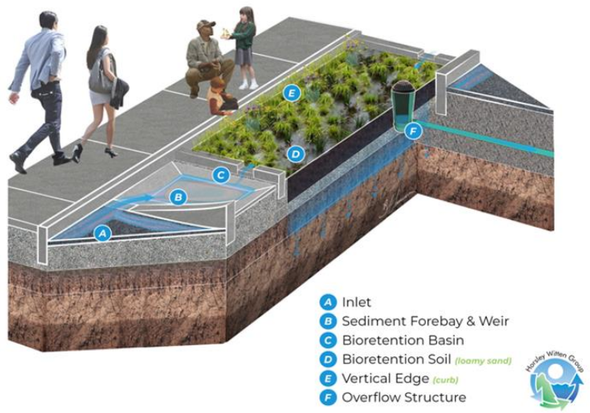
Bioretention Area at Wahikuli Wayside Park – HWG



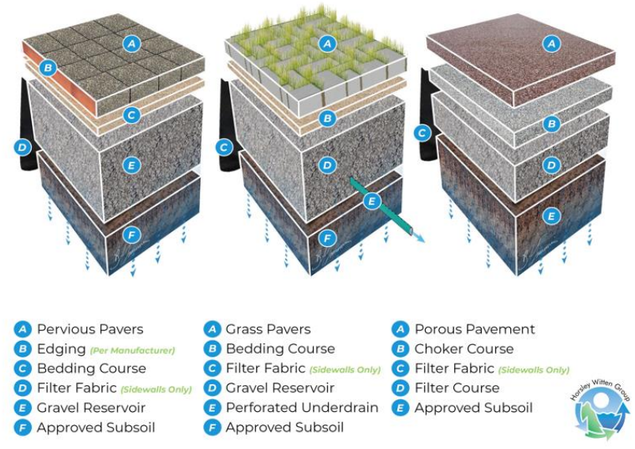
Permeable Paver Parking – photo from HOK, in Pacific Island LID Guide (HWG, 2014)



Tree Trench Schematic - HWG



Roadside Bioretention Schematic - HWG



Permeable Paver Schematic - HWG

BUILDING BACK GREENER:

WETLANDS AND CONNECTIONS

As the community works together to rebuild after the devastating August 2023 wildfires, we have a unique opportunity to re-envision a greener Lahaina – a Lahaina closer to the historic village documented to be lush with springs, wetlands, and groves of breadfruit trees. The ancient Hawaiians understood the intricate connections between land and water and embraced *mālama ʻāina*.

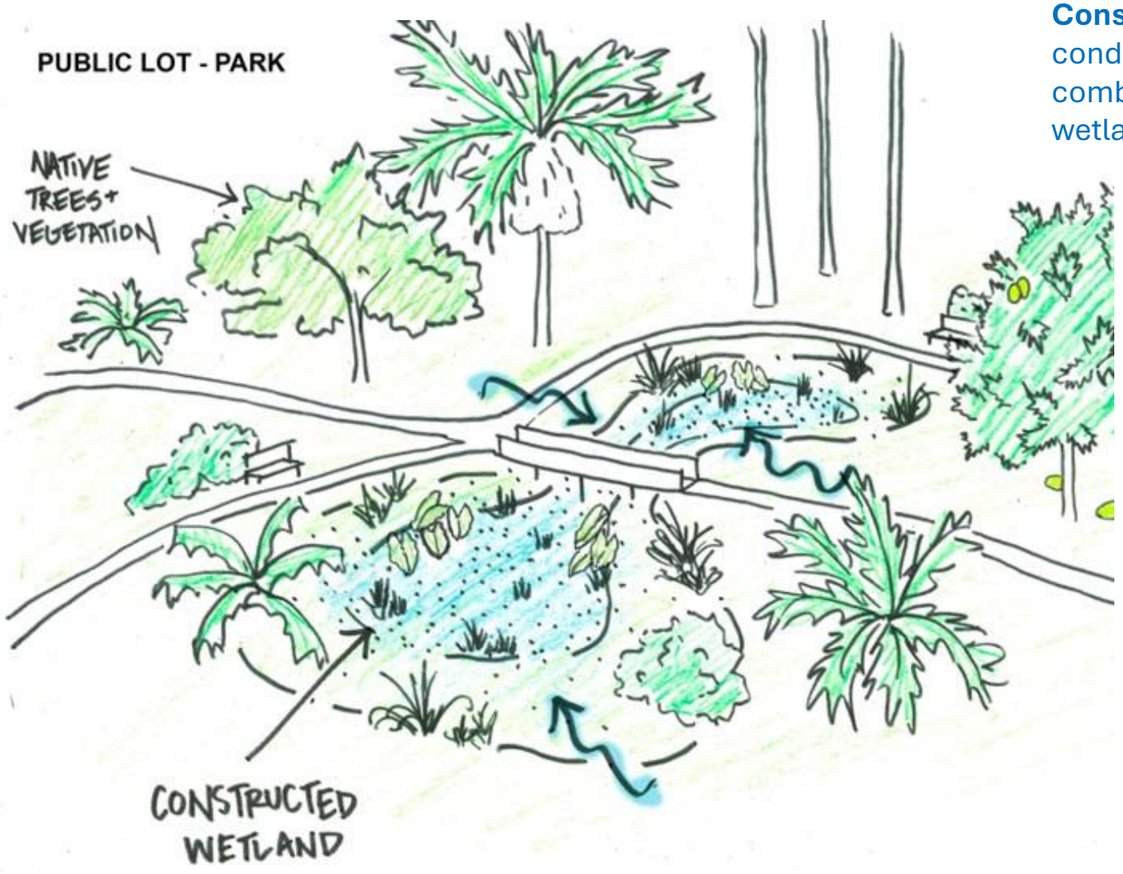
The rains in the West Maui mountains are a vital source of water to support a restored hydrological system within the study area. Constructed wetlands and native vegetation plantings need to be paired with watershed-wide action, mauka to makai, to ensure water will be available. These recommendations can:

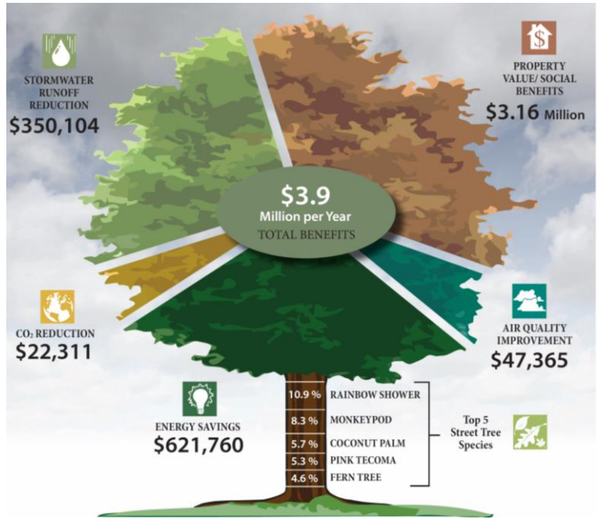
- **Restore natural flow paths and wetland systems**
- **Maintain groundwater**
- **Provide surface water storage**
- **Improve habitat and biodiversity**
- **Provide recreational opportunities**
- **Improve quality of life**
- **Build coastal resiliency**

Examples on the back

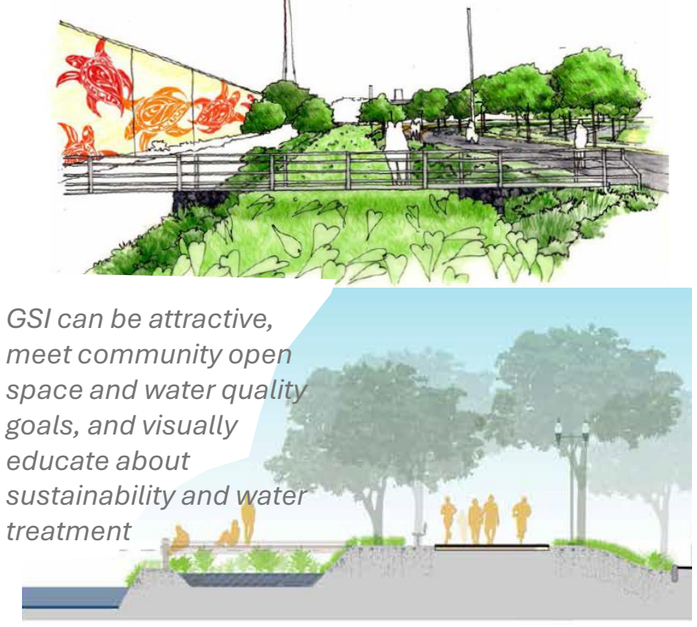


Constructed Stormwater Wetlands are GSI practices that take advantage of high groundwater conditions and hydrologic connections to mimic natural wetland processes. These can be used in combination with native vegetation and restored and/or farmed wetlands (loʻi) to recreate historic wetland complexes. While wetlands need a lot of space, they work well as a part of a park system.





Benefits of Urban Trees in Honolulu – Fact Sheet - Hawaii DLNR Division of Forestry and Wildlife



GSI can be attractive, meet community open space and water quality goals, and visually educate about sustainability and water treatment

Excerpt of a Constructed Stormwater Wetland Concept in Park Setting – Greening America's Communities, Honolulu, HI (EPA, 2018)



Taro Field (loʻi kalo) on Kauai – UH Sea Grant GSI Guide



Breadfruit (ʻUlu) Grove – Tree That Feed – The Breadfruit Tree (Usvat, 2013)

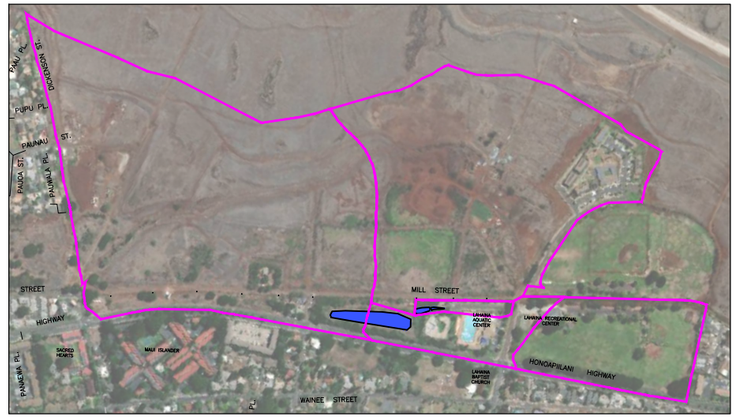


Constructed Stormwater Wetland - HWG

ATTACHMENT B: PILOT PROJECT SUMMARY SHEETS



SITE LAYOUT



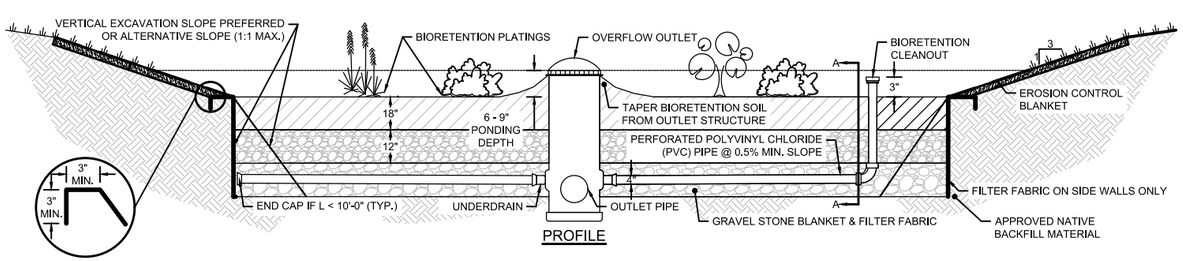
DRAINAGE MAP
1" = 1000'

SITE ID: R-1 SUMMARY TABLE

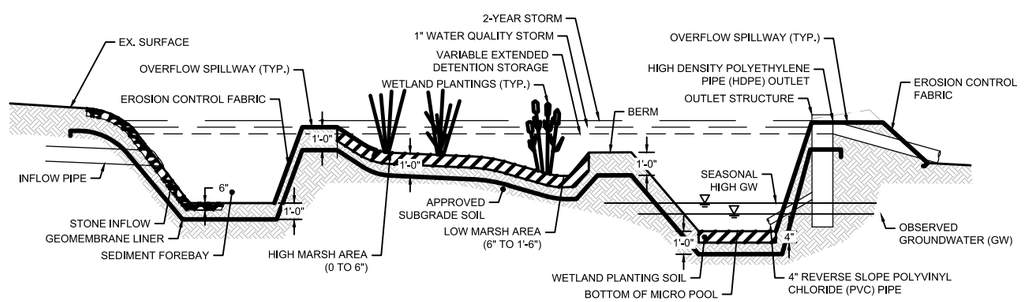
TOTAL DRAINAGE AREA	144.4 ACRES
TOTAL IMPERVIOUS AREA	19.6 ACRES
TOTAL TREATMENT AREA	45,060 SF
TOTAL WQV GOAL	70,350 CF
TOTAL WQV PROVIDED	85,050 CF

Aquatic Center Basin Retrofit **Site ID: R-1**
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$0.5	SF	90000	$45,000
Earthwork	$35	CY	3000	$105,000
Constructed Wetland	$12	SF	41000	$492,000
Bioretention	$30	SF	3100	$93,000
			Construction	$735,000
			30% Contingency	$221,000
			Total	**$956,000**



BIORETENTION FACILITY W/ OVERFLOW OUTLET
NOT TO SCALE



CONSTRUCTED WETLAND
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
www.horsleywitten.com
90 Route 6A, Unit 1
Sandwich, MA 02563
Phone: (508) 833-6600
Fax: (508) 833-3150

Checked By: SMS
Drawn By: SMS, MM
Design By: SMS
Date: AUGUST 2025

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: R-1 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ---

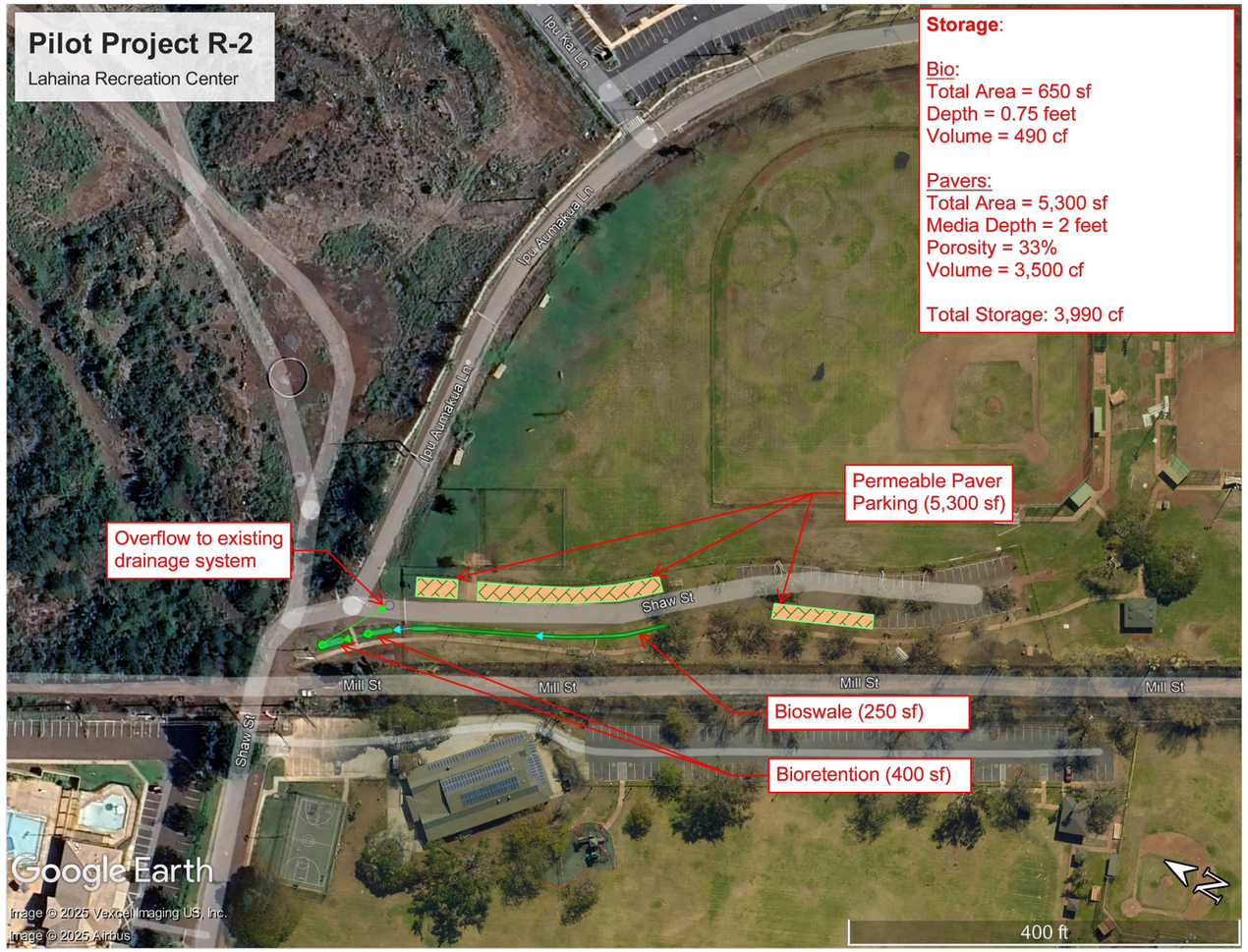
Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 1 of 9

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SITE LAYOUT



DRAINAGE MAP
1" = 500'

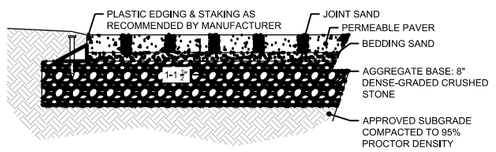
SITE ID: R-2 SUMMARY TABLE

TOTAL DRAINAGE AREA	17.2 ACRES
TOTAL IMPERVIOUS AREA	0.8 ACRES
TOTAL TREATMENT AREA	5,950 SF
TOTAL WQV GOAL	1,219 CF
TOTAL WQV PROVIDED	3,990 CF

Lahaina Recreation Center **Site ID: R-2**
Planning Level Cost

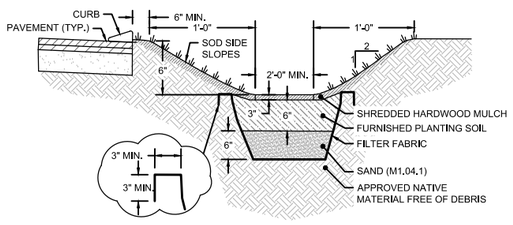
Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$0.5	SF	20000	$10,000
Earthwork	$35	CF	440	$15,400
Permeable Pavers	$35	SF	5300	$185,500
Bioswale	$125	LF	250	$31,250
Bioretention	$30	SF	400	$12,000

Construction	$254,150
30% Contingency	$77,000
Total	**$331,150**

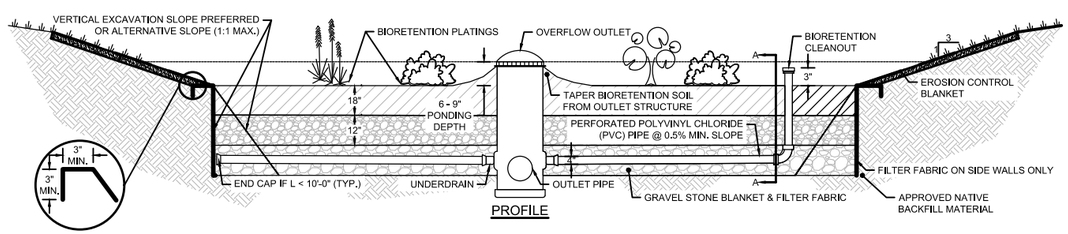


NOTES:
1. EXCAVATE ANY UNSUITABLE, UNSTABLE OR UNCONSOLIDATED MATERIAL FROM SUBGRADE.
2. COMPACT BASE TO 95% STANDARD PROCTOR DENSITY.
3. FILL ANY DEPRESSIONS IN BASE WITH BASE MATERIAL.
4. SCREEN BEDDING SAND LEVEL TO AN EVEN THICKNESS OF 1 TO 1 ½".

PERMEABLE PAVERS SECTION
NOT TO SCALE



BIOSWALE
NOT TO SCALE



PROFILE

BIORETENTION FACILITY W/ OVERFLOW OUTLET
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
www.horsleywitten.com
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Sandwich, MA 02563
Phone: (508) 833-6600
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Checked By: SMS
Drawn By: SMS, MM
Design By: SMS
Date: AUGUST 2025

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: R-2 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
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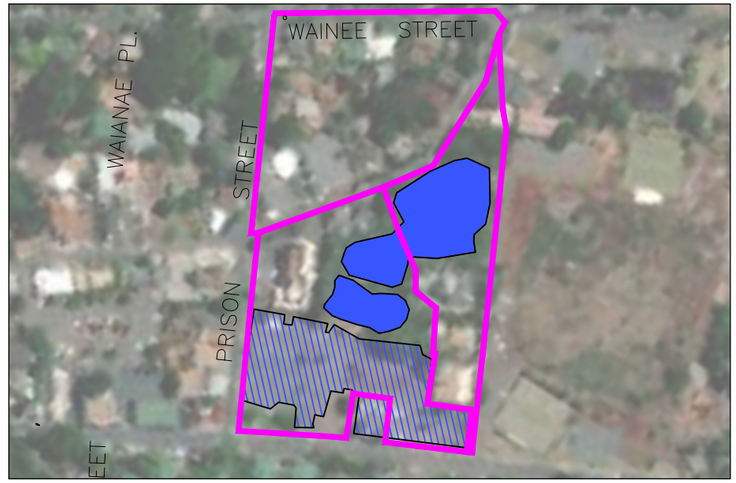
Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 2 of 9

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DRAINAGE MAP
1" = 500'

SITE ID: R-3 SUMMARY TABLE

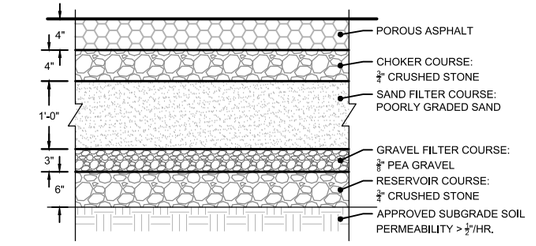
TOTAL DRAINAGE AREA	9.0 ACRES
TOTAL IMPERVIOUS AREA	7.2 ACRES
TOTAL TREATMENT AREA	114,500 SF
TOTAL WQV GOAL	16,988 CF
TOTAL WQV PROVIDED	116,300 CF

Public Parking and Wetland Connectivity **Site ID: R-3**
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$0.5	SF	142120	$71,060
Earthwork	$35	CF	7625	$266,875
Constructed Wetland	$12	SF	10500	$126,000
Restore Existing Wetland	$2	SF	37500	$75,000
Permeable Pavement*	$20	SF	39900	$798,000
			Construction	$1,336,935
			30% Contingency	$402,000
			Total	**$1,738,935**

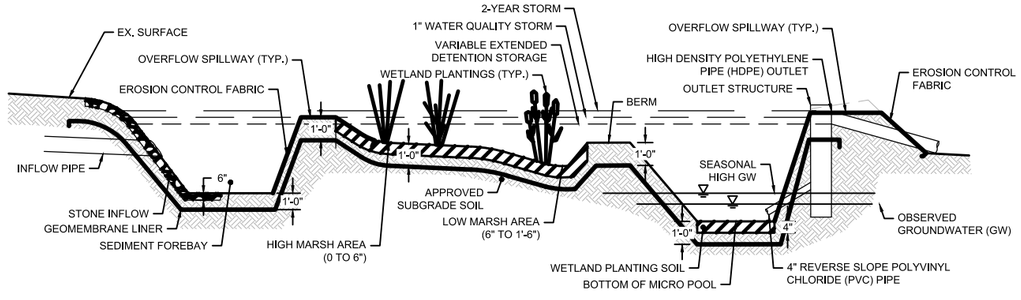
*Assumes only parking stalls will be permeable pavement

SITE LAYOUT



NOTES:
1. SANDY-LOAM AND/OR LOAMY-SAND TOPSOIL MATERIAL WILL BE EXCAVATED FROM ALL PAVED AREAS PRIOR TO SUB-BASE INSTALLATION.
2. SUB-GRADE (EXISTING MATERIAL) WILL CONSIST OF INERT MATERIAL THAT IS HARD, DURABLE STONE AND/OR COARSE SAND, FREE FROM LOAM & CLAY TO A DEPTH NOT LESS THAN 4'-0" BELOW THE FINISH PAVEMENT SURFACE.
3. SUBGRADE FILL WILL BE COMPACTED TO 95% COMPACTION UNLESS OTHERWISE DIRECTED BY THE ENGINEER.

POROUS PAVEMENT
NOT TO SCALE



CONSTRUCTED WETLAND
NOT TO SCALE

Revisions

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Horsley Witten Group, Inc.
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90 Route 6A, Unit 1
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Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: R-3 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

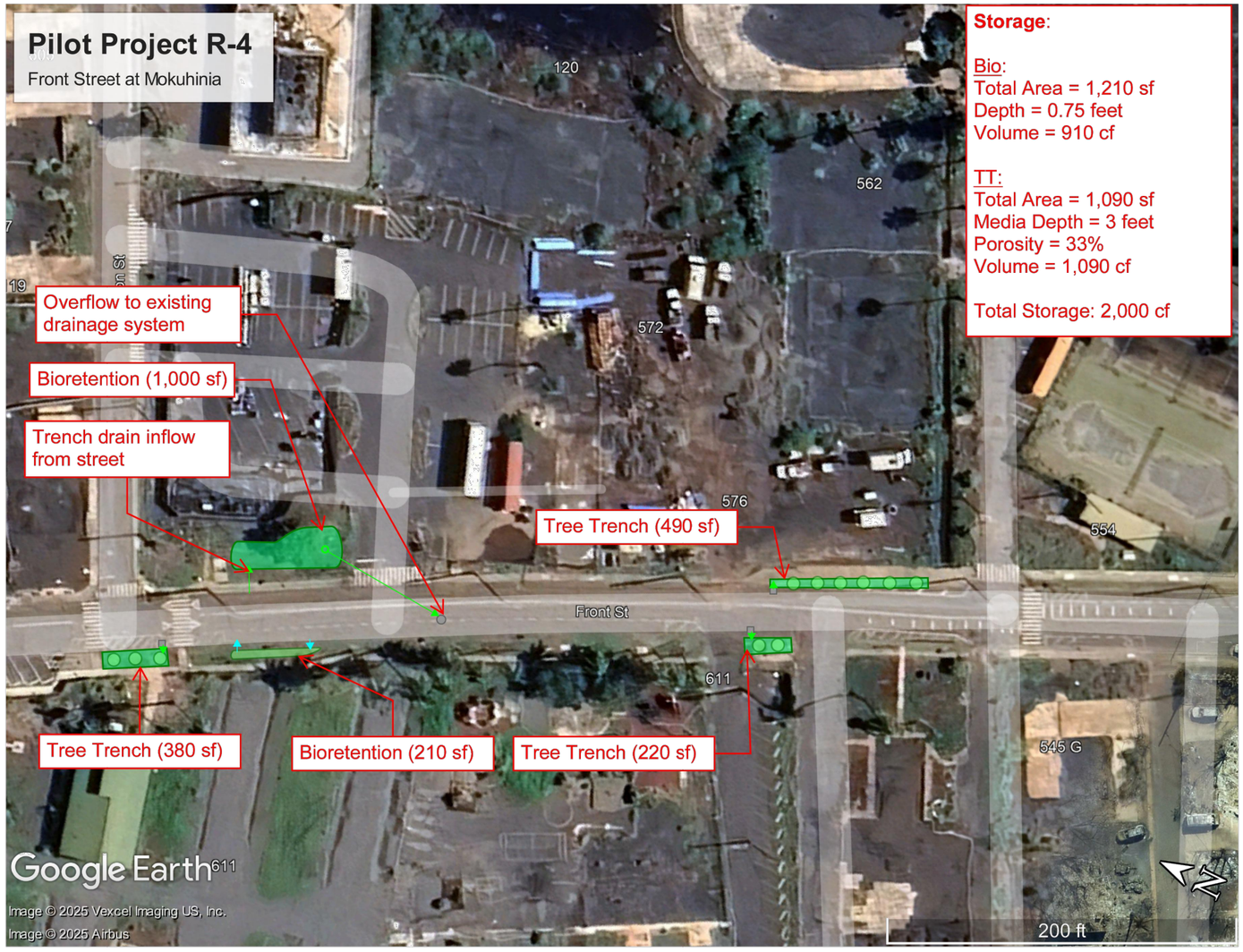
Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc.
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 3 of 9

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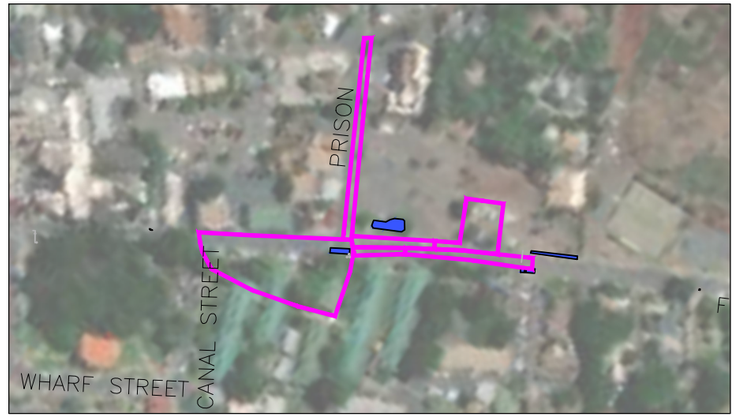
Storage:

Bio:
Total Area = 1,210 sf
Depth = 0.75 feet
Volume = 910 cf

TT:
Total Area = 1,090 sf
Media Depth = 3 feet
Porosity = 33%
Volume = 1,090 cf

Total Storage: 2,000 cf

SITE LAYOUT

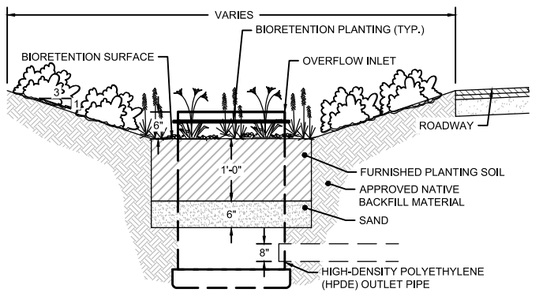


DRAINAGE MAP
1" = 300'

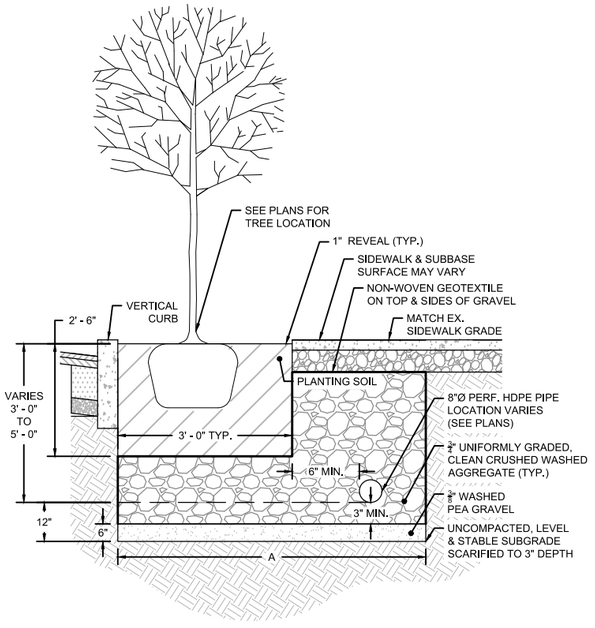
SITE ID: R-4 SUMMARY TABLE	
TOTAL DRAINAGE AREA	1.31 ACRES
TOTAL IMPERVIOUS AREA	1.21 ACRES
TOTAL TREATMENT AREA	2,300 SF
TOTAL WQV GOAL	4,922 CF
TOTAL WQV PROVIDED	2,000 CF

Front Street at Mokuhinia **Site ID: R-4**
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$0.5	SF	20000	$10,000
Earthwork	$35	CY	110	$3,850
Bioretention	$30	SF	1210	$36,300
Tree Trench	$40	SF	1090	$43,600
Infrastructure Connections	$15,000	LS	1	$15,000
			Construction	$108,750
			30% Contingency	$33,000
			Total	**$141,750**



ROADSIDE BIORETENTION
NOT TO SCALE



ENHANCED STORMWATER TREE TRENCH
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
www.horsleywitten.com
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Sandwich, MA 02563
Phone: (508) 833-6600
Fax: (508) 833-3150

Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: R-4 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

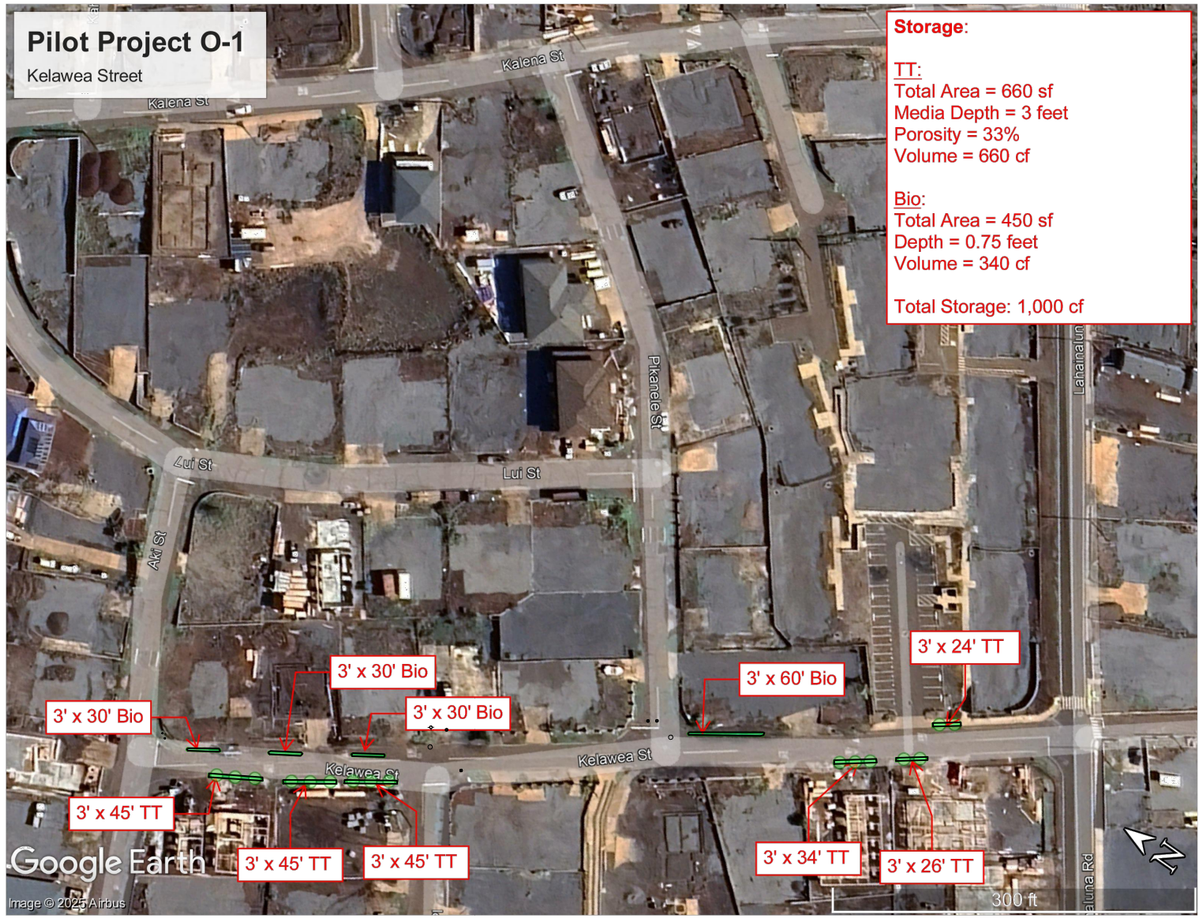
Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc.
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 4 of 9

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SITE LAYOUT



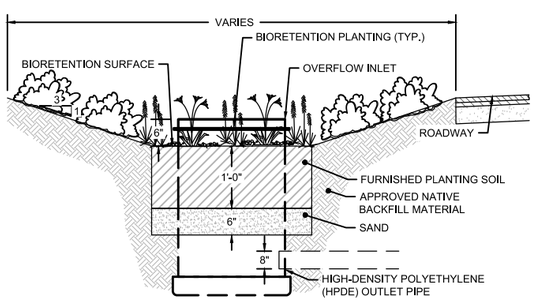
DRAINAGE MAP
1" = 300'

SITE ID: O-1 SUMMARY TABLE

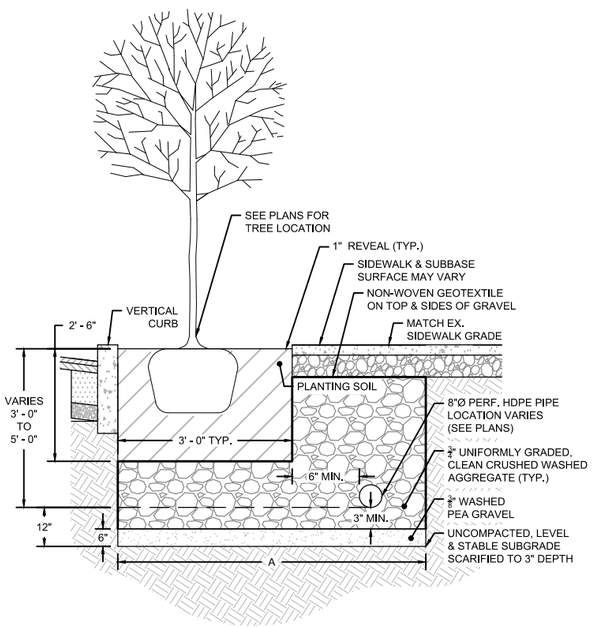
TOTAL DRAINAGE AREA	8.9 ACRES
TOTAL IMPERVIOUS AREA	7.8 ACRES
TOTAL TREATMENT AREA	1,110 SF
TOTAL WQV GOAL	22,172 CF
TOTAL WQV PROVIDED	1,000 CF

Kelawea Street **Site ID: O-1**
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$1	LF	12500	$6,250
Earthwork	$35	CY	100	$3,500
Bioretention	$30	SF	450	$13,500
Tree Trench	$40	SF	660	$26,400
Infrastructure Connections	$25,000	LS	1	$25,000
			Construction	$74,650
			30% Contingency	$23,000
			Total	**$97,650**



ROADSIDE BIORETENTION
NOT TO SCALE



ENHANCED STORMWATER TREE TRENCH
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

Horsley Witten Group, Inc.
Sustainable Environmental Solutions
www.horsleywitten.com
90 Route 6A, Unit 1
Sandwich, MA 02563
Phone: (508) 833-6600
Fax: (508) 833-3150

Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: O-1 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

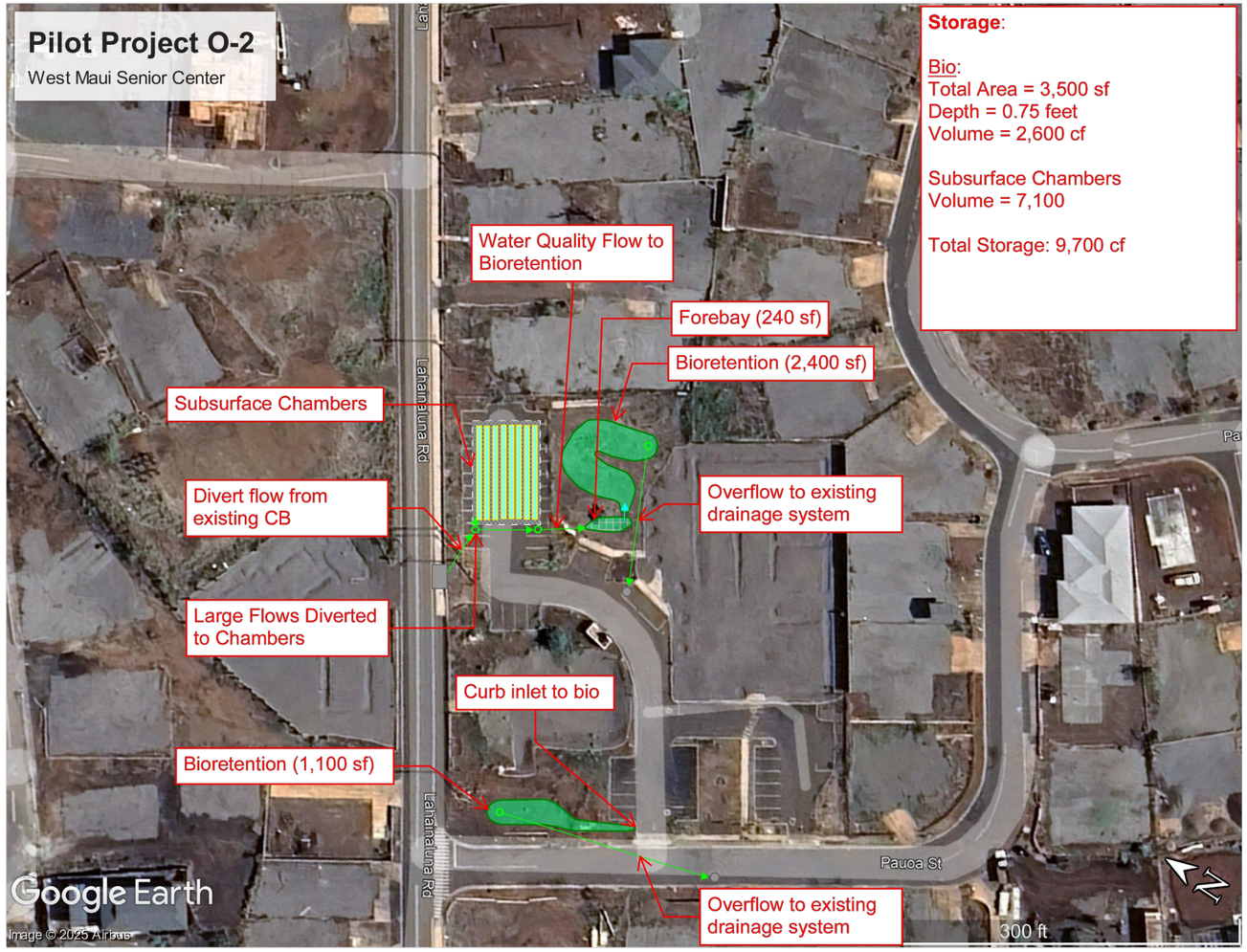
Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc.
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 5 of 9

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SITE LAYOUT



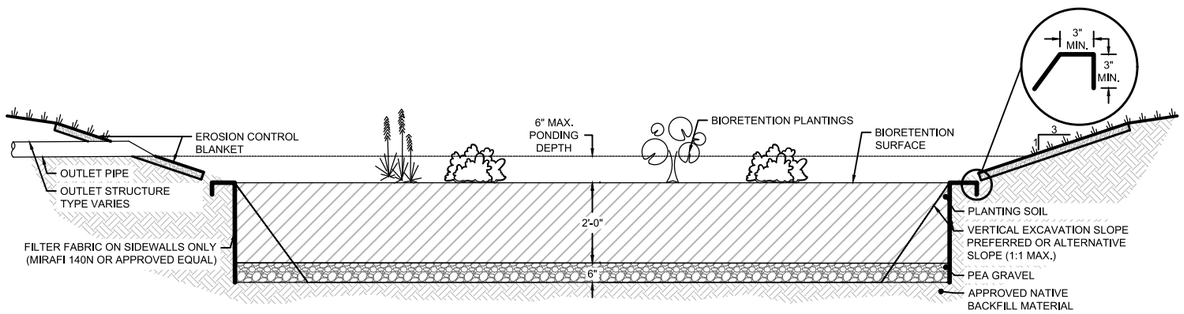
DRAINAGE MAP
1" = 1000'

SITE ID: O-2 SUMMARY TABLE

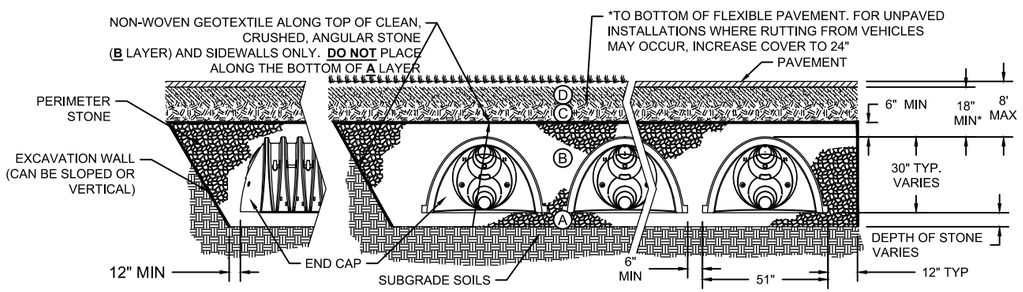
TOTAL DRAINAGE AREA	6.4 ACRES
TOTAL IMPERVIOUS AREA	5.7 ACRES
TOTAL TREATMENT AREA	7,000 SF
TOTAL WQV GOAL	21040 CF
TOTAL WQV PROVIDED	9,700 CF

West Maui Senior Center Site ID: O-2
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$9	SF	300	$2,700
Earthwork	$30	CY	455	$13,650
Subsurface Chambers	$20	CF	9700	$194,000
Bioretention	$30	SF	3500	$105,000
Infrastructure Connections	$15,000	LS	1	$15,000
			Construction	$330,350
			30% Contingency	$100,000
			Total	**$430,350**



BIORETENTION FACILITY
NOT TO SCALE



INFILTRATION CHAMBERS
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

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Sustainable Environmental Solutions
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Date: AUGUST 2025 | Designed By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: O-2 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc.
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Sandwich, MA 02536
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Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 6 of 9

last modified: 08/20/25 printed: 08/21/25 by gg H:\Projects\EPA\OCR\24074 BPA CO 68HERH24F0399 Lahaina Drainage and GI\Drawings\24074_ST_concepts.dwg



SITE LAYOUT



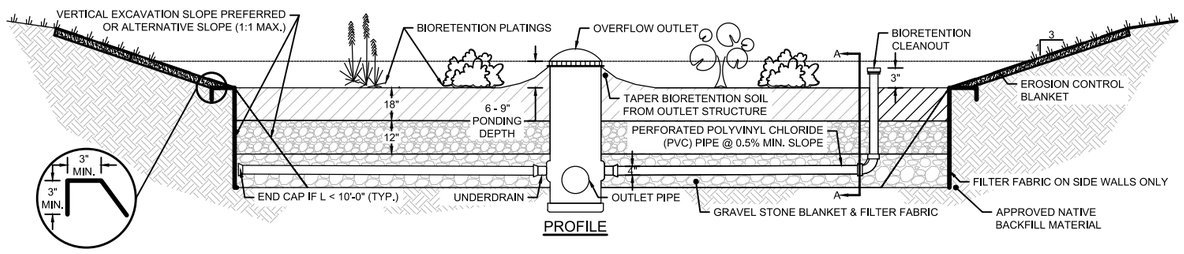
DRAINAGE MAP
1" = 200'

SITE ID: O-3 SUMMARY TABLE

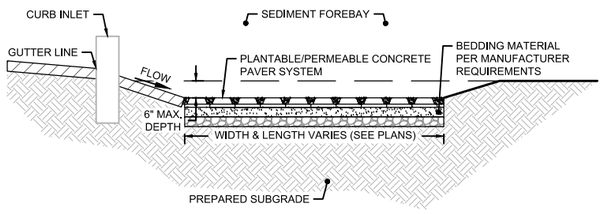
TOTAL DRAINAGE AREA	1.7 ACRES
TOTAL IMPERVIOUS AREA	1.5 ACRES
TOTAL TREATMENT AREA	1,690 SF
TOTAL WQV GOAL	2,047 CF
TOTAL WQV PROVIDED	1,260 CF

David Malo Circle Apartments Site ID: O-3
Planning Level Cost

Item	Unit Cost	Unit	Quantity	Subtotal
Erosion Control	$0.5	SF	7200	$3,600
Earthwork	$35	CY	50	$1,750
Bioretention	$30	SF	1690	$50,700
Infrastructure Connection	$8,000	LS	1	$8,000
			Construction	$64,050
			30% Contingency	$20,000
			Total	**$84,050**



BIORETENTION FACILITY W/ OVERFLOW OUTLET
NOT TO SCALE



SEDIMENT FOREBAY
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

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Sustainable Environmental Solutions
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Phone: (508) 833-6600
Fax: (508) 833-3150

Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: O-3 SUMMARY SHEET

Prepared For:
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
Phone: 415-947-8000
Fax: ----

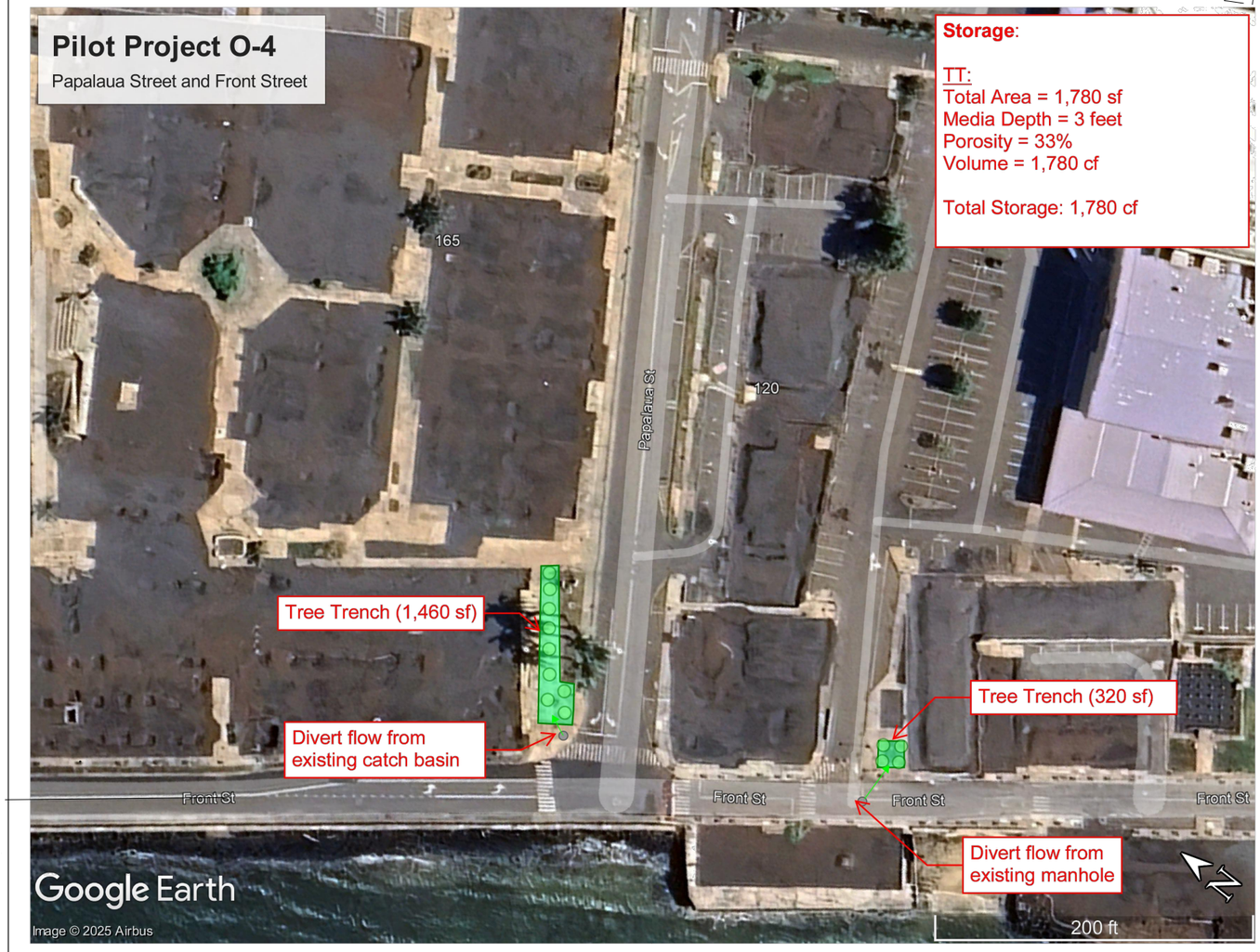
Survey & Preliminary Layout Provided By:
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Sandwich, MA 02536
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Project Number: 24074

Sheet Number: 7 of 9

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SITE LAYOUT

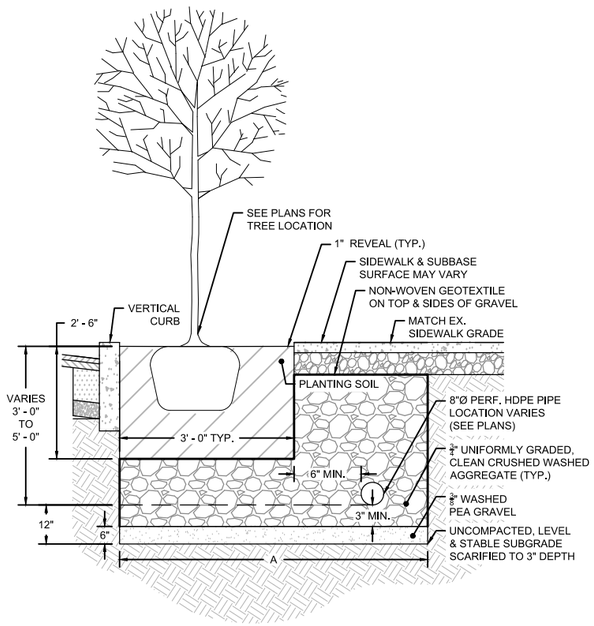
Papalaua Street and Front Street Planning Level Cost		Site ID: O-4		
Item	**Unit Cost**	**Unit**	**Quantity**	**Subtotal**
Erosion Control	$0.5	LF	5150	$2,575
Earthwork	$35	CY	25	$875
Tree Trench	$40	SF	1780	$71,200
			Construction	$74,650
			30% Contingency	$23,000
			Total	**$97,650**



DRAINAGE MAP
1" = 300'

SITE ID: O-4 SUMMARY TABLE

TOTAL DRAINAGE AREA	1.9 ACRES
TOTAL IMPERVIOUS AREA	1.8 ACRES
TOTAL TREATMENT AREA	1,780 SF
TOTAL WQV GOAL	6,400 CF
TOTAL WQV PROVIDED	1,780 CF



ENHANCED STORMWATER TREE TRENCH
NOT TO SCALE

Revisions

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Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: O-4 SUMMARY SHEET

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Phone: 415-947-8000
Fax: ----

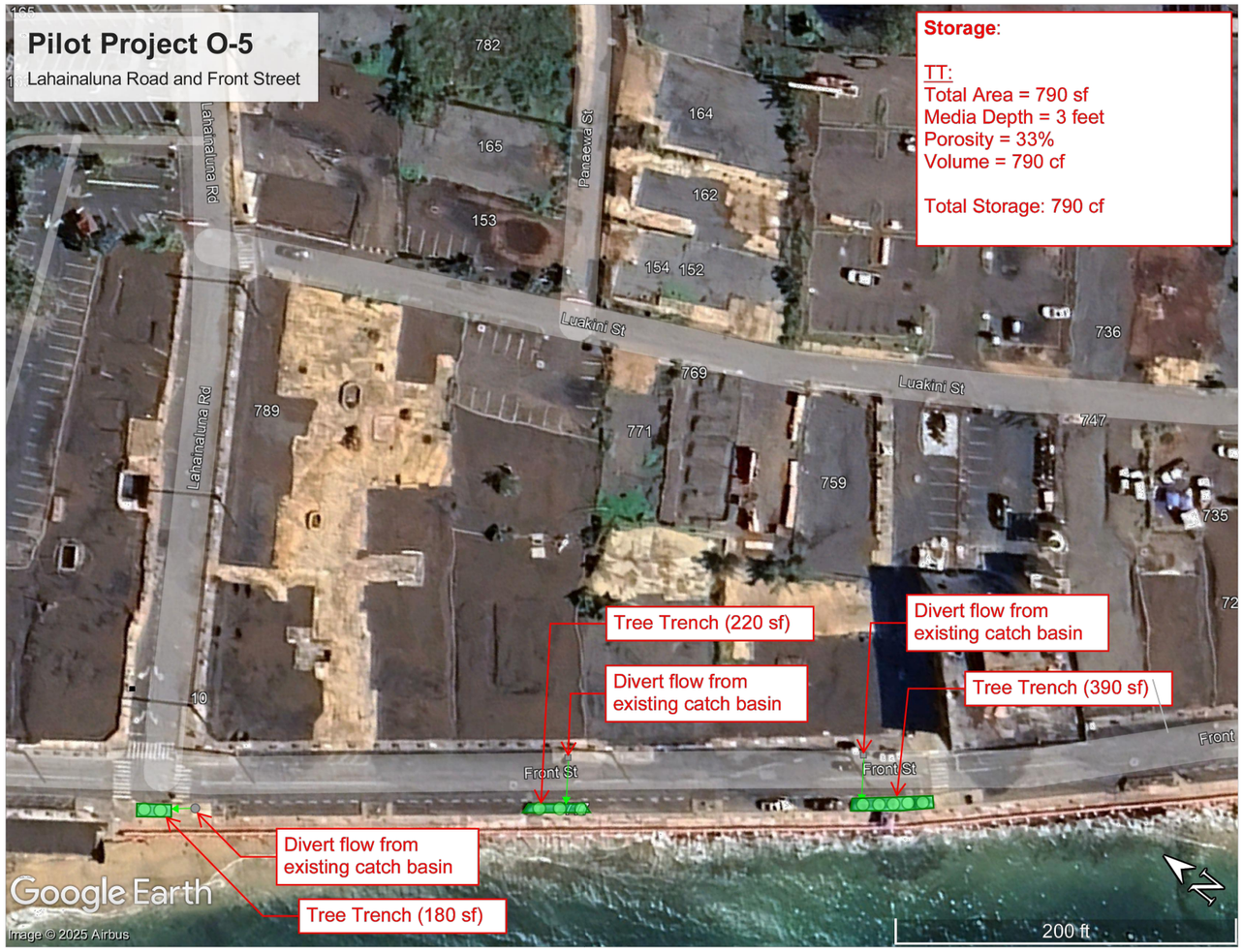
Survey & Preliminary Layout Provided By:
Horsley Witten Group, Inc.
90 Route 6A
Sandwich, MA 02536
Phone: 508-833-6600
Fax: 508-833-3150

Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

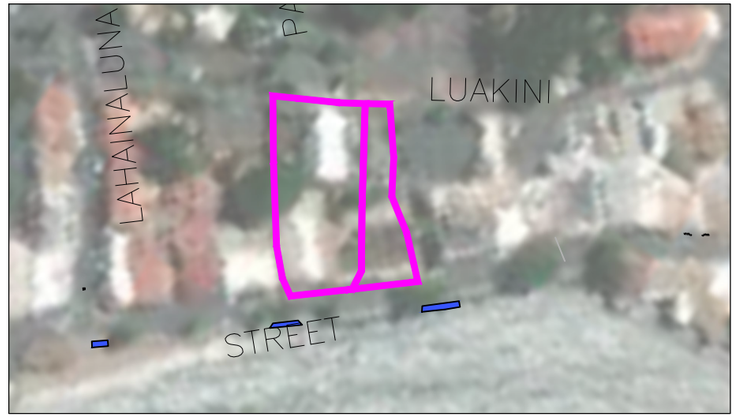
Sheet Number: 8 of 9

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SITE LAYOUT

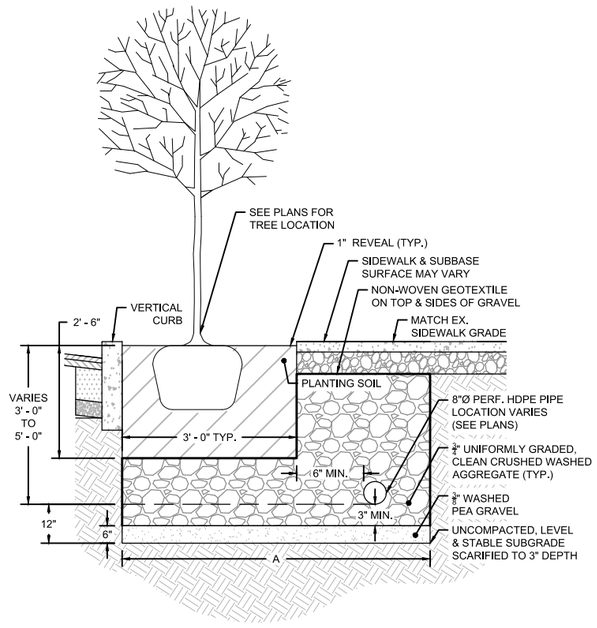
Lahainaluna Road and Front Street Site ID: O-5 Planning Level Cost				
Item	**Unit Cost**	**Unit**	**Quantity**	**Subtotal**
Erosion Control	$0.5	LF	3000	$1,500
Earthwork	$35	CY	90	$3,150
Tree Trench	$40	SF	790	$31,600
			Construction	$36,250
			30% Contingency	$11,000
			Total	**$47,250**



DRAINAGE MAP
1" = 200'

SITE ID: O-5 SUMMARY TABLE

TOTAL DRAINAGE AREA	0.9 ACRES
TOTAL IMPERVIOUS AREA	0.9 ACRES
TOTAL TREATMENT AREA	790 SF
TOTAL WQV GOAL	3,660 CF
TOTAL WQV PROVIDED	790 CF



ENHANCED STORMWATER TREE TRENCH
NOT TO SCALE

Revisions

Rev	Date	By	Appr	Description

Horsley Witten Group, Inc.
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90 Route 6A, Unit 1
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Date: AUGUST 2025 | Design By: SMS | Drawn By: SMS, MM | Checked By: SMS

Plan Set: PILOT PROJECTS
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: O-5 SUMMARY SHEET

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Registration:
NOT FOR CONSTRUCTION

Project Number: 24074

Sheet Number: 9 of 9

last modified: 08/20/25 printed: 08/21/25 by gg H:\Projects\EPA\OCR\24074 BPA CO 68HERH24F0399 Lahaina Drainage and GI\Drawings\24074_ST_concepts.dwg

ATTACHMENT C: MODELING REPORT

LAHAINA HYDROLOGIC/HYDRAULIC AND WATER QUALITY MODELING SUMMARY



August 21, 2025

Prepared by: Horsley Witten Group

Prepared for: US Environmental Protection Agency and
Maui County Department of Public Works

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1.0 INTRODUCTION

This report summarizes the development and input assumptions for the hydrologic and hydraulic (H&H) modeling and the water quality modeling performed in support of the Lahaina Drainage Master Plan Green Stormwater Infrastructure (GSI) Supplement. The H&H modeling focused on Drainage Areas R and O/D within the Lahaina Drainage Master Plan Study Area, and used HydroCAD to perform the analyses. The water quality analysis was performed using a spreadsheet model based on annual pollutant loading from different land uses and pollutant removal efficiencies for different stormwater management practices, and was performed for Drainage Area R and O/D, the entire Lahaina Drainage Master Plan Study Area, and for each of the proposed GSI pilot projects.

The remainder of this report is organized as follows:

Section 2. Hydrologic/Hydraulic Model – A description of how the four drainage scenarios were analyzed using a HydroCAD model that was developed for this project, and a summary of the impacts of each scenario on total runoff volume and peak discharge rates.

Section 3: Water Quality Model – A description of how the four drainage scenarios were analyzed using a spreadsheet model based on the Watershed Treatment Model, and a summary of the impacts of each scenario on total nitrogen, total phosphorus, total suspended solids, and fecal coliform loading.

Attachments - These include drainage area maps for the Drainage Area R and O/D, more detailed condition maps for the drainage networks modeled under existing and proposed conditions, as well as information on pipe sizes and lengths. HydroCAD model result reports are not included due to the excessive number of pages, but will be provided by HW upon request.

2.0 HYDROLOGIC/HYDRAULIC MODEL

2.1 Model Scenarios

HW modeled four scenarios representing different regimes of stormwater management in the study area (Note: the study area for the H&H modeling is Drainage Areas R and O/D), with the goal of comparing the benefits of each stormwater management regime against a pre-fire condition (considered a Baseline Condition).

Scenario 1: Pre-fire land use and drainage conditions (this is the Baseline against which other scenarios are measured.)

Scenario 2: Pre-fire condition plus the gray infrastructure (pipes and culverts) drainage improvements proposed in the 2005 Drainage Master Plan prepared by Belt Collins Hawaii Ltd.

Scenario 3: The drainage improvements of Scenario 2 plus the pilot projects recommended by HW in this document.

Scenario 4: The drainage improvements and pilot projects of Scenarios 3 plus implementation of widespread GSI across public and private properties in the study area.

The HydroCAD modeling scenarios were used to assess the following GSI implementation conditions:

Scenario 1: Establish baseline runoff volume and peak discharge rates at Outfalls O, D, R1, and R2.

Scenario 2: Evaluate benefits of 2005 DMP improvements, which consisted of changes to gray infrastructure (pipes and culverts primarily), compared to the Baseline.

Scenario 3: Evaluate additional benefits of pilot projects, compared to Scenario 2.

Scenario 4: Evaluate additional benefits of widespread GSI implementation, compared to Scenario 3.

2.2 Methods

This analysis used the existing drainage infrastructure information provided in the 2005 Drainage Master Plan as a basis for recreating a drainage system model. However, instead of using StormCAD, HW used HydroCAD, which is based on the NRCS TR-55 method. The reason we selected HydroCAD for this analysis is that HydroCAD allows us to incorporate conveyance elements of the drainage system, such as pipes and outfalls, as well as integrate storage and infiltration processes to reflect GSI. This modeling approach allowed us to evaluate how well infiltration and detention (implemented through the use of GSI) can potentially reduce peak discharge rates and volumes of stormwater at various outfall locations or study points. The HydroCAD model also allows the user to estimate volume and flow condition within the piped drainage systems and to pinpoint potential locations where backups occur during various design storms.

Drainage Areas

Drainage Areas were modified from the 2005 Drainage Master Plan to reflect changes in land use that had occurred between the preparation of the 2005 DMP and the year 2023 (the Pre-Fire Baseline condition). The drainage areas for drainage lines D, O, and R were then broken down into subcatchments and delineated within AutoCAD Civil3D. Subcatchment terminology is equivalent to the *tributary drainage areas* from the 2005 Drainage Master Plan. Maui County Parcel boundaries provided by Hawaii Statewide GIS Program were exported from GIS and imported into Civil3D. Land use by parcel was determined and delineated in Civil3D using the Hawaii GIS parcel data, Maui County Zoning, and aerial imagery[1]. The hydrologic soil group data layer was exported from GIS to Civil3D and then to HydroCAD[2]. HydroCAD delineates each of

[1] Hawaii GIS. maucotmk.shp: Hawaii GIS. May 2024.
Hawaii GIS. Maui County Zoning 2023: Hawaii GIS. October 2023
Maxar. Maxar (Vivid) Imagery: April 17, 2024

[2] USDA NRCS. Soils_HSG.shp: USDA NRCS. October 2023.

the areas by land use[3], soil type[4], and subcatchment and then places each subcatchment in the model.

Precipitation

HW evaluated design storms ranging from the 1.5-inch water quality storm (based on the 90th percentile 24-hour rainfall depth in West Maui) and the 1-, 25-, and 100-year 24-hour storm events. Per the HydroCAD Rainfall Event Lookup Table, sites in West Maui should use the HI 3 NRCS Atlas 14 24-hour rainfall distributions for Hawaii as published in WinTR-55 v2 to estimate the rainfall depth of the 24-hour design storms. 24-hour rainfall data were obtained from NOAA Atlas 14, Volume 10 Version 3 (accessed June 9, 2025). As a factor of safety to account for increased precipitation from climate change, the design storm rainfall depth was scaled as 0.9 times the upper limit of the 90% confidence interval (i.e., the 95th percentile) for a given storm recurrence interval. Design storms are shown below in **Table 1**.

Table 1. Design Storms – Lahaina, HI

Design Storm	Storm Depth (inches)	NOAA 95% Confidence Storm Depth (inches)	Adjusted Storm Depth (inches)
Water Quality Storm	1.5	-	-
1-year 24-hour	2.29	2.68	2.41
25-year 24-hour	7.16	8.48	7.63
100-year 24-hour	9.79	11.70	10.53

Assumptions

The Storage-Indication method within HydroCAD was selected to model reach and pond routing. The following assumptions were made in developing the HydroCAD model:

- Time of Concentration (TC) is five (5) minutes for a majority of subcatchments. For a few larger subcatchments, the TC was calculated separately for increased accuracy.
- Pipes
    - Pipe Routing
        - The pipe routing was based on information from the 2005 Drainage Master Plan, cross referenced and updated to incorporate drainage infrastructure GIS data provided by the County of Maui and further updated to reflect drainage connections clarified through observations and best estimates in the field by HW in May 2025[5].
    - Manning's roughness coefficient (n)

[3] From NOAA Office of Coastal Management C-CAP, 2011

[4] From USDA Soil Conservation Service, 2019

[5] Brown & Caldwell. LahainaStorm.gdb: Maui County, Hawaii. January 2024
Brown & Caldwell. WMDL_pipes.shp: Maui County, Hawaii. 2020.
Brown & Caldwell. WMDL_structures.shp: Maui County, Hawaii. 2020

        - Drainage pipe material was not identified in the available data sets for a majority of the pre-fire drainage system. Pipe material was assumed to be concrete with a Mannings number of 0.011.
    - Slopes
        - Pipe invert elevations were taken from the 2005 DMP when available.
        - When not available from the 2005 DMP, pipe invert elevations were taken from the drainage infrastructure GIS data provided by the County of Maui.
        - Not available from either source above, but data was known for pipes upstream and downstream of the pipes, pipe slopes and invert elevations were interpolated to fit within the known upstream and downstream elevations.
        - Otherwise, a pipe slope of 2.0% was assumed.
- Structures
    - Rim elevations
        - Rim elevations were taken from the 2005 DMP when available.
        - If rim elevation was not available from the 2005 DMP, the structure information from the drainage system infrastructure layers provided by the County of Maui was consulted.
        - If rim elevation was not available from the County of Maui data layer, the rim elevation was assumed from the contours derived from the Lahaina_TerrainModel.tif[6].
    - Overflow
        - A secondary overflow outlet was added to any structure that gave an overtopping warning in HydroCAD. The overflow outlet was modeled as a broad crested weir with an invert elevation that was assumed to be 0.1' below the rim elevation of the structure. This secondary outlet was directed to the next downstream inlet/catch basin.
- Drainage Areas
    - Drainage areas R and O/D were delineated based on HW's updated mapping of the existing drainage infrastructure and the most current topographic information available to us. The Drainage Area boundaries are generally the same as those presented in the 2005 Drainage Master Plan, although minor updates were incorporated by HW to reflect changes to the drainage infrastructure since 2005 associated with new development and land use changes and associated changes in land topography that were evident from the body of information provided by the County as well as May 2025 field observations. See Attachment B for Drainage Area Maps.
- Land Cover and Curve Number
    - Land cover type is assigned in HydroCAD to represent the percent of impervious cover typically associated with a given land cover as well as and the curve number. Since the assumptions for the percent imperviousness and curve numbers associated with different land uses in Lahaina varied from the

[6] Hawaii GIS. Lahaina_Contours_10ft.shp: Hawaii GIS. May 2021.

HydroCAD defaults, we assigned land uses with a certain set of characteristics to a different land cover type that better represents the impervious cover percentage and curve number, even if the land cover title is not entirely accurate. As a result, the land cover type categories become surrogates for the percent impervious cover. The land cover type adjustments we made in our model to better represent the actual observed percent impervious cover are explained below. The curve number is a function of the cumulative precipitation depth, soil cover, land use and antecedent soil moisture. A curve number is selected in HydroCAD based on the selected land use and hydrologic soil group (HSG).

  - During our May 2025 site visit to Lahaina, HW observed a high percentage of impervious area on a majority of lots. To reflect this observation, all residential parcels were modeled with an impervious area percentage of 85%, categorized as 'Urban Commercial" in the HydroCAD models.
  - Any commercial parcels that appeared to be close to 100% covered by buildings were modeled as "roofs" to adequately represent the high percentage of impervious area on the lot.
  - Sites dedicated to parking were modeled as "paved parking lots, driveways," which carries an impervious cover of 100%.
  - Industrial sites are modeled with 72% impervious area.
  - Roadways are modeled as "Paved; curbs and storm sewers" due to the impervious coverage most closely matching that of the roads in Lahaina.
- Infiltration
  - Site located mauka of Honoapi'ilani Highway are assumed to have a greater depth to groundwater and higher land elevation that sited located closer to the coast. As a result, the model assumes that infiltration can occur in these areas. For areas located Makai of Honoapi'ilani Highway, groundwater is understood to be shallower, and the land surface elevation is lower and topographically flatter. As a result, the model assumes that infiltration from GSI practices does not occur in these areas.
- Calculation Settings
  - Selected to calculate separate runoff for each Curve Number within HydroCAD. This allows for a more accurate modeling of runoff from impervious surfaces to the Pilot Projects, particularly during smaller storms.

2.2.1 Scenario 1: Pre-fire Conditions

For the Scenario 1 HydroCAD model, HW modeled the drainage infrastructure that existed immediately pre-fire , including pipes, swales, catch basins, curb inlets, and manholes. The areas of each land cover type are enumerated below for Drainage Areas O/D and R representing Scenario 1 in the HydroCAD model.

Table 2. Runoff Curve Number Summary in Drainage Area O/D – Scenarios 1 and 2

Cover type	Area, ft^2	Area, *ac*	Curve Number	HSG	Percent Impervious
Paved Parking	3,311	0.08	98	HSG A	100%
	132,335	3.04	98	HSG B	100%
Paved Road (with Curb and Catch Basin)	206,126	4.73	98	HSG A	100%
	933,970	21.44	98	HSG B	100%
Roof	125,322	2.88	98	HSG B	100%
Urban Commercial/Residential	451,761	10.37	89	HSG A	85%
	2,983,729	68.50	92	HSG B	85%
Urban Industrial	1,250,477	28.71	81	HSG A	72%
Grass	140,481	3.23	39	HSG A	0%
TOTAL	6,227,512	142.96	--	--	--
WEIGHTED AVERAGE	--	--	88	--	--

Table 3. Runoff Curve Number Summary in Drainage Area R – Scenarios 1 and 2

Cover type	Area, ft^2	Area, *ac*	CN	HSG	Percent Impervious
Paved Parking	176,941	4.06	98	HSG B	100%
Paved Road (with Curb and Catch Basin)	25,134	0.58	98	HSG A	100%
	855,649	20.00	99	HSG B	100%
Urban Commercial/Residential	217,931	5.00	89	HSG A	85%
	3,324,369	78.72	92	HSG B	85%
Grass, Good	386,639	8.88	39	HSG A	0%
	1,454,294	33.39	61	HSG B	0%
Brush	1,539,367	35.34	39	HSG A	0%
	3,113,146	71.47	56	HSG B	0%
Woods/Grass Comb.	38,812	0.89	43	HSG B	0%
TOTAL	11,252,506	258.32	--	--	--
WEIGHTED AVERAGE	--	--	47	--	--

2.2.2 Scenario 2: Gray Infrastructure

HW created HydroCAD models for Drainage Areas O/D and R that included the drainage system upgrades that were proposed in the 2005 Drainage Master Plan[7]. These upgrades extend and adjust the drainage infrastructure to capture more stormwater runoff into the drainage system

[7] These proposed improvements were not implemented, as of June 2025.

than was previously captured. These models were created to evaluate the peak discharge and runoff volume impacts of the proposed 2005 DMP improvements (Scenario 2) against the existing Pre-Fire drainage network (Scenario 1). Scenario 2 also served as a baseline from which to evaluate the additional benefits of proposed GSI pilot projects (Scenario 3) and widespread GSI implementation (Scenario 4). The drainage improvements proposed in the 2005 DMP for Drainage Area O/D (**Table 4**), and Drainage Area R (**Table 5**) are shown below. Yellow shading indicates a recommended upgrade to an existing drain line. Green shading indicates a recommended new drain line. Red shading indicates a recommendation to abandon a drain line.

Table 4. Summary of 2005 Drainage Improvements in Model – Drainage Area O/D

Street Name/ Pipe Line	Existing Configuration	Proposed Configuration
Papalaua Street	18″ (Outfall O to Front St); 24″ and 30″ (Front St to Wainee St)	7′ x 4′ Box (Outfall O to Front St); 6′ x 4′ Box (Front St to Wainee St)
Honoapiilani Highway @ Lahaina Clinic	24″ Culvert to Graded Swale	24″ Pipe to Wainee St Line
Wainee Street	36″ (Papalaua St to Lahaina Square); Unknown Ø (Lahaina Square Trunk Line)	48″ (Papalaua St to Lahaina Square); 18″ (Lahaina Square Trunk Line)
Wainee Street	(None)	60″ (Lahainaluna Rd to Panaewa Pl); 40″ (Panaewa Pl to Sacred Hearts Church)
Panaewa Place	(None)	60″ (Wainee St to Honoapiilani Hwy); 48″ (Honoapiilani Hwy to 24″ Culvert from David Malo Apartments)
Lahaina Square	36″ (Lahaina Square to Honoapiilani Hwy); 24″ (Honoapiilani Hwy to Mill St)	48″ (Lahaina Square to Honoapiilani Hwy); 48″ (Honoapiilani Hwy to Mill St)
Off Pauoa Street Property	30″	54″ (Lahainaluna Rd to Property); 48″ (at existing pipe to Pauoa St); Abandon in place existing pipe; 42″, connect inflow from existing 18″ line (along property boundary);
Lahainaluna Road	5′ x 3′ Box (Outfall D to Front St); 5′ x 2.5′ Box (Front St to 802 Front St)	10′ x 6′ Box (Outfall D to Front St); 10′ x 6′ Box (Front St to Honoapiilani Hwy); 72″ (Honoapiilani Hwy to Kuhua St); 60″ (Kuhua St to Kelawea St)
Luakini Street	(None)	30″ (Lahainaluna Rd to Panaewa St)
Kuhua Street	(None)	36″ (Lahainaluna Rd to end)

Table 5. Summary of 2005 Drainage Improvements Incorporated into the Model – Drainage Area R

Street Name/ Pipe Line	Existing Configuration	Proposed Configuration
Outfall Easement	Double 8′ x 4′ Box (Outfall R to Front St)	Triple 12′ x 4′ Box (R2 Outfall to Front St)
Front Street	4′ x 2.5′ Box (Outfall Easement to Kamehameha Iki Park); 12″ (Kamehameha Iki Park to Sewage Pump Station); 4′ x 1.5′ Box Kamehameha Iki Park to Shaw St)	Double 6′ x 4′ Box (Outfall Easement to Kamehameha Iki Park); Double 6′ x 3′ Box (Kamehameha Iki Park to Sewage Pump Station); Double 7′ x 3′ Box (Kamehameha Iki Park to Shaw St)
Mokuhinia Place	24″ (Front St to Luakini St)	Double 10′ x 4′ Box (Front St to Luakini St)
Luakini Street	24″ (Mokuhinia Pl to Wainee St St)	Double 10′ x 4′ Box (Mokuhinia Pl to Wainee St St)
Wainee Street	24″ (Prison St to Maui Islander)	Double 8′ x 4′ Box (Prison St to Luakini St); 42″, abandon Prison St line (Prison St to Maui Islander); Double 10′ x 4′ Box (Luakini St to Punana Leo O Lahaina); Double 48″ (Punana Leo O Lahaina to Shaw St)
Prison Street	(None)	Double 8′ x 4′ Box (Wainee Street to 24″ Culvert from Honopiilani Hwy)
Punana Leo O Lahaina Easement	(None)	Double 10′ x 4′ Box (Wainee Street to Double 24″ Culvert from Honopiilani Hwy)
R1 Outfall Easement	(None)	8′ x 4′ Box (Outfall R1 to Front St)
Prison St	24″ (Front St to Wainee St)	8′ x 4′ Box (Front St to 133 Prison St); 6′ x 4′ Box (133 Prison St to Luakini St)
Luakini St	(None)	6′ x 3′ Box (Prison St to 626 Luakini St)

As noted above, a large portion of the drainage area contributing to Drain Line O under Scenario 1 is proposed to be diverted to Drain Line D in Scenario 2, as part of the 205 DMP recommendations, representing a change in the area and land cover distribution of the overall drainage areas contributing to each network. Likewise, while only a single outfall exists for Drain Line R in Scenario 1, Scenario 2 proposes to add a new outfall and divide the drain line between Outfall R1 (new outfall location) and Outfall R2 (existing Outfall R location). The areas of each land cover type are enumerated below for Drainage Areas D, O and R representing Scenario 2 in the HydroCAD model.

2.2.3 Scenario 3: Gray + GSI Pilots

HW developed nine GSI pilot projects to address localized flood challenges as well as to take advantage of opportunities in both Drainage Area R and Drainage Area O/D. The pilot projects were incorporated into the Scenario 3 HydroCAD model as described below. For each of these pilot projects we modeled the four design storms listed in **Table 1** to evaluate the reduction in peak flow and volume achieved by each proposed pilot project. We also evaluated the capacity by modeling incremental storm sizes to determine at what depth storm the GSI practice will fill to capacity and overflow or divert to the stormwater system.

Table 6. Runoff Curve Number Summary in Drainage Area O/D – Scenarios 3 and 4

Cover type	Area, ft^2	Area, *ac*	CN	Note	Percent Impervious
Paved Parking	3,311	0.08	98	HSG A	100%
	132,335	3.04	98	HSG B	100%
Paved Roadway	206,169	4.73	98	HSG A	100%
	934,014	21.44	98	HSG B	100%
Roof	125,322	2.88	98	HSG B	100%
Urban Commercial/Residential	451,717	10.37	89	HSG A	85%
	2,983,686	68.50	92	HSG B	85%
Urban Industrial	1,250,520	28.71	88	HSG A	72%
Grass	140,437	3.22	39	HSG A	0%
TOTAL	6,227,512	142.96	--	--	--
WEIGHTED AVERAGE	--	--	89	--	--

Table 7. Runoff Curve Number Summary in Drainage Area R– Scenarios 3 and 4

Cover type	Area, ft^2	Area, *ac*	CN	Note	Percent Impervious
Paved Parking	181,819	4.17	98	HSG B	100%
Paved Roadway	31,189	0.72	98	HSG B	100%
	849,681	19.86	98	HSG A	100%
Urban commercial/Residential	304,484	6.99	89	HSG B	100%
	3,237,728	76.73	92	HSG A	0%
Grass, Good	386,290	8.87	39	HSG B	0%
	1,449,851	33.28	61	HSG A	85%
Brush	1,539,323	35.34	35	HSG B	85%
	3,113,146	71.47	56	HSG A	0%
Woods/Grass Comb.	38,812	0.89	65	HSG B	0%
TOTAL	11,252,550	258.32	--	--	--
WEIGHTED AVERAGE	--	--	69	--	--

O-1 Kelawea Street

The proposed GSI for pilot project O-1 consists of four bioswales and six tree trenches. This pilot project serves two subcatchments, O3A and O3C. Subcatchment O3A drains to Tree Trench 1 (TT1) and Bioretention 1 (B1). Subcatchment O3C drains to Tree Trench 2 (TT2) and Bioretention 2 (B2). Pilot project O-1 is located mauka of Honoapi'ilani Highway and is located on B soils. Therefore, it is modeled with a 1.02 in/hour infiltration rate.

O-2 West Maui Senior Center

The proposed GSI for pilot project O-2 consists of a sediment forebay, bioretention, and subsurface chambers to manage runoff from a portion of Lahainaluna Road as well as the Senior Center. Pilot project O-2 serves subcatchments, O5, OS1, O3B, O3D and OB4. Pilot Project O-2 also receives overflow from Pilot Project O-1. Flow from Lahainaluna Road is directed to the sediment forebay. Overflow from Sediment Forebay 1 (S1) flows to Bioretention 3 (B3). Starting at the 1.1-inch storm, flow begins to flow to the chamber system.

The subsurface chambers (C1) are modeled as ADS StormTech SC-740b chambers. The system contains 9 rows of 10 chambers for a total of 90 chambers.

Pilot project O-2 is located mauka of Honoapi'ilani Highway and is located on B soils. Therefore, all elements of pilot project O-2 are modeled with a 1.02 in/hour infiltration rate.

O-3 David Malo Circle Apartments

The proposed GSI for pilot project O-3 consists of three bioretention cells. The total volume of the cells is 1,260 cubic feet. Subcatchment OB5 drains to Bioretention 5 (B5), Subcatchment OB6 drains to Bioretention 6 (B6) and OB7 drains to Bioretention 7 (B7). Overflow from B5 and B7 drain to B6 before entering the drainage system.

Pilot project O-3 is located mauka of Honoapi'ilani Highway and is located on B soils. Therefore, it is modeled with a 1.02 in/hour infiltration rate.

O-4 Papalaua Street and Front Street

The proposed GSI for pilot project O-4 consists of two tree trenches, one located along Papalaua Street and one located along Front Street. These tree trenches are modeled as having no infiltration capacity and are meant to capture and treat stormwater for water quality purposes. The total storage volume of O-4 is 1,780 cubic feet. Subcatchment O1120 flows to Tree Trench 3 (TT3) and Subcatchment O1110 flows to Tree Trench 4 (TT4)

Pilot project O-4 is located makai of Honoapi'ilani Highway and therefore is modeled with no infiltration due to the likelihood of high groundwater.

O-5 Lahainaluna Road and Front Street

The proposed GSI for pilot project O-5 consists of three tree trenches located along Front Street. These tree trenches are modeled as having no infiltration capacity and are meant capture and treat stormwater for water quality purposes. The tree trenches are modeled as single tree trench in HydroCAD with a total storage volume is 790 cubic feet.

A 6" pipe is proposed to divert a portion of flow from CB300 to the tree trenches. Subcatchments D300 and D310 drain to CB300.

Pilot project O-5 is located makai of Honoapi'ilani Highway and therefore is modeled with no infiltration due to the likelihood of high groundwater.

R-1 Aquatic Center Basin Retrofit

Pilot Project R-1 proposes to retrofit an existing stormwater basin into a constructed wetland and add a sediment forebay and bioretention cell upstream of the constructed wetland.

Subcatchment Sed drains to the Sediment Forebay 2 (S2) which flows to Bioretention 8 (B8) and then overflows to Constructed Wetland 1 (W1). Subcatchments R2410, R3100, R3122, and R3150 flow to Constructed Wetland 1. Overflow from pilot project R-2 also flows to Constructed Wetland 1.

Based on feedback from the Department of Public Works, the constructed wetland is modeled as having no infiltration. The sediment forebay and bioretention were modeled with a 1.02 in/hour infiltration rate because the site is located mauka of Honoapi'ilani Highway and is located on B soils.

R-2 Lahaina Recreation Center

The proposed GSI for pilot project R-2 consists of permeable pavers, bioretention, and a bioswale. The permeable pavers provide storage in the gravel layer underneath the pavers, from which the water can then infiltrate into the ground below.

Subcatchment Bio drains to bioswale (B9) which flows to bioretention (B10). Subcatchment Pav flows to permeable pavers 1 (P1). Overflow from the bioretention and permeable pavers enters the drainage system and flows to the Constructed Wetland 1 (W1) in pilot project R-1.

Pilot project R-2 is located mauka of Honoapi'ilani Highway and is located on B soils, therefore it is modeled with a 1.02 in/hour infiltration rate.

R-3 Prison Street Public Parking

The proposed GSI for pilot project R-3 consists of repaving the existing public parking with permeable pavers as well as creating a constructed wetland. Overflow from the permeable paver parking lot will flow to the constructed stormwater wetland for detention and water quality treatment, and then to a restored wetland system before overflowing if needed back into an existing drainage ditch on Mokuhina Place. Subcatchment R2500 drains to permeable pavers 2 (P2). Overflow from the permeable pavers drains to the constructed wetland (W2). Subcatchments R2103 and R2394 drain to the constructed wetland (W2).

R-4 Front Street at Mokuhina Place

Pilot Project R-4 consists of two bioretention cells and three tree trenches. The purpose of these practices is to slow runoff and provide water quality treatment to the runoff from Front Street.

Subcatchment R2170 drains to tree trench 6 (TT6). Subcatchment R2100A drains to tree trench 7 (TT7). Subcatchment R2150 drains to tree trench 8 (TT8). Subcatchment R2180 drains to bioretention 11 (B11). Subcatchment R2131A drains to bioretention 12 (B12).

The bioretention and tree trenches are located makai of Honoapi'ilani Highway and are modeled with no infiltration due to the likelihood of high groundwater.

2.2.4 Scenario 4: Widespread GSI

HW developed widespread GSI implementation recommendations for residential, commercial, and public parcels, as well as public rights-of-way (ROW). The widespread GSI was modeled as additional pond nodes in HydroCAD to replicate the performance of the GSI. The volume of each pond was equivalent to the area of impervious cover in each drainage area multiplied by the target depth of precipitation that would be captured by widespread GSI in each rebuilding category (**Table 8**).

Table 8. Widespread GSI Equivalent Volume Assumptions

Rebuilding Category	Treatment Depth (in)	Implementation Rate
Residential	1	20%
Commercial < 1 acre	1	50%
Commercial > 1 acre	2.41	100%
Public Development	1	100%
Public ROW	1	20%

Storage nodes were added at 7 locations in the HydroCAD network: one at downstream end of the mauka section (i.e., the Honoapi'ilani Highway) and makai section (i.e., just above the outfall) of each drain line (O, D, R1, and R2). For storage locations mauka of Honoapi'ilani Highway, an infiltration rate of 1.02 in/hour was assumed. Volumes at each node are shown below in **Table 9**.

Table 9. Equivalent Widespread GSI Storage Nodes

Drain Line	Node Volume (ac-ft)	
	Makai	Mauka
O	0.26	1.33
D	0.27	0.02
R1	0.31	0
R2	1.11	0.76

Attachments A-E include more detailed maps of the drainage areas and pipe networks under each scenario. Full printouts of the HydroCAD results are packaged separately and can be provided upon request.

2.3 Results

The HydroCAD model is conservative and uses Atlas 14 rainfall data that takes into account increased storm intensity due to climate change. In addition, the model only allows for infiltration mauka of the highway. The Rawls infiltration rate for HSG B soils was used for the widespread green stormwater infrastructure ponds mauka of Honoapi'ilani Highway as a majority of the site is located in HSG B soils. However, there are HSG A soils in the study area. Green stormwater infrastructure implemented on HSG A soils will likely have a higher infiltration rate and be able to treat and infiltrate a higher volume of stormwater.

2.3.1 Gray Infrastructure Improvements

HW modeled the gray infrastructure drainage improvements proposed in the 2005 Lahaina Drainage Master Plan. The gray stormwater infrastructure proposed in the 2005 Lahaina Drainage Master Plan serve to reduce flooding on roadways and to convey flows from large storms safely out of town. However, gray stormwater infrastructure does not reduce peak flows, reduce volumes, or provide water quality treatment. Gray stormwater infrastructure improvements are needed to keep drainage off private properties and to ensure public safety. The proposed gray infrastructure improvements are extensive, and focus should be put on implementing these improvements during the rebuilding process as there will be more opportunities for easements.

2.3.2 Pilot Projects

HW evaluated the impacts of each pilot project on total runoff volume and peak discharge rate based on the contributing drainage area and outflow point of each pilot project for the 1.5-inch Water Quality storm. For smaller storms, the pilot projects are effective at reducing flowrates from Scenario 2 as well as providing water quality treatment for the sites,

Pilot Projects R-1 and R-2 both had significant impacts, are located on public parcels, and were not located in burn areas. HW recommends starting with these projects. However, gray infrastructure improvements are tied into these pilot projects to prevent flooding of private properties downstream of R-1.

Volume and discharge reductions are shown below for Drainage Area O/D (**Table 10**) and Drainage Area R (**Table 11**).

Table 10. Modeled Stormwater Volume and Discharge Reductions from Pilot Projects (1.5" Storm) – Drainage Area O/D

Site ID	Total Runoff (ac-ft)			Peak Discharge (cfs)		
	Scenario 2	Scenario 3	% Reduction	Scenario 2	Scenario 3	% Reduction
O-1 Kelawea Street	0.57	0.51	11%	15.13	7.52	50%
O-2 West Maui Senior Center	0.56	0.37	34%	7.26	6.32	13%
O-3 David Malo Circle Apartments	0.12	0.05	61%	1.64	0.69	58%
O-4 Papalaua Street and Front Street	0.18	0.14	21%	2.24	1.48	34%
O-5 Lahainaluna Road and Front St.	0.10	0.08	15%	1.19	1.18	1%

Table 11. Modeled Stormwater Volume and Discharge Reductions from Pilot Projects (1.5" Storm) – Drainage Area R

Site ID	Total Runoff (ac-ft)			Peak Discharge (cfs)		
	Scenario 2	Scenario 3	% Reduction	Scenario 2	Scenario 3	% Reduction
R-1 Aquatic Center Basin Retrofit	1.74	0.00	100%	2.26	0.00	100%
R-2 Lahaina Recreation Center	0.09	0.03	67%	0.57	0.42	26%
R-3 Prison Street Public Parking	0.63	0.00	100%	8.22	0.00	100%
R-4 Front Street at Mokuhinia	0.11	0.07	35%	1.44	0.90	38%

2.3.3 Widespread Application of GSI

HW compared the total runoff volume and peak discharge rate at the outfalls under each scenario, as summarized in **Tables 12** and **13**. Scenario 4 shows a greater reduction in volumes and flows than Scenario 3. Scenario 4 also provides a greater amount of water quality treatment.

Our models confirm that widespread green stormwater infrastructure improves water quality and reduces peak flows and volumes. Widespread GSI will be most effective when implemented farther up in the watershed. Where much of the area is developed or redeveloped, we recommend integrating smaller GSI practices throughout. GSI is generally more effective for smaller storms as many practices cannot detain large volumes. However, larger restored or constructed wetland complexes will manage larger storms more efficiently. HW recommends maximizing opportunities to restore wetland areas.

2.3.4 Drainage Area O/D Volume and Peak Discharge Reductions

The volumes that flow out of outfalls D and O in Scenarios 3 and 4 are less than Scenario 2. The percent reduction from Scenario 2 is shown for Scenarios 3 and 4.

Table 12. Modeled Runoff Volume Reduction – Outfall O

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	7.5	14.8	60.7	87.1
2. Pre-Fire Condition plus 2005 Drainage Improvements*	5.4	10.7	43.4	61.9
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	5.3 *(2%)*	10.5 *(1%)*	43.2 *(0%)*	61.7 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	2.8 *(47%)*	7.9 *(23%)*	40.4 *(7%)*	58.9 *(5%)*

* Significant decrease in proposed volume to Outfall O is due to diversion of portions of Drain Line O to Drain Line D

Table 13. Modeled Runoff Volume Reduction – Outfall D

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	1.6	2.9	10.8	15.2
2. Pre-Fire Condition plus 2005 Drainage Improvements*	4.5	8.6	35.1	50.4
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects*	4.3 *(4%)*	8.4 *(3%)*	34.7 *(1%)*	50.1 (1%)
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI*	1.3 *(72%)*	5.1 *(18%)*	31.2 *(5%)*	46.5 *(4%)*

* Significant increase in proposed volume to Outfall D is due to diversion of portions of Drain Line O to Drain Line D

Scenarios 2, 3, and 4 direct more water to Outfall D than in Scenario 1. **Table 14** shows the total volumes of outfalls D and O.

Table 14. Modeled Runoff Volume Reduction – Drainage Area O/D

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	16.4	17.8	71.5	102.3
2. Pre-Fire Condition plus 2005 Drainage Improvements*	9.9	19.3	78.5	112.3
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	9.6 *(3%)*	18.9 *(2%)*	77.9 *(1%)*	111.8 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	4.1 *(59%)*	13.1 *(32%)*	71.6 *(9%)*	105.4 *(6%)*

* Increase in volume is due to extensions of the drain system, which carries water from further out on certain subdrainage areas that is not captured in the pre-fire condition. In addition, proposed volume to Outfall D is due to diversion of portions of Drain Line O to Drain Line D

The peak flows of all the scenarios are compared in **Tables 15** and **16**. The percent reduction in peak flows from Scenario 2 is shown for Scenarios 3 and 4.

Table 15. Modeled Peak Discharge Reduction – Outfall O

Scenario	Peak Flow (cfs) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	99.9	193.1	735.9	1,036.9
2. Pre-Fire Condition plus 2005 Drainage Improvements	71.0	137.1	482.2	673.2
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	70.4 *(1%)*	135.5 *(1%)*	482.0 *(0%)*	672.9 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	42.2 *(41%)*	134.4 *(2%)*	480.0 *(0%)*	670.2 *(0%)*

Table 16. Modeled Peak Discharge Reduction - Outfall D

Scenario	Peak Flow (cfs) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	20.1	36.0	126.2	175.8
2. Pre-Fire Condition plus 2005 Drainage Improvements*	59.3	113.0	466.2	661.5
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects*	57.3 *(3%)*	109.7 *(3%)*	465.8 *(0%)*	660.9 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI*	18.9 *(64%)*	108.2 *(4%)*	462.2 *(1%)*	656.4 *(1%)*

*Significant increase in proposed flow to Outfall D is due to diversion of portions of Drain Line O to Drain Line D

2.3.5 Drainage Area R Volume and Peak Discharge Reductions

The volumes that flow out of outfalls R1 and R2 in Scenario 4 lower than those of the Scenario 2 (**Tables 17-19**). The percent reduction from Scenario 2 is provided for Scenarios 3 and 4.

Table 17. Modeled Runoff Volume Reduction – Outfall R1

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition*	-	-	-	-
2. Pre-Fire Condition plus 2005 Drainage Improvements	2.3	4.2	14.6	19.6
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	2.3 *(0%)*	4.2 *(0%)*	14.7 *(0%)*	19.6 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	1.5 *(34%)*	3.4 *(18%)*	13.8 *(5%)*	18.9 *(4%)*

*Outfall R1 does not exist in Scenario 1.

Table 18. Modeled Runoff Volume Reduction – Outfall R2

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	8.1	16.6	85.6	148.1
2. Pre-Fire Condition plus 2005 Drainage Improvements	5.9	12.4	72.9	119.2
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	3.5 *(41%)*	8.1 *(35%)*	69.9 *(4%)*	114.4 *(4%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	1.7 *(71%)*	5.3 *(57%)*	65.5*(10%)*	109.9*(8%)*

Table 19. Modeled Runoff Volume Reduction – Drainage Area R

Scenario	Volume Discharged per Storm Event (ac-ft) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	8.1	16.6	85.6	148.1
2. Pre-Fire Condition plus 2005 Drainage Improvements	8.1	16.6	87.5	138.8
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	5.7 *(30%)*	12.2 *(26%)*	84.5 *(4%)*	134.0 *(3%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	3.2 *(61%)*	8.7*(48%)*	79.3 *(9%)*	128.8 *(7%)*

The peak flows of the scenarios were also compared and summarized in **Tables 20-21**.

Table 20. Modeled Peak Discharge Reduction – Outfall R1

Scenario	Peak Flow (cfs) *(% Reduction from Scenario 2)*			
	1.5" Water Quality	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition*	-	-	-	-
2. Pre-Fire Condition plus 2005 Drainage Improvements	25.3	32.8	66.2	70.8
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	25.2 *(0%)*	32.8 *(0%)*	66.2 *(0%)*	70.7 *(0%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	23.2 *(8%)*	32.7 *(0%)*	66.1 *(0%)*	70.6 *(0%)*

*Outfall R1 does not exist in Scenario 1.

Table 21. Modeled Peak Discharge Reduction – Outfall R2

Scenario	Peak Flow (cfs) *(% Reduction from Scenario 2)*			
	1.5" Water Quality Storm	1-year 24-hour	25-year 24-hour	100-year 24-hour
1. Pre-Fire Condition	86.1	126.4	957.0	1,685.4
2. Pre-Fire Condition plus 2005 Drainage Improvements	60.8	130.7	953.5	1,516.0
3. Pre-Fire condition with 2005 Drainage Improvements and GSI Pilot Projects	50.5 *(17%)*	111.0 *(15%)*	604.6 *(37%)*	1,498.6 *(1%)*
4. Pre-Fire condition with 2005 Drainage Improvements, GSI Pilot Projects and widespread GSI	4.3 *(93%)*	66.2 *(49%)*	497.8 *(48%)*	1,1,477.4 *(3%)*

2.4 Model Limitations

The HydroCAD model is a useful tool for evaluating pipe capacity in addition to the impacts of GSI on runoff volume and peak discharge rates. While this software offers a more wholistic approach to modeling stormwater runoff than the StormCAD model developed for the 2005 DMP, the model does have inherent limitations:

2.4.1 Volume Loss from Overflow

Catch basins, which are typically modeled with insignificant storage when considering volume control, were modeled with limited storage above their rim elevations. This created small amounts of ponding along roadways and allowed excess flow to be directed to the next downgradient catch basin when outgoing pipes are surcharged. The same is true for existing basins, such as the aquatic center basin: some storage is provided above the maximum outlet elevation to allow the HydroCAD model to account for surcharge volume. When stormwater backs up too much and exceeds the elevation of this buffer storage, HydroCAD is unable to account for the excess volume, and it is discarded from the system. As a result, scenarios with limited pipe capacity that tend to back up water at catch basin inlets and existing drainage basins (i.e., Scneario 1) yield outputs that underestimate the total runoff volume and peak discharge rates at the study points.

2.4.2 Localized Ponding

Though small storage volumes were provided around catch basin rims and at existing basins, storage volumes were not modeled for the countless low points in roadways, landscaped areas, and yards across the watershed. While some runoff is assumed to be captured in these local low points (modeled as "initial abstraction"), the HydroCAD model does not indicate where or how much ponding occurs across the landscape as a result of backed up drainage systems or areas without flow paths to catch basins. To understand the locations and depths of localized ponding, a more complex spatial model would be needed.

2.4.3 Widespread GSI Simplification

In the HydroCAD model, widespread GSI implementation in Scenario 4 was modeled as two representative nodes along each drain line, as discussed above, rather than as hundreds of discrete pond nodes. In addition, the cover type of the subcatchments was not revised to reflect the increased proportion of permeable area associated with widespread GSI. This simplification was conservative, as it does not fully account for the reduced volume of runoff that would be generated as a result of the decreased impermeable cover. Pipe capacity throughout the drainage network would also be expected to increase if widespread GSI were modeled as individual pond nodes throughout the watershed, since runoff volumes would be reduced at the "start of pipe" rather than the "end of pipe."

3.0 WATER QUALITY MODEL

A water quality modeling analysis was conducted to evaluate the pollutant loading reductions that could be achieved by each individual pilot project, as well as for various stormwater management scenarios compared to the pre-fire baseline scenario.

3.1 Scenarios 1 & 2

HW developed a Microsoft Excel spreadsheet-based model to estimate existing pollutant loading rates (i.e., Scenario 1 – pre-fire conditions) for four pollutants– total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and fecal coliform bacteria (FC) – across the study area, the Line O and R subwatersheds, and for the contributing drainage areas to each of the pilot projects. Existing pollutant loads were used as a baseline to evaluate effectiveness of proposed pilot projects and widespread GSI recommendations.

The spreadsheet-based model used primary inputs (i.e., annual rainfall, land use, and soil types) to apply standard event mean concentrations and runoff coefficients to generate existing pollutant load estimates[8]. These primary inputs were based on the default values used in the Watershed Treatment Model[9] (WTM), shown below in **Table 22**. An annual total rainfall depth of 10.6 inches was used based on data collected by USGS in Lahaina between 1978-2001[10]. **Table 23** summarizes the existing pollutant loading estimates at the drainage areas to the pilot projects, Lines O and R, and the study area.

[8] Event mean concentrations (EMC) and pollutant loading rates were derived from the National Stormwater Quality Database (NSQD), which is a summary of stormwater data from over 200 jurisdictions across the United States (Pitt et al., 2003). Land uses with impervious cover were assigned an EMC. Land uses without impervious cover were assigned a pollutant loading rate. This could be adjusted for Hawaiian loading rates as data becomes available.

[9] Caraco, D. 2013. Watershed Treatment Model (WTM). Center for Watershed Protection. Ellicott City, MD.

[10] Stock, J.D., and Cerovski-Darriau, Corina, 2021, Sediment budget for watersheds of West Maui, Hawaii: U.S. Geological Survey Scientific Investigations Report 2020-5133, https://doi.org/10.3133/sir20205133

Table 22. Event Mean Concentrations

WTM Land Use Category	C-CAP 2011 Land Cover Input	TN (mg/L)	TP (mg/L)	TSS (mg/L)	FC (MPN/ 100 mL)
High Density Residential (<0.25 ac lots)	High Intensity Developed*	2.1	0.31	49	20,300
Recreational/ Beach	-Open Space Developed -Unconsolidated Shore	1.2	0.20	49	20,000
Roadway (Paved)	*All land cover within ROW*	2.3	0.25	99	13,700
		TN (lb/ac)	**TP (lb/ac)**	**TSS (lb/ac)**	**FC (#B/ac)**
Forest (vacant)	-Bare Land -Evergreen Forest -Grassland -Palustrine Emergent Wetland -Scrub Shrub	1.8	0.25	100	12
Open Water	-Open Water	12.8	0.5	155	0

*High Intensity Developed includes both residential and commercial land uses

Table 23. Scenario 1 Annual Pollutant Loading at Key Study Points

Drainage Area		Existing Annual Pollutant Loading Rate			
Subwatershed	**Site ID**	**TN (lb/yr)**	**TP (lb/yr)**	**TSS (lb/yr)**	**FC (#B/yr)**
R	R-1 Aquatic Center Basin Retrofit	262.8	38.6	12,555	4,215
	R-2 Lahaina Recreation Center	17.1	2.6	766.8	682.1
	R-3 Prison Street Public Parking	12.2	1.8	412.7	413.0
	R-4 Front Street at Mokuhinia	3.5	0.5	97.0	133.6
	Overall Line R*	**380.8**	**53.3**	**14,158**	**13,340**
O/D	O-1 Kelawea Street	18.4	2.8	459.3	865.3
	O-2 West Maui Senior Center	11.3	1.7	403.7	431.3
	O-3 David Malo Circle Apartments	4.1	0.6	112.0	171.7
	O-4 Papalaua Street and Front Street	5.5	0.8	127.6	240.9
	O-5 Lahainaluna Road and Front Street	2.6	0.4	64.2	113.4
	Overall Line O/D*	**510.2**	**70.0**	**16,653**	**19,475**
Overall Study Area*		**2,137.7**	**292.6**	**72,163**	**79,215**

*Loading rates for Overall Lines R, O/D, and the Study Area are derived from larger contributing areas than the sum of the pilot projects.

HW assumed that the proposed gray infrastructure upgrades proposed in the 2005 DMP upgrades would not have an impact on water quality. As such, Scenario 2 pollutant loading is assumed to be identical to that of Scenario 1.

3.2 Scenario 3

Proposed recommendations were modeled for each of the pilot projects and for the widespread recommendations in order to evaluate their impact on pre-fire annual pollutant load rates. Load reductions for proposed GSI SCMs were based on the most recently available performance curves for TN[11], TP[12], TSS[13], and FC[14] for New England and on the same GSI pollutant removal pathways for SCMs proposed for Lahaina. Removal rates provided in several of the Hawaiian stormwater guidance manuals use similar, but older values derived from stateside references. Pollutant removal rates represent removal from surface water loading and may not adequately account for outputs to groundwater, particularly from nutrients (TN and TP).

Each pollutant load reduction was calculated from the recommended performance curve for each SCM (per the guidance of each curve's source document) and the depth of runoff treated by each proposed practice. For each pilot project, the depth of treated runoff was determined using the Scenario 3 HydroCAD model. Pollutant reduction rates for pilot projects in Drainage Area R (**Table 24**) and Drainage Area O (**Table 25**) are shown below. In some cases, the reduction rates reflect the combined treatment for multiple SCMs at each site.

Table 24. Proposed Pollutant Load Reduction Rates for Drainage Area R Pilot Projects

Site ID	Treatment Depth (in)	Proposed Load Reduction Rates			
		TN (%)	TP (%)	TSS (%)	FC (%)
R-1 Aquatic Center Basin Retrofit	2.0	100%	100%	100%	100%
R-2 Lahaina Recreation Center	2.0 (Permeable Pavers) 0.6 (Bioswale and Bioretention)	100%	99%	100%	98%
R-3 Prison Street Public Parking	2.0	100%	100%	100%	100%
R-4 Front Street at Mokuhinia	0.9 (Bioretention Areas) 0.7 (Tree Trenches)	99%	94%	100%	94%

[11] From the Massachusetts MS4 General Permit (as modified January 6, 2021), Appendix F, Attachment 3

[12] Ibid.

[13] From EPA Region 1 BMP Accounting and Tracking Tool (BATT) v2.1

[14] From New England Stormwater Retrofit Manual (2021) and Tisbury, MA Impervious Cover Disconnection (ICD) Project (2020)

Table 25. Proposed Pollutant Load Reduction Rates for Drainage Area O Pilot Projects

Site ID	Treatment Depth (in)	Proposed Load Reduction Rates			
		TN (%)	TP (%)	TSS (%)	FC (%)
O-1 Kelawea Street	0.4	92%	77%	94%	73%
O-2 West Maui Senior Center	2.0 (Chambers and Bioretention Area 1)	100%	100%	100%	100%
	0.8 (Bioretention Area 2)				
O-3 David Malo Circle Apartments	1.0 (Bioretention Area 1 and 2)	99%	96%	100%	98%
	0.7 (Bioretention Area 3)				
O-4 Papalaua St. and Front St.	0.5 (Tree Trench 1)	92%	74%	93%	67%
	0.2 (Tree Trench 2)				
O-5 Lahainaluna Road and Front St	0.3	85%	68%	82%	56%

3.3 Scenario 4

For the widespread application of GSI, pollutant load reduction rates were determined based on the performance curves of the GSI recommendations. A rainfall depth of 1.5 inches was assumed for the widespread GSI scenario, corresponding to the regulatory standard for treatment at new development and redevelopment sites larger than 1 acre. Implementation rates were assumed for each rebuilding category based on a mix of opt-in GSI implementation (residential and small commercial) and regulatory requirements (large commercial and public). These assumptions are summarized in **Table 26**.

Table 26. Rebuilding Category Water Quality Assumptions for 1.5" Rainfall Depth Target

Rebuilding Category		GSI SCMs	Implementation Rate
Residential		Rain Barrels/Cisterns, Permeable Pavers, Surface Infiltration	20%
Commercial	Mauka, <1 acre	Permeable Pavement, Tree Trenches, Bioretention	50%
	Mauka, ≥1 acre	Same as <1 acre, plus Infiltration Basin	100%
	Makai, <1 acre	Permeable Pavement, Tree Trenches, Bioretention with Underdrain	50%
	Makai, ≥1 acre	Same as <1 acre, plus Infiltration Basin	100%
Public	Developments (Mauka)	Same as Commercial (Mauka, ≥1 acre)	100%
	Developments (Makai)	Same as Commercial (Makai, ≥1 acre)	100%
	ROW	Tree Trenches	20%
	Constructed Stormwater Wetland	Constructed Stormwater Wetland	100%

In Scenario 4, pollutant loading was modeled as a "treatment train" from widespread GSI practices to pilot projects. That is to say, pollutant removal of runoff was assumed to have occurred at the rates of the GSI SCMs described in **Table 26** prior to runoff entering the pilot projects. Pilot projects provided treatment of the remaining pollutant load[15].

3.4 Results

3.4.1 Pilot Projects

Predicted annual load reductions provided by each pilot project are listed below for Drainage Area R (**Table 27**) and Drainage Area O/D (**Table 28**).

Table 27. Modeled Pollutant Load Reduction from Pilot Projects in Drainage Area R

Site ID	Proposed Annual Load Reduction			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
R-1 Aquatic Center Basin Retrofit	262.8	38.6	12,555	4,215
R-2 Lahaina Recreation Center	17.0	2.6	765.9	669.6
R-3 Prison Street Public Parking	12.2	1.8	412.7	413.0
R-4 Front Street at Mokuhinia	3.4	0.5	97.0	125.1

Table 28. Modeled Pollutant Load Reduction from Pilot Projects in Drainage Area O/D

Site ID	Proposed Annual Load Reduction			
	TN (lb/yr)	TP (lb/yr)	TSS (lb/yr)	FC (#B/yr)
O-1 Kelawea Street	17.0	2.1	433.3	629.8
O-2 West Maui Senior Center	11.2	1.7	403.7	425.2
O-3 David Malo Circle Apartments	4.1	0.6	111.9	168.0
O-4 Papalaua Street and Front Street	5.0	0.6	116.5	164.7
O-5 Lahainaluna Road and Front St.	2.2	0.3	52.3	63.5

3.4.2 Widespread Application of GSI

Water quality benefits for the various stormwater management scenarios examined are summarized below for Drainage Area R (**Table 29**), Drainage Area O (**Table 30**), and the study area (**Table 31**).

[15] As a treatment train example, if an initial SCM treated 50% of a loading of 1lb of TSS, then 1lb X 50% = 0.5lb of TSS would remain to be directed to a second SCM. If that SCM also treated 50% of TSS, it would only remove 0.5lb X 50% = 0.25lb of remaining TSS; 0.25lb would remain untreated.

Table 29. Modeled Pollutant Load Reduction for Drainage Area R

Scenario	Proposed Remaining Annual Loading			
	TN (lb/yr) (% Red.)	TP (lb/yr) (% Red.)	TSS (lb/yr) (% Red.)	FC (#B/yr) (% Red.)
1. Pre-Fire Condition*	380.8 *(0%)*	53.3 (0%)	14,158 *(0%)*	13,340 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	85.4 *(78%)*	9.9 (82%)	327.0 *(98%)*	7,918 *(41%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	32.7 *(91%)*	4.1 (92%)	85.9 *(99%)*	2,807 *(79%)*

*Equivalent to existing pollutant loading for all study areas.

Table 30. Modeled Pollutant Load Reduction for Drainage Area O/D

Scenario	Proposed Remaining Annual Loading			
	TN (lb/yr) (% Red.)	TP (lb/yr) (% Red.)	TSS (lb/yr) (% Red.)	FC (#B/yr) (% Red.)
1. Pre-Fire Condition*	510.2 *(0%)*	70.0 *(0%)*	16,653 *(0%)*	19,475 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	470.7 *(8%)*	64.7 *(7%)*	15,536 *(7%)*	18,024 *(7%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	225.1 *(56%)*	33.9 *(51%)*	5,514 *(67%)*	8,358 *(57%)*

*Equivalent to existing pollutant loading for all study areas.

Table 31. Modeled Pollutant Load Reduction for Study Area

Scenario	Proposed Remaining Annual Loading			
	TN (lb/yr) (% Red.)	TP (lb/yr) (% Red.)	TSS (lb/yr) (% Red.)	FC (#B/yr) (% Red.)
1. Pre-Fire Condition*	2,138 *(0%)*	292.6 *(0%)*	72,164 *(0%)*	79,215 *(0%)*
2. Pre-Fire Condition plus 2005 Drainage Improvements*				
3. Pre-Fire Condition with 2005 Drainage Improvements and GSI Pilot Projects	1803 *(16%)*	244.0 *(17%)*	57,215 *(21%)*	72,342 *(9%)*
4. Pre-Fire Condition with 2005 Drainage Improvements, GSI Pilot Projects, and Widespread GSI	875.0 *(59%)*	127.6 *(56%)*	21,770 *(70%)*	34,245 *(57%)*

*Equivalent to existing pollutant loading for all study areas

4.0 CONCLUSIONS AND MODEL LIMITATIONS

The spreadsheet-based water quality model helps quantify the benefits that GSI could provide beyond the impacts to runoff volumes and peak discharge rates described in **Section 2.0**. There are significant water quality benefits of installing GSI across Lahaina as the rebuilding process continues, and in the years to come as future development occurs.

4.1.1 Significant Pollutant Removal from Widespread GSI

Installation of widespread GSI as modeled in Scenario 4 is predicted to reduce pollutant loading by more than half across the four pollutant types assessed. Specifically: TN (59% reduction), TP (56% reduction), TSS (70% reduction), and FC (57% reduction).

4.1.2 Large Projects on Public Property Make an Outsized Impact

In Scenario 3, GSI pilot projects were found to have a more sizeable impact in Drainage Area R than in Drainage Area O/D. Looking at TSS removal alone, the pilot projects were modeled to reduce TSS outputs by 98% in Drainage Area R, but only by 7% in drainage area O/D. This can be attributed to a few individual GSI pilot projects that were evaluated in Drainage Area R. Pilot project R-1 (Aquatic Center Basin Retrofit) accounts for over 88% of the TSS removal in Drainage Area R, thanks to a large contributing drainage area and a large storage volume. At a distant second, Pilot Project R-2 (Lahaina Recreation Center) accounts for over 5% of the TSS removal in Drainage Area R. Because both of these potential project sites are publicly owned and are located somewhat ideally in the mid to upper area of the watershed, as well as the fact that these were not damaged by the 2023 wildfires, these two pilot projects appear to be among the most feasible.

4.1.3 Conservative Implementation Assumptions

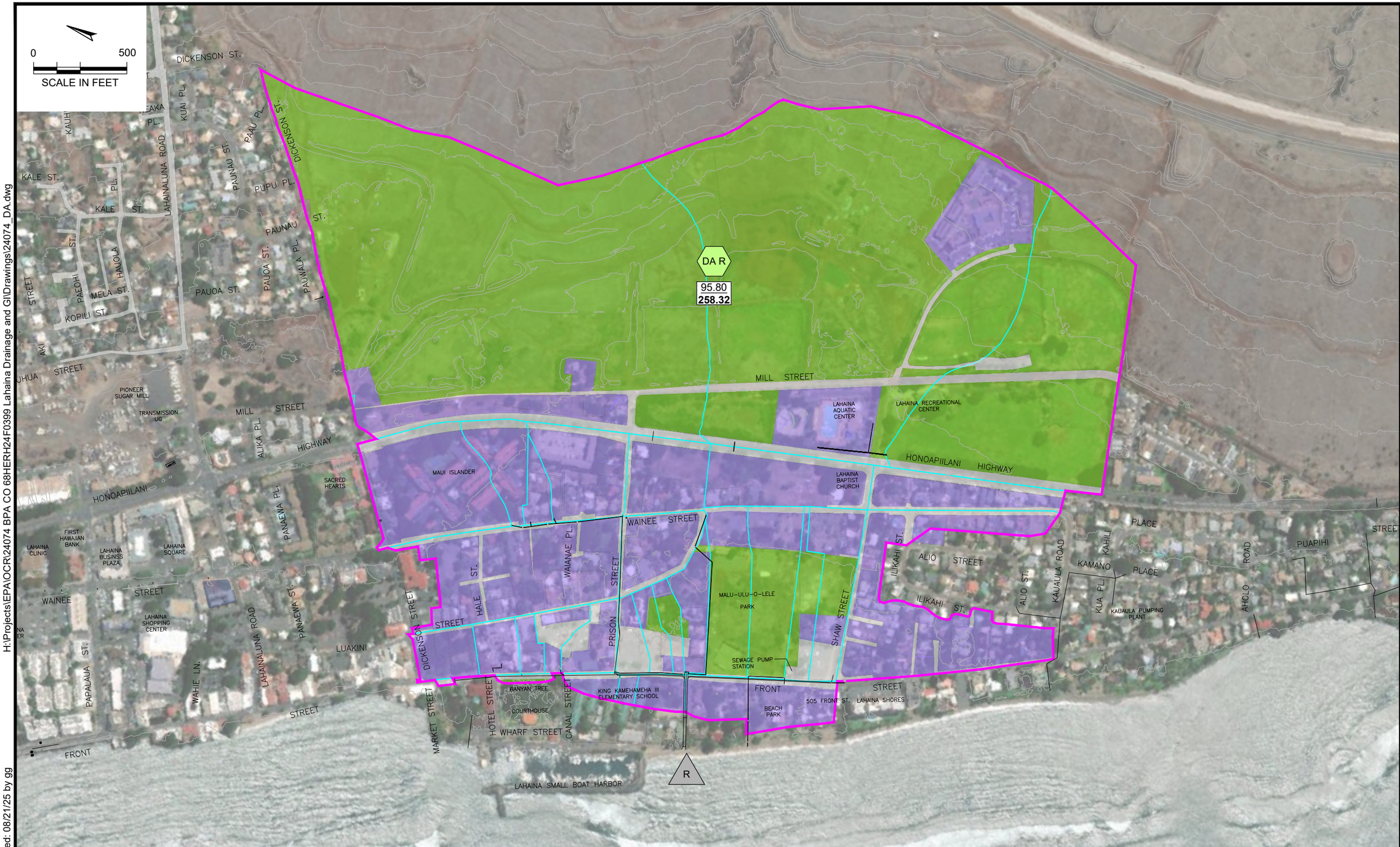
Even with the significant pollutant reductions modeled in Scenario 4 as a result of widespread GSI implementation, the model incorporates conservative assumptions about implementation rates across public ROWs (20%), small commercial parcels (50%), and residential lots (20%). Proactive efforts to encourage private entities to install GSI, or initiatives to help fund and install GSI, could increase the implementation rates that occur in reality. Similarly, installing roadside GSI along ROWs beyond those damaged by the 2023 wildfires would further benefit to water quality beyond what was modeled.

4.1.4 Groundwater Loading

As noted above in **Section 3.1**, the pollutant removal rates used for GSI in the water quality model are based on values determined in mainland studies. Pollutant removal rates specifically apply to surface water outflow from GSI, and are not based on outflow to groundwater. Outflow to groundwater contributes more significantly to nutrient loading in island and coastal settings like Lahaina, and nutrient removal rates for GSI in Hawaii could be substituted here if available. Implementation of "greener" practices, or GSI with plants, would be expected to increase nutrient uptake and decrease output to groundwater as compared to "grayer" practices that infiltrate runoff without incorporating plants.

ATTACHMENT A – Drainage Area Maps

- Existing Drainage Area Map – DA R
- Existing Drainage Area Map – DA O&D
- Proposed Drainage Area Map – DA R
- Proposed Drainage Area Map – DA O&D



DRAINAGE AREA BOUNDARY
ROOF
GRASS
INDUSTRIAL
COMMERCIAL
PAVEMENT
IMP. AREA **TOTAL AREA** (ACRES)
25
50

LEGEND

DA — DRAINAGE AREA
SP — STUDY POINT
10' MAJOR CONTOUR
SUBCATCHMENTS

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Plan Set: DRAINAGE AREA MAPS - ATTACHMENT A
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

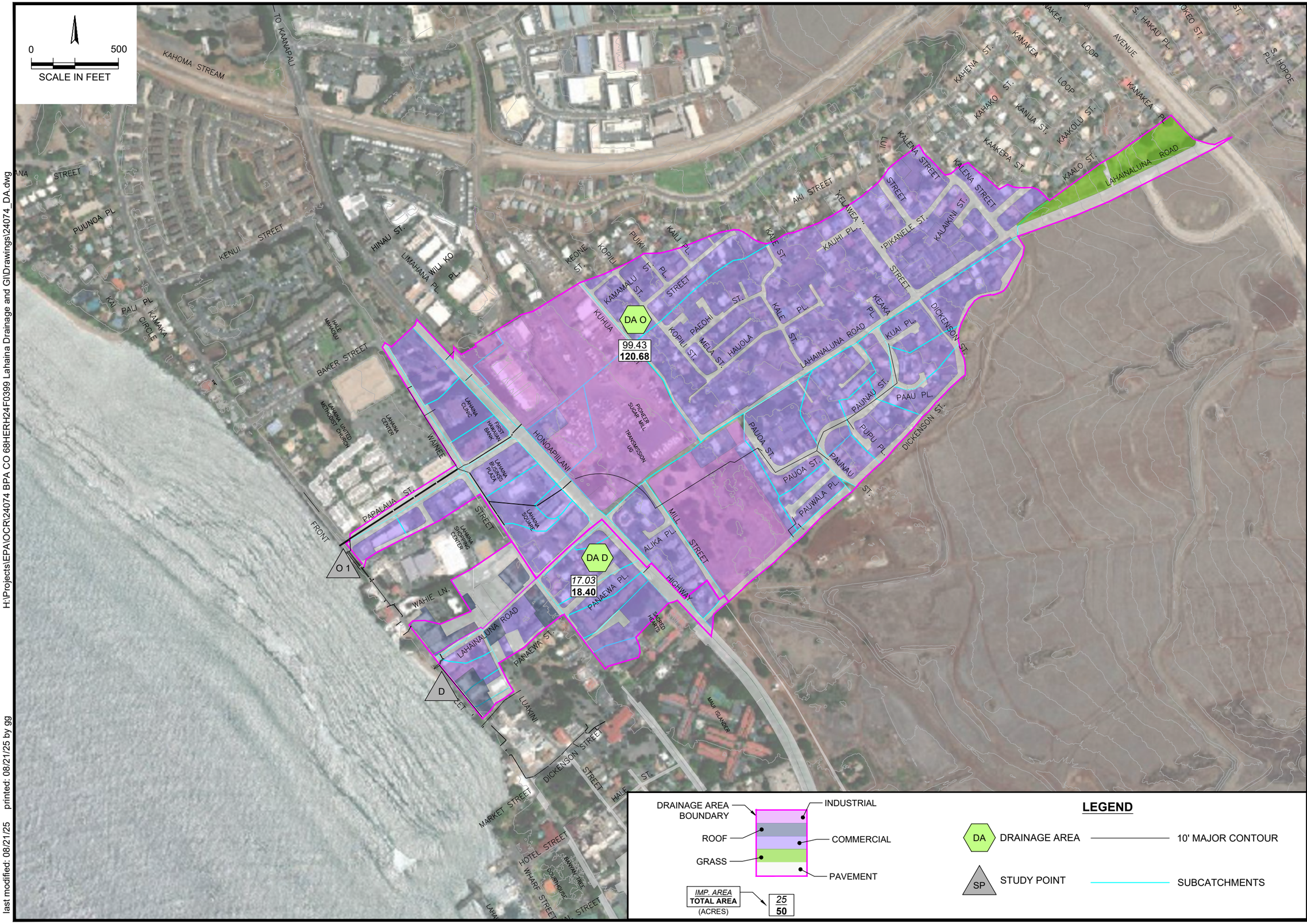
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Plan Title: OUTFALL O&D - PRE-FIRE DRAINAGE AREAS

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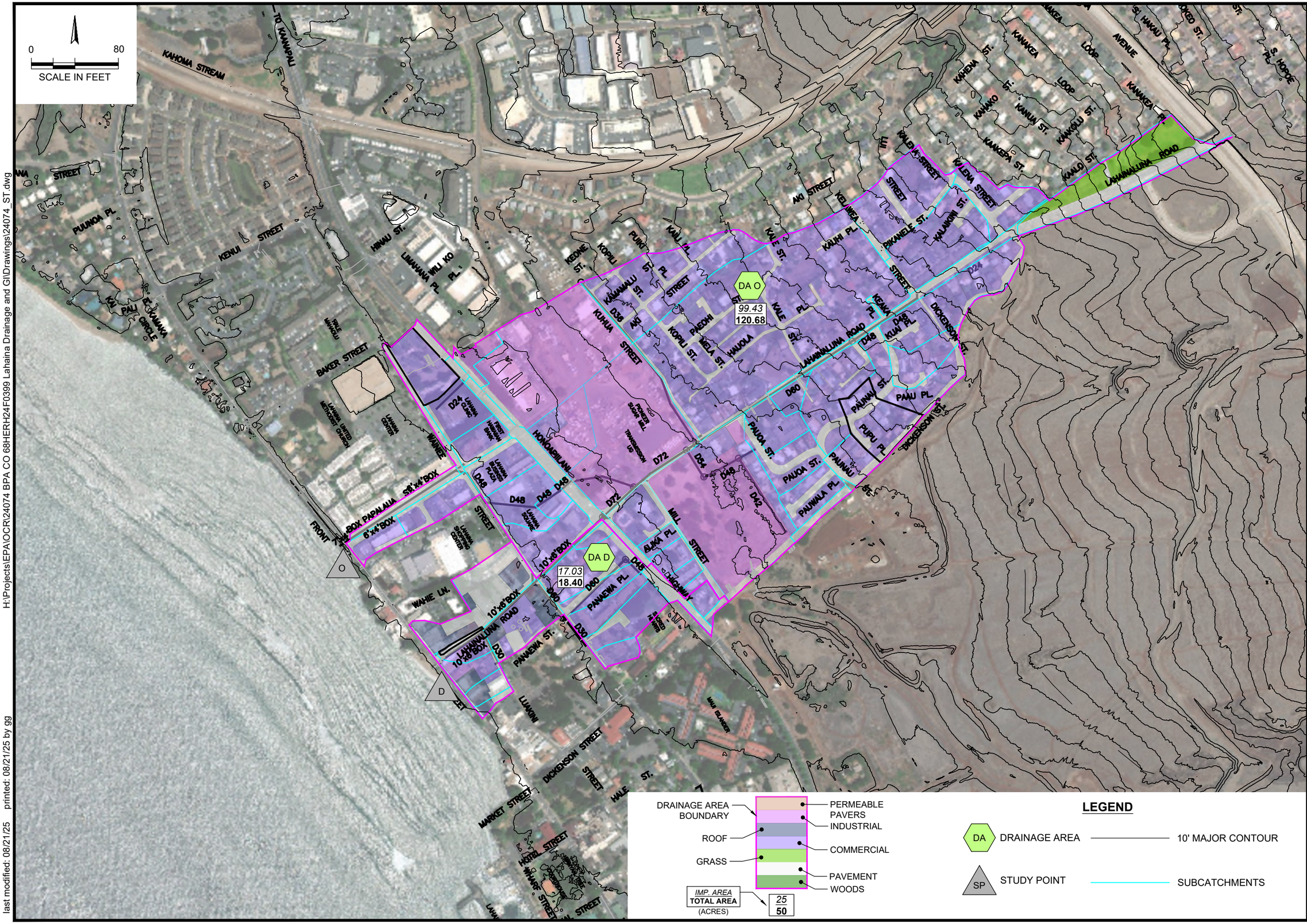
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ATTACHMENT B – Existing Drainage Conditions

- Existing Drainage Infrastructure Reference Sheets – DA R
- Existing Drainage Infrastructure Reference Sheets – DA O&D

0 500
SCALE IN FEET

DA R

DR R-1
DR R-2
DR R-3
DR R-4
DR R-5
DR R-6

R

DICKENSON ST.
KUAI PL.
PAAU PL.
PAUNAU ST.
PUPU PL.
PAUNAU ST.
PAUOA ST.
PAUWALA PL.
KALE ST.
KOPILI ST.
MELA ST.
PAEOHI ST.
HAUOLA ST.
AKI STREET
UHUA STREET
PIONEER SUGAR MILL
TRANSMISSION U/G
MILL STREET
ALIKA PL.
HIGHWAY
HONOAPIILANI
SACRED HEARTS
MAUI ISLANDER
PANAEWA PL.
LAHAINALUNA ROAD
LAHAINA AQUATIC CENTER
LAHAINA BAPTIST CHURCH
HONOAPIILANI HIGHWAY
WAINEE STREET
WAINAE PL.
PRISON STREET
MALU-ULU-O-LELE PARK
SEWAGE PUMP STATION
SHAW STREET
ILIKAHI ST.
ALIO STREET
KAUAULA ROAD
KAHILI PLACE
KAMANO PLACE
KUA PL.
KAUAULA PUMPING PLANT
AHOLO ROAD
PUAPIHI STREET
FIRST HAWAIIAN BANK
LAHAINA CLINIC
LAHAINA BUSINESS PLAZA
LAHAINA SQUARE
LAHAINA SHOPPING CENTER
WAINEE STREET
PAPALAUA ST.
WAHIE LN.
LUAKINI STREET
DICKENSON STREET
HALE STREET
HOTEL STREET
WHARF STREET
CANAL STREET
BANYAN TREE
COURTHOUSE
KING KAMEHAMEHA III ELEMENTARY SCHOOL
FRONT STREET
BEACH PARK
505 FRONT ST. LAHAINA SHORES
LAHAINA SMALL BOAT HARBOR

LEGEND

DA — DRAINAGE AREA
SP — STUDY POINT
10' MAJOR CONTOUR
DRAINAGE AREA BOUNDARY

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2180A
R2320
R2310
R2300
R2241
R2231
R2220
R2211
R2180
R2170
R2200
R2261
R2243
R2232
R2190
R2120
R2242
R2231
R2221
R2211
R2180
R2241
R2220
R2240
R2230
R2230
R2210
R2150
R2130
R2170
R2262
R2131
R2140
R2131
R2262
R2260

WAIA
STREE
PRISON
HALE ST.
STREET
DICKENSON STREET
BANYAN TREE
COURTHOUSE
KING KAMEHAMEHA III ELEMENTARY SCHOOL
MARKET STREET
HOTEL STREET
WHARF STREET
CANAL STREET

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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MALU-ULU-O-LELE PARK

SEWAGE PUMP STATION

SHAW STREET

FRONT STREET

505 FRONT ST. LAHAINA SHORES

BEACH PARK

R2170 R2160 R2103 R2390 R1131 R1132 R1151 R1161

R2103 R2390 R2120 R2160 R2102 R2391 CB R1131 R1132 R1151 R1161

R2170 R2110 R2101 R2100 R2100 DMH R1130 R1140 R1150 R1160 R1162

R2104 CB R1120 R1141

R1141

R1110

OUTFALL R

CB R1100

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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SCALE IN FEET

MAUI ISLANDER

D270

R2380 R2370 R2360 R2361 R2350

R2380 R2370 R2360 R2350

ST.

AE PL.

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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0 80
SCALE IN FEET

LAHAINA RECREATIONAL CENTER

R3122
R3121
R3120
R3130
R3140
R3150
R3150

HONOAPIILANI HIGHWAY

IRRIGATION DITCHES

24" PIPE CULVERT

1161B

ILIKAHI ST.

ALIO STREET

KAHILI ROAD

ST.

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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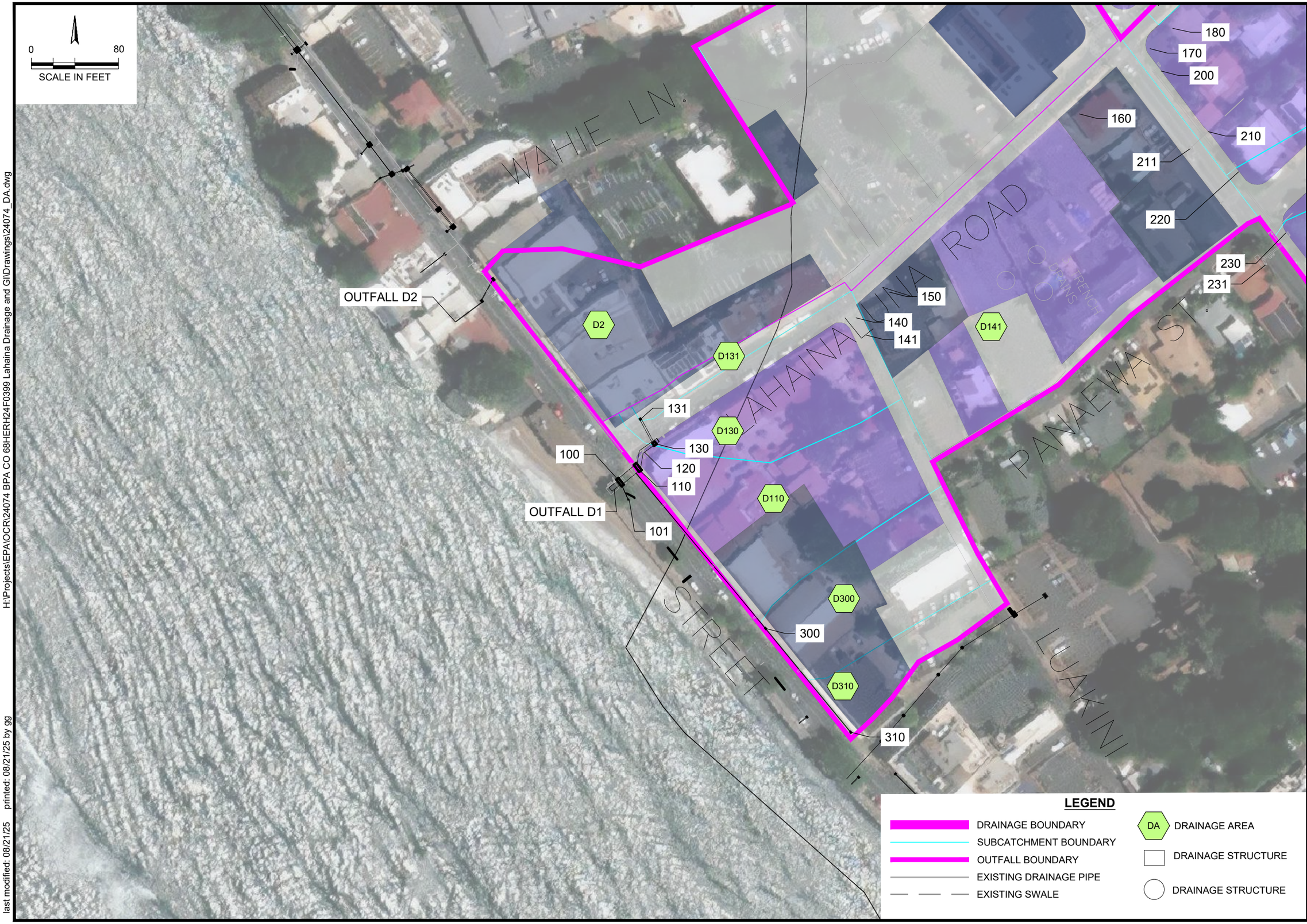
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0 80
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O1511
O1510
O1160
O1500
O1400
O1410
O1160
O1150
O1140
O1130
O1131
O1120
O1110
O1100
OUTLET O2
O1101
O1420
O1431
O1430
O1420
O1400
O1170
O1180
O1230
O1190
O1220
O1200
O1210

1420A
O1511
O1160
O1400
O1180
O1120
O1131
O1110
O1190
O1220

LAHAINA CLINIC
FIRST HAWAIIAN BANK
HONOAPIILANI
LAHAINA CENTER
UNITED CHURCH
WAINEE
LAHAINA BUSINSS PLAZA
PAPALAUA
ST
STREET
LAHAINA SHOPPING CENTER
LAHAINA SQUARE
PONT

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LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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Sustainable Environmental Solutions
90 Route 6A Sandwich, MA 02563
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Checked By: SMS

Plan Set: EX INFRASTRUCTURE REFERENCE SHEETS - ATTACHMENT B
LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

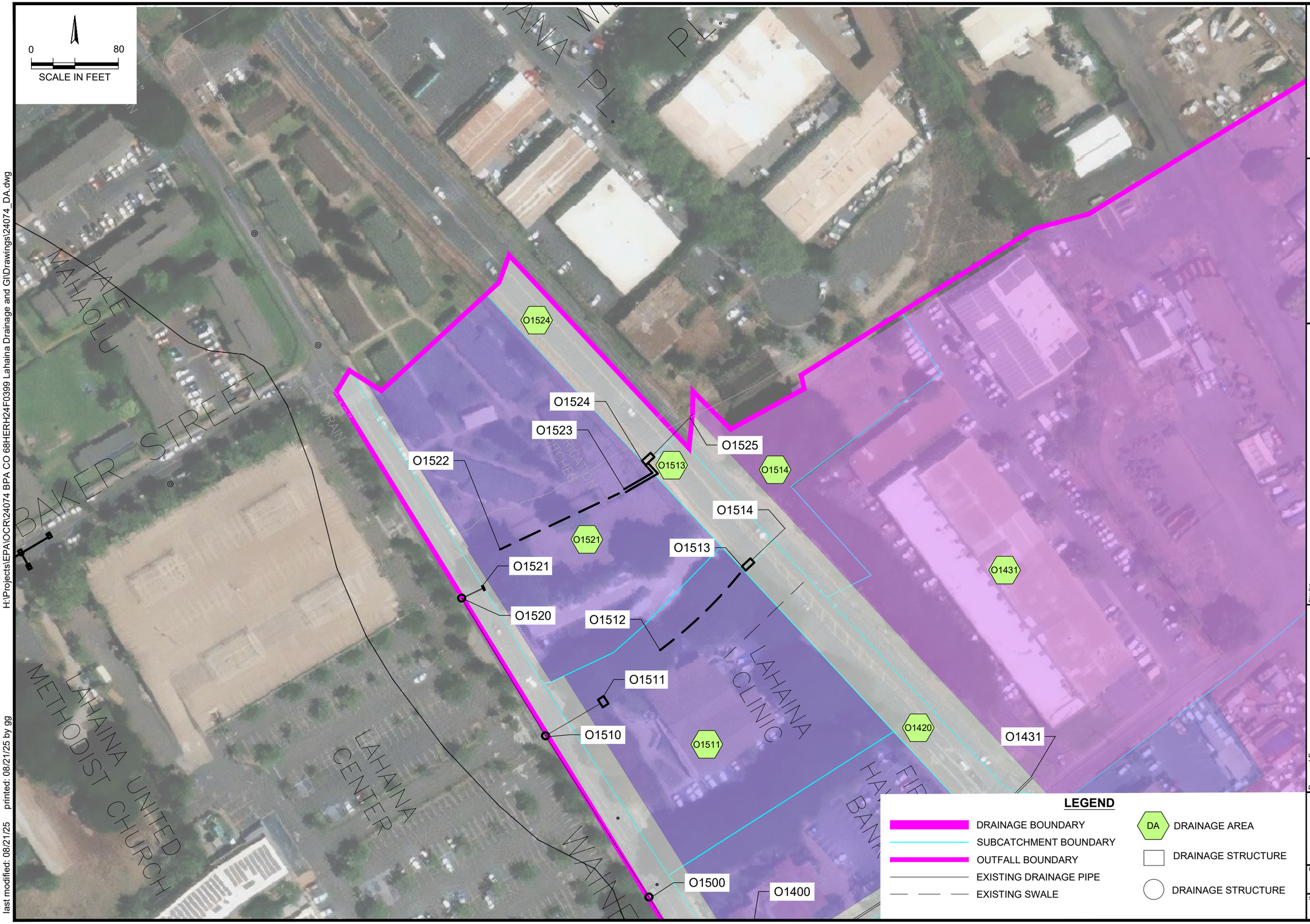
Plan Title: INSET DR O-1

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: INSET DR O-2

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0 80
SCALE IN FEET

O1240
O1241
O1245
O1246
O1232
O1270
O1260
O1261
O1250
O1231
O1230
O1254
O1252
O1253
O1251
1230A
D191
D190
191
190
D210
270
260
D220
D230
SEPTIC TANK
TRANSMISSION UG
MILL STREET
ALIKA PL.
PAUOA ST.
PAUWALA
PANAEWA PL.
HIGHWAY
BAY
SAG H
DRIVE
PAUOA PL.
PAUOA PL.

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA, HAWAII

Plan Title: INSET DR O-3

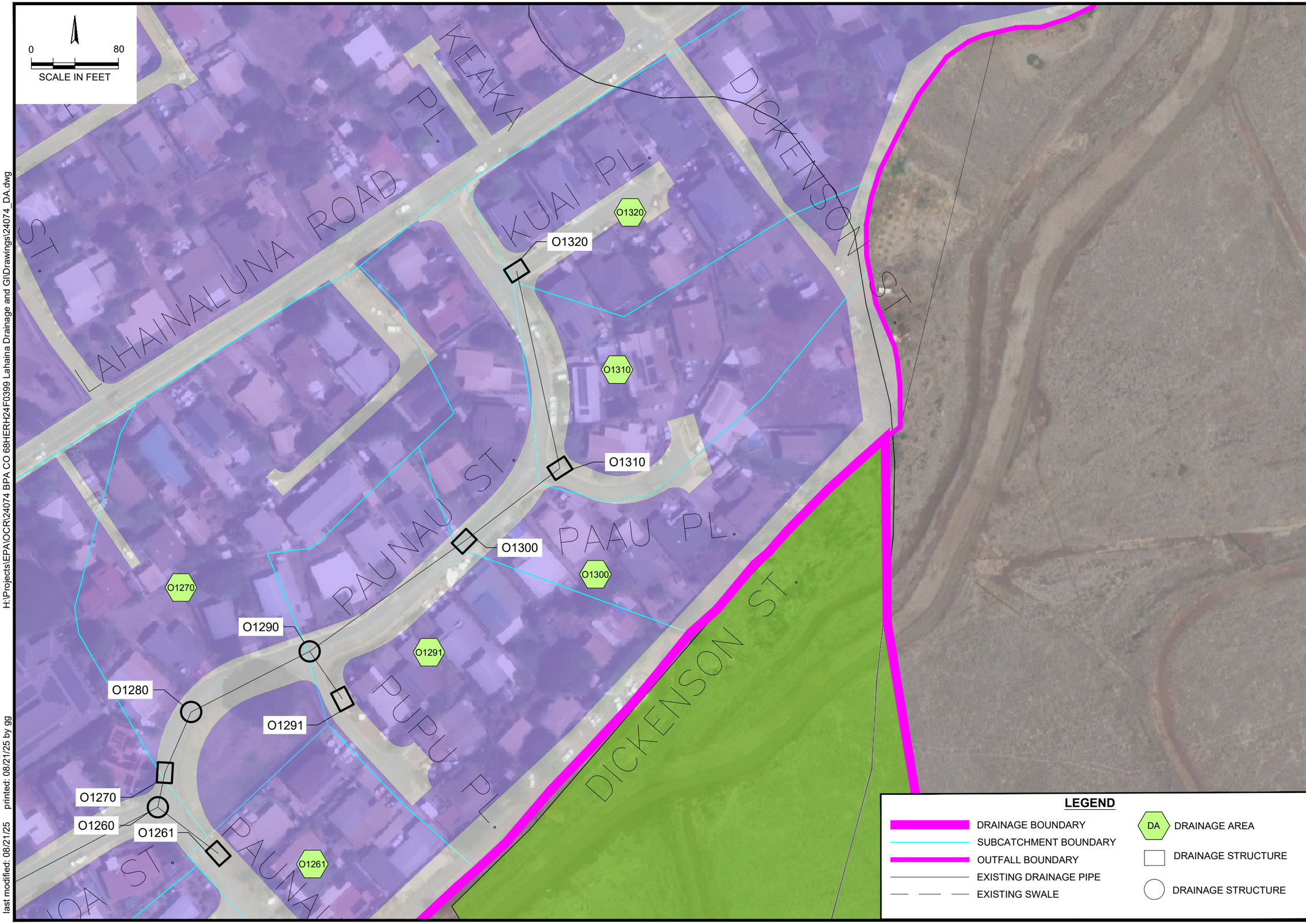
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LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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ATTACHMENT C – Proposed Drainage Conditions

- Proposed Drainage Infrastructure Reference Sheets – DA R
- Proposed Drainage Infrastructure Reference Sheets – DA O&D

0 500
SCALE IN FEET

DA R

DR R-1
DR R-2
DR R-3
DR R-4
DR R-5
DR R-6

R1
R2

LEGEND

DA DRAINAGE AREA

10' MAJOR CONTOUR

SP STUDY POINT

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Plan Title: DA R KEY SHEET

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LAHAINA, HAWAII

Plan Set:

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0 80
SCALE IN FEET

MALU-ULU-O-LELE PARK

DOUBLE 10'x4' BOX

DOUBLE SEWAGE PUMP STATION 6'x3' BOX

DOUBLE 6'x4' BOX

DOUBLE FRONT 7'x3' BOX

TRIPLE CULVERT 12' BOX

SHAW STREET

505 FRONT ST. LAHAINA SHORES

BEACH PARK

R2500 R2103 R2390 R1131 R1132 R1151 R1161

R2103 R2390 R2120 R2160 R2102 R2170 R2391 CB R1131 R1132 R1151 R1161

2100A R2160 R2170 R2110 R2101 R2100 DMH R1130 R1140 R1160 R1162

R2104 CB R1120 R1150 R1141 R2100 R1141

OUTFALL R1 R1110 OUTFALL R CB R1100

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

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Plan Title: INSET DA R-3

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0 80
SCALE IN FEET

R2410
R2380
R2370
R2360
R2350
R2361
R2350
R2380
R2370
R2360

MAUI ISLANDER
DOUBLE 8'X4' BOX
D42
ST.

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Set:

INSET DA R-4

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0 80
SCALE IN FEET

R2410
R3122
SED
LAHAINA AQUATIC CENTER
R3100
R2410
PR2405
R2400
R2350
R2340
1151B
R3100
R3110
DOUBLE 10'x4' BOX
DOUBLE D48
LAHAINA BAPTIST CHURCH
PR2395
R2340
R2394
WAINEE STREET
R2394
R2390
R1131
R1132
R1151
2180A
R2330
R2393
DOUBLE 10'x4' BOX
R2392
R2320
R2103

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: INSET DA R-5

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0 80
SCALE IN FEET

LAHAINA RECREATIONAL CENTER

R3100
R3122
R3121
R3120
R3130
R3140
R3150
R3150

HONOAPIILANI HIGHWAY

24" PIPE CULVERT

1151B
1161B
R1161B
PR2396

IRRIGATION DITCHES

R1151
R1161

ILIKAHI ST.
ALIO STREET
ST.
KAHILI ROAD

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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Plan Title: INSET DA R-6

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LAHAINA, HAWAII

Plan Set:

DA D&O KEY SHEET

Plan Title:

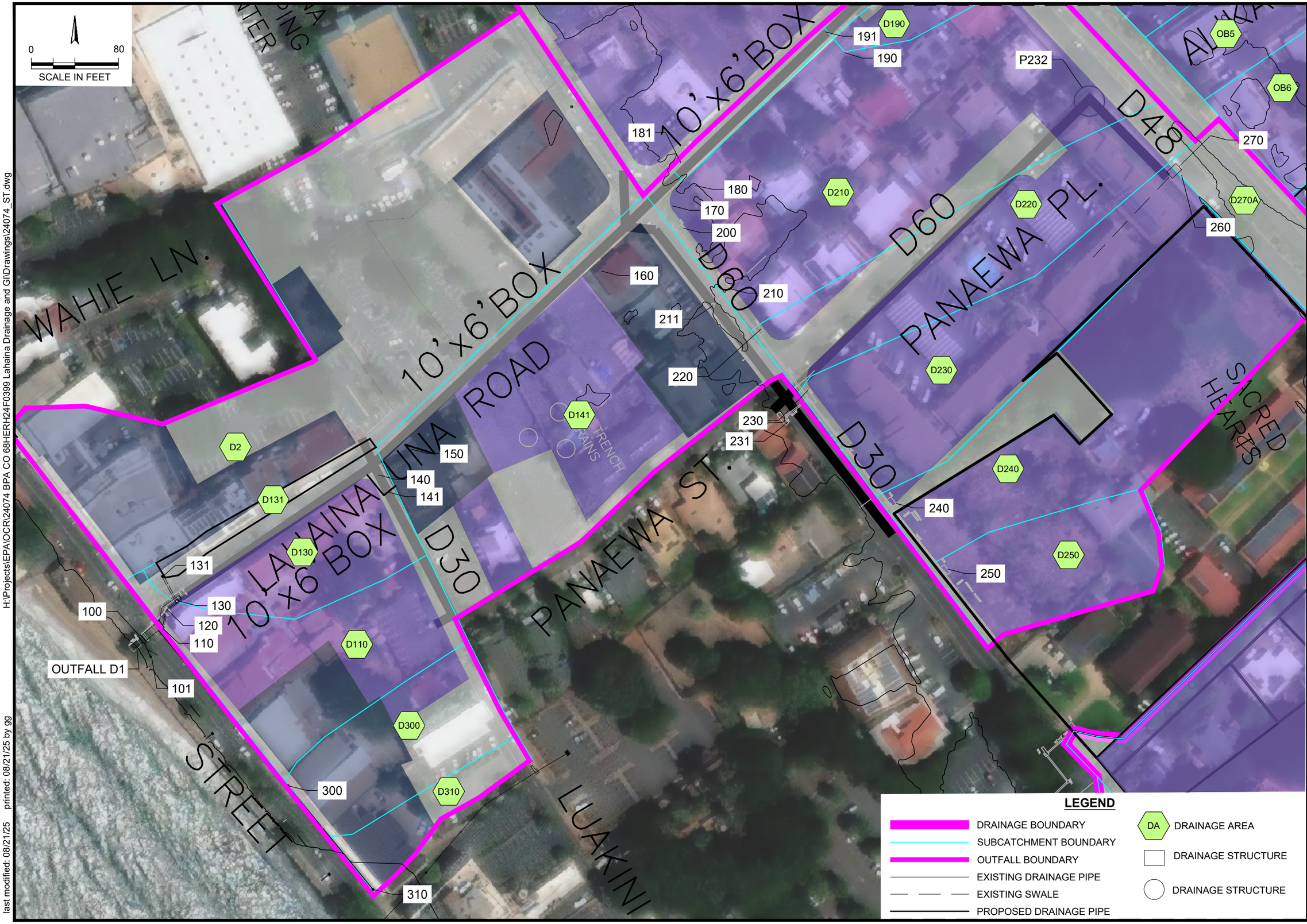
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LAHAINA, HAWAII

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Project Number: 24074

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0 80
SCALE IN FEET

O1511 O1510 O1160 O1500 O1400 O1410 O1160 O1170 O1180 O1150 O1140 O1130 O1131 O1120 O1110 O1100 OUTLET O2 O1101 O1190 O1200 O1210 O1220 O1230 O1420 O1430 O1431

D24 D48 D48 D48

LAHAINA UNITED METHODIST CHURCH
LAHAINA CENTER
WAINEE
FIRST HAWAIIAN BANK
LAHAINA CLINIC
HONOAPIILANI
LAHAINA BUSINESS PLAZA
6'X4' BOX PAPALAUA
6'X4' BOX
7'X4' BOX
LAHAINA SHOPPING CENTER
STREET
LAHAINA SQUARE
1420A

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: INSET DA O-1

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0 80
SCALE IN FEET

HALE MAHAOLU

KER STREET

DRAIN

CULVERT

IRRIGATION DITCHES

O1524
O1524
O1523
O1522
O1521
O1160
O1525
O1514
O1514
O1513
O1513
O1521
O1520
O1512
O1511
O1511
O1510
O1420
O1431
O1431
O1430
O1420
1420A
O1400
O1500
O1400
O1410
O1160
O1170
O1180
O1180

D24

LAHAINA CLINIC

LAHAINA UNITED METHODIST CHURCH

LAHAINA CENTER

WAINEE

FIRST HAWAIIAN BANK

HONOAPI

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
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- PROPOSED DRAINAGE PIPE
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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

Plan Title: INSET DA O-2

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0 80
SCALE IN FEET

TRANSMISSION
MILL
UG
O1231
D72
PO1550
PO1540
D54
O1232
D48
PO1542
O1240
PAUOA ST.
O1241
O1245
O1246
OB4
O1242
O1280
O1270
O1260
O1261
PAUOA ST.
O1240
O1250
PO1541
PO1530
SEPTIC TANK
O1231
D72
O1230
D42
O1254
PAUWALA
O1251
O1254
O1253
O1251
O1252
O1252
P192
1230A
D191
D190
191
190
P232
D210
ALIKI PL.
OB5
MILL STREET
OB6
270
D48
OB7
D60
D220
D270A
260
D230
D240
D270B
HIGHWAY
CONC. DITCH
R.C.P.
BOX
PE

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
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- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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Checked By: SMS

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Plan Title: INSET DA O-3

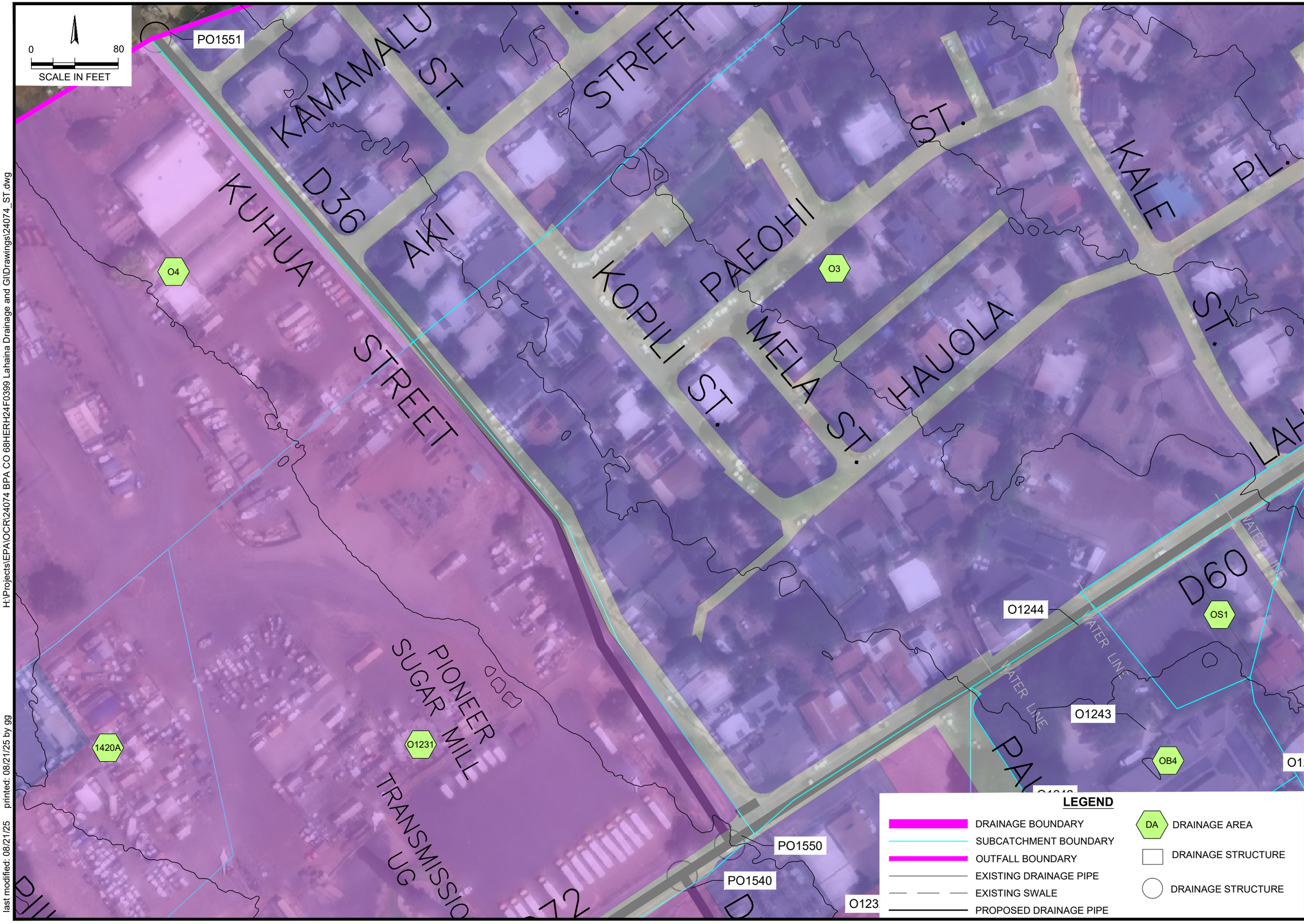
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LAHAINA DRAINAGE MASTER PLAN
LAHAINA, HAWAII

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0 80
SCALE IN FEET

LAHAINALUNA ROAD
KEAKA PL.
D48
KUAI PL.
DICKENSON ST.
PAUNAU ST.
PAAU PL.
PUPU PL.
D60
WATER LINE

O3D
O3
O1320
O1310
PO1560
O1300
OS1
O1270
O1290
O1291
OB4
O1280
O1261
O1420

LEGEND

- DRAINAGE BOUNDARY
- SUBCATCHMENT BOUNDARY
- OUTFALL BOUNDARY
- EXISTING DRAINAGE PIPE
- EXISTING SWALE
- PROPOSED DRAINAGE PIPE
- DA DRAINAGE AREA
- DRAINAGE STRUCTURE
- DRAINAGE STRUCTURE

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LAHAINA, HAWAII

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ATTACHMENT D – Pipe Information Sheets

- Catchment D Stormwater Pipe Data
- Catchment O Stormwater Pipe Data
- Catchment R Stormwater Pipe Data

Catchment D Pre-Fire Stormwater Pipe Data									
Catch Basin		Invert Elevation					Size		
Downstream	Upstream	Downstream	Upstream	Length (ft)	Slope (Ft/ft)	Shape	Diameter (in)	Width (in)	Height (in)
Outlet D	100	3.5	3.8	11	0.027	Box		60	36
100	101	3.8	4.14	17	0.020	Circular	12		
100	110	6.5	6.6	22.5	0.004	Box		96	24
110	300	6.64	8.27	231	0.007	Circular	18		
300	310	8.27	9.4	152	0.007	Circular	18		
110	120	6.64	6.73	18	0.005	Box		60	30
120	130	6.73	6.83	15	0.007	Box		60	30
130	131	6.83	7.8	28	0.035	Horizontal Elipse		14	23
130	140	6.83	7.68	269	0.003	Circular	48		
140	141	7.68	8.08	20	0.020	Circular	18		
140	150	7.68	7.83	49	0.003	Circular	42		
150	160	7.83	8.77	300	0.003	Circular	42		
160	170	8.77	9.12	112	0.003	Circular	42		
170	180	9.12	9.80	34	0.020	Circular	18		
180	181	9.80	10.42	31	0.020	Circular	18		
180	190	9.80	14.36	228	0.020	Circular	18		
190	191	14.36	15.02	33	0.020	Circular	18		
170	200	9.12	9.20	24	0.003	Circular	18		

200	210	9.20	9.75	82		Circular	18		
210	211	9.19	9.75	28	0.020	Circular	18		
210	220	9.75	10.09	51	0.007	Circular	18		
220	230	10.09	10.69	102	0.006	Circular	18		
230	231	10.69	10.87	41	0.004	Circular	18		
230	240	10.69	11.44	144	0.005	Circular	18		
240	250	11.44	11.94	102	0.005	Circular	18		
240	260	11.44	21.24	490	0.02	Graded Swale		12	1
260	270	21.24	22.24	50	0.02	Circular	24		

Legend	
Assumed	
Not Applicable	

Catchment D Proposed Stormwater Pipe Data									
Catch Basin		Invert Elevation					Size		
Downstream	Upstream	Downstream	Upstream	Length (ft)	Slope (Ft/ft)	Shape	Diameter (in)	Width (in)	Height (in)
Outfall D	100	3.5	3.8	11	0.027	Box		60	36
100	101	3.8	4.14	17	0.020	Circular	12		
100	110	6.5	6.6	22.5	0.004	Box		96	24
110	300	6.64	8.27	231	0.007	Circular	18		
300	310	8.27	9.4	152	0.007	Circular	18		
110	120	6.64	6.73	18	0.005	Box		120	72
120	130	6.73	6.83	15	0.007	Box		120	72
130	131	6.83	7.8	28	0.035	Horizontal Elipse		14	23
130	140	6.83	7.68	269	0.003	Box		120	72
140	141	7.68	8.08	20	0.020	Circular	30		
140	150	7.68	7.83	49	0.003	Box		120	72
150	160	7.83	8.77	300	0.003	Box		120	72
160	170	8.77	9.12	112	0.003	Box		120	72
170	180	9.12	9.80	34	0.020	Box		120	72
180	181	9.80	10.42	31	0.020	Circular	18		
180	190	9.80	14.36	228	0.020	Box		120	72
190	191	14.36	15.02	33	0.020	Circular	18		
190	P192	14.36	16.71	235	0.010	Box		120	72

170	200	9.12	9.20	24	0.003	Circular	60		
200	210	9.20	9.75	82	0.007	Circular	60		
210	211	9.19	9.75	28	0.020	Circular	18		
210	220	9.75	10.09	51	0.007	Circular	60		
220	230	10.09	10.69	102	0.006	Circular	60		
230	P232	10.69	20.53	492	0.020	Circular	60		
230	231	10.69	10.87	41	0.004	Circular	60		
230	240	10.69	11.44	144	0.005	Circular	30		
240	250	11.44	11.94	102	0.005	Circular	30		
232	260	20.53	21.24	127	0.006	Circular	48		
240	260	11.44	21.24	490	0.02	Graded Swale		12	1
260	270	21.24	22.24	50	0.02	Circular	24		

Legend	
Assumed	
Added/Updated for Proposed	
Not Applicable	

Catchment O Pre-Fire Stormwater Pipe Data									
Catch Basin		Invert Elevation					Size		
Downstream	Upstream	Downstream	Upstream	Length (ft)	Slope (FT/FT)	Shape	Diameter (in)	Width (in)	Height (in)
Outlet O	O1120	4.4	4.7	70	0.004	Circular	30+36		
O1120	O1130	4.7	7.1	300	0.008	Circular	30+24		
O1130	O1131	7.1	8.06	48	0.020	Circular	18		
O1130	O1140	7.1	8.6	132	0.011	Circular	24 & 30		
O1140	O1150	8.6	10.3	143	0.012	Circular	24 & 30		
O1150	O1160	10.3	11.4	139	0.008	Circular	24 & 30		
O1160	O1170	11.4	11.7	31	0.010	Circular	36		
O1170	O1180	11.7	11.9	32.79	0.006	Circular	36		
O1180	O1190	11.9	12.7	196	0.004	Circular	36		
O1190	O1200	12.8	14.48	84	0.020	Circular	18		
O1200	O1210	14.58	16.02	72	0.020	Circular	18		
O1190	O1220	12.7	16.8	270	0.015	Circular	36		
O1220	O1230	16.8	19	168	0.013	Circular	36		
O1230	O1231	19	20	66	0.015	Circular	24		
O1231	O1232	20	32	1229	0.010	Circular	30		
O1232	O1240	32	35	155	0.019	Circular	30		
O1240	O1241	35	39.1	31	0.132	Circular	18		
1241	1242	39.1	40.84	87	0.020	Circular	36		
1242	1243	40.84	42.7	93	0.020	Circular	36		
1243	1244	42.7	45.3	130	0.020	Circular	36		
O1240	O1250	35	37	174	0.011	Circular	18		
O1250	O1260	37	39.8	269	0.010	Circular	24		

O1260	O1261	39.8	41.54	87	0.020	Circular	18		
O1260	O1270	39.8	40.5	41	0.017	Circular	24		
O1270	O1280	40.5	41	76	0.007	Circular	24		
O1280	O1290	41	49	153	0.052	Circular	24		
O1290	O1291	49	50.32	66	0.020	Circular	18		
O1290	O1300	49	63	218	0.064	Circular	18		
O1300	O1310	63	69	138	0.043	Circular	18		
O1310	O1320	69	77	232	0.034	Circular	18		
O1251	O1252	36	37	50	0.020	Circular	24		
O1251	O1253	36	37.2	60	0.020	Circular	18		
O1253	O1254	37.2	38.1	45	0.020	Circular	18		
O1160	O1400	11.4	11.8	41	0.010	Circular	38		
O1400	O1410	11.8	12.36	28	0.020	Circular	24		
O1410	O1420	12.46	19.5	286	0.025	Circular	24		
O1420	O1430	19.5	20	9	0.056	Circular	24		
O1430	O1431	20	21	72	0.014	Circular	24		
O1160	O1500	11.4	11.75	142	0.002	Circular	24		
O1500	O1510	11.75	12.2	220	0.002	Circular	24		
O1510	O1511	12.3	13.76	73	0.020	Circular	12		
O1511	O1512	13.86	15.54	84	0.020	Open Ditch		10'	2'
O1512	O1513	15.64	22.4	338	0.020	Open Ditch		10'	2'
O1513	O1514	22.5	23.56	53	0.020	Circular	24		
O1510	O1520	12.2	13.2	185	0.541	Circular	18		

O1520	O1521	13.2	14.5	23	0.057	Circular	18		
O1521	O1522	14.5	15.46	48	0.020	Circular	18		
O1522	O1523	15.46	18.48	151	0.020	Swale		2	1
O1523	O1524	18.48	19.46	49	0.020	CRM Ditch		2	1
O1524	O1525	19.46	20.78	66	0.020	Circular	24		

Legend	
Assumed	
Not Applicable	

Catchment O Proposed Stormwater Pipe Data									
Catch Basin		Invert Elevation					Size		
Downstream	Upstream	Downstream	Upstream	Length (ft)	Slope (FT/FT)	Shape	Diameter (in)	Width (in)	Height (in)
Outlet O	O1120	4.4	4.7	70	0.004	Box		84	48
O1120	O1130	4.7	7.1	300	0.008	Box		72	48
O1130	O1131	7.1	8.06	48	0.020	Circular	18		
O1130	O1140	7.1	8.6	132	0.011	Box		72	48
O1140	O1150	8.6	10.3	143	0.012	Box		72	48
O1150	O1160	10.3	11.4	139	0.008	Box		72	48
O1160	O1170	11.4	11.7	31	0.010	Circular	48		
O1170	O1180	11.7	11.9	32.79	0.006	Circular	48		
O1180	O1190	11.9	12.7	196	0.004	Circular	48		
O1190	O1200	12.8	14.48	84	0.020	Circular	18		
O1200	O1210	14.58	16.02	72	0.020	Circular	18		
O1190	O1220	12	13.5	270	0.006	Circular	48		
O1220	O1230	13.5	15	168	0.009	Circular	48		
O1230	O1231	15	16	66	0.015	Circular	48		
O1231	PO1530	16	24.73	360	0.024	Circular	48		
P192	PO1530	16.71	24.73	250	0.032	Circular	72		
PO1530	PO1540	24.73	28.43	370	0.010	Circular	72		
PO1540	PO1550	28.43	29.79	68	0.020	Circular	72		
PO1550	PO1551	29.79	41.26	1147	0.010	Circular	36		
O1244	PO1560	45.3	57.3	600	0.020	Circular	48		
PO1540	PO1541	28.43	30.3	187	0.010	Circular	54		
PO1541	PO1542	30.3	32.6	230	0.010	Circular	48		
O1231	O1232	16	32	1229	0.013	Circular	30		

O1232	**O**1240	32	35	155	0.019	Circular	30		
PR1542	O1240	32.6	35	120	0.020	Circular	48		
O1240	O1241	35	39.1	31	0.132	Circular	18		
O1241	O1242	39.1	40.84	87	0.020		36		
O1242	O1243	40.84	42.7	93	0.020		36		
O1243	O1244	42.7	45.3	130	0.020	Circular	36		
PO1550	O1244	29.79	45.3	475	0.033	Circular	60		
O1240	O1250	35	37	174	0.011	Circular	18		
O1250	O1260	37	39.8	269	0.010	Circular	24		
O1260	O1261	39.8	41.54	87	0.020	Circular	18		
O1260	O1270	39.8	40.5	41	0.017	Circular	24		
O1270	O1280	40.5	41	76	0.007	Circular	24		
O1280	O1290	41	49	153	0.052	Circular	24		
O1290	O1291	49	50.32	66	0.020	Circular	18		
O1290	O1300	49	63	218	0.064	Circular	18		
O1300	O1310	63	69	138	0.043	Circular	18		
O1310	O1320	69	77	232	0.034	Circular	18		
PO1542	O1251	32.6	36	500	0.010	Circular	42		
O1251	O1252	36	37	50	0.020	Circular	24		
O1251	O1253	36	37.2	60	0.020	Circular	18		
O1253	O1254	37.2	38.1	45	0.020	Circular	18		
O1160	O1400	11.4	11.8	41	0.010	Circular	38		
O1400	O1410	11.8	12.36	28	0.020	Circular	24		
O1410	O1420	12.46	19.5	286	0.025	Circular	24		

O1420	O1430	19.5	20	9	0.056	Circular	24		
O1430	O1431	20	21	72	0.014	Circular	24		
O1160	O1500	11.4	11.75	142	0.002	Circular	24		
O1500	O1510	11.75	12.2	220	0.002	Circular	24		
O1510	O1511	12.3	13.76	73	0.020	Circular	12		
O1511	O1512	13.86	15.54	84	0.020	Circular	24		
O1512	O1513	15.64	22.4	338	0.020	Circular	24		
O1513	O1514	22.5	23.56	53	0.020	Circular	24		
O1510	O1520	12.2	13.2	185	0.541	Circular	18		
O1520	O1521	13.2	14.5	23	0.057	Circular	18		
O1521	O1522	14.5	15.46	48	0.020	Circular	18		
O1522	O1523	15.46	18.48	151	0.020	Swale		2	1
O1523	O1524	18.48	19.46	49	0.020	CRM Ditch		2	1
O1524	O1525	19.46	20.78	66	0.020	Circular	24		

Legend	
Assumed	
Added/Updated for Proposed	
Not Applicable	

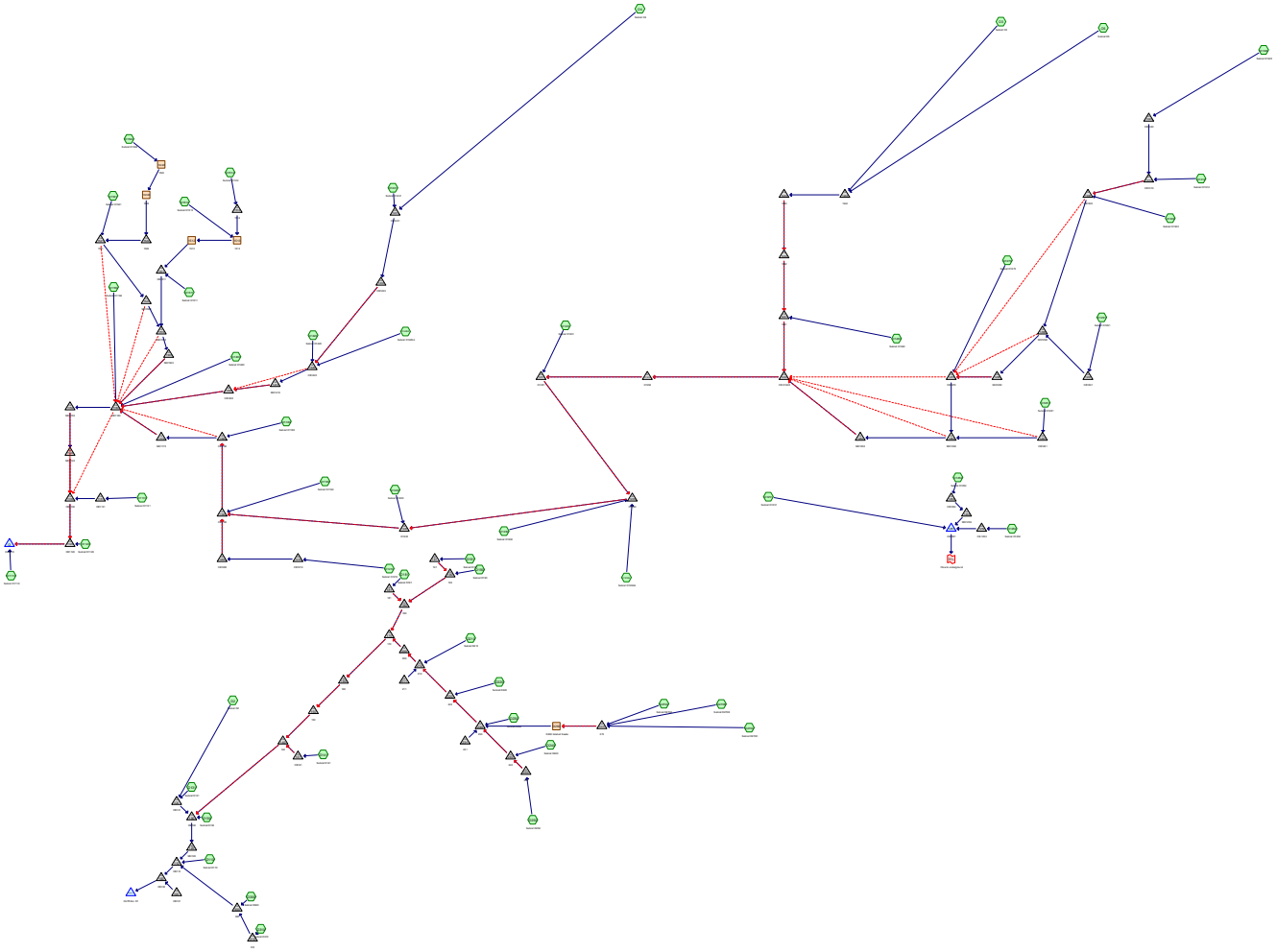
Catchment R Pre-Fire Stormwater Pipe Data									
Catch Basin		Invert Elevation					Size		
Downstream	Upstream	Downstream	Upstream	Length (ft)	Slope (Ft/ft)	Shape	Diameter (in)	Width (in)	Height (in)
Outfall R	R1100	0	1.32	105.7	0.012	Round	18		
R1100	R1110	1.32	2.32	196.4	0.005	Round	18		
R1110	R1120	2.32	2.4	17	0.005	Round	18		
R1120	R1130	1.97	2.36	191	0.002	Round	18		
R1130	R1131	2.32	2.4	11	0.007	Round	18		
R1131	R1132	2.4	2.79	186.5	0.002	Round	12		
R1130	R1140	1.97	2.36	189	0.002	Rectangular		48	24
R1140	R1141	2.79	3	15.5	0.014	Round	8		
R1132	R1140	2.79	3	11	0.019	Round	8		
R1140	R1150	2.36	2.95	249.5	0.002	Rectangular		48	18
R1150	R1151	2.95	3.4	5.8	0.078	Rectangular		23	14
R1150	R1160	2.95	3.26	65.7	0.005	Rectangular		23	14
R1160	R1161	3.26	3.36	5.8	0.017	Rectangular		23	14
Outfall R2	2100	0.68	1.4	209	0.003	Rectangular		72	48
R2100	R2101	1.4	1.6	10	0.020	Rectangular		72	48
R2100	R2102	1.4	1.48	10	0.008	Rectangular		72	48
R2102	R2110	1.48	1.96	156	0.003	Rectangular		60	30
R2110	R2120	1.96	2.23	138	0.002	Rectangular		60	30
R2120	r2130	2.23	3.1	197	0.004	Rectangular		60	30
R2130	R2140	3.1	3.2	10	0.010	Rectangular		60	24

R2140	R2150	3.2	3.24	14	0.003	Rectangular		38	24
R2130	R2131	3.1	3.36	13	0.020	Rectangular		23	14
R2102	R2103	1.48	2	15	0.035	Rectangular		72	48
R2103	R2160	1.415	1.45	7	0.005	Round	24		
R2160	R2170	1.45	2.11	121	0.005	Round	24		
R2170	R2180	2.11	2.74	212	0.003	Round	24		
R2180	R2220	2.74	2.9	28	0.006	Round	18		
R2190	R2200	3.2	3.3	3	0.033	Rectangular		24	24
R2200	R2300	3.3	3.7	187	0.002	Round	24		
R2300	R2310	3.7	4.1	74	0.005	Round	24		
R2310	R2320	4.1	4.8	242	0.003	Round	24		
R2320	R2330	4.8	5.7	242	0.004	Round	24		
R2330	R2340	5.7	6	76	0.004	Round	24		
R2340	R2350	6	8	240	0.008	Round	24		
R2350	R2360	8	9.6	151	0.011	Round	24		
R2360	R2370	9.6	10.5	128	0.007	Round	24		
R2370	R2380	10.5	11.5	56	0.018	Round	24		
R2150	R2210	3.42	4.5	267	0.004	Rectangular		38	24
R2210	R2220	4.5	4.73	46	0.005	Rectangular		30	19
R2210	R2211	4.5	4.94	22	0.020	Round	18		
R2220	R2221	5.61	5.75	11.5	0.012	Rectangular		23	14
R2220	R2230	4.73	5.61	173.48	0.005	Rectangular		30	19
R2230	R2231	6	6.1	7.5	0.013	Rectangular		23	14
R2230	R2240	5.61	6.15	131	0.004	Rectangular		23	14

R2240	R2241	7.05	7.29	14.1	0.017	Horizontal Elipse		14	23
R2240	R2260	6.15	7.05	222	0.004	Rectangular		23	14
R2260	R2261	7.05	7.29	9.3	0.026	Rectangular		23	14
R2260	R2262	7.05	7.33	11	0.025	Rectangular		23	14
R2390	R2394	2.08	6	994	0.004	Circular	24		
R2130	R2131	3.2	3.47	13.5	0.020	Rectangular		48	30
R3100	R3110	9	9.1	125	0.001	Circular	24		
R3110	R3120	9.1	10.38	142	0.009	Circular	24		
R3120	R3121	10.38	11.29	109	0.008	Circular	18		
R3121	R3122	11.29	11.54	44	0.006	Circular	18		
R3120	R3130	9.10	9.44	26	0.014	Circular	24		
R3130	R3140	9.44	10.23	56	0.014	Circular	24		
R3140	R3150	10.23	10.38	8.25	0.014	Circular	24		

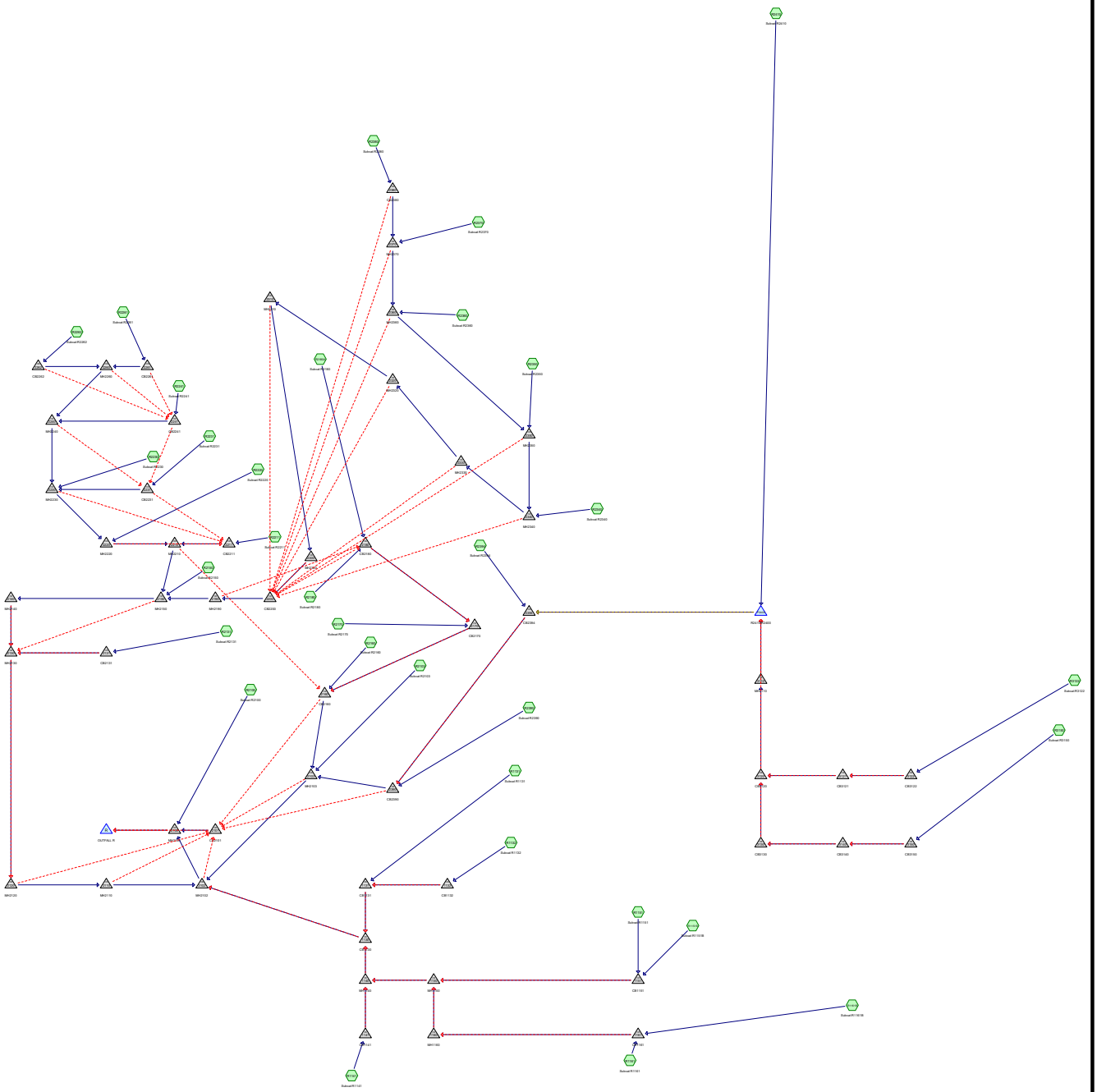
Legend	
Assumed	
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ATTACHMENT E – HydroCAD Routing Diagrams



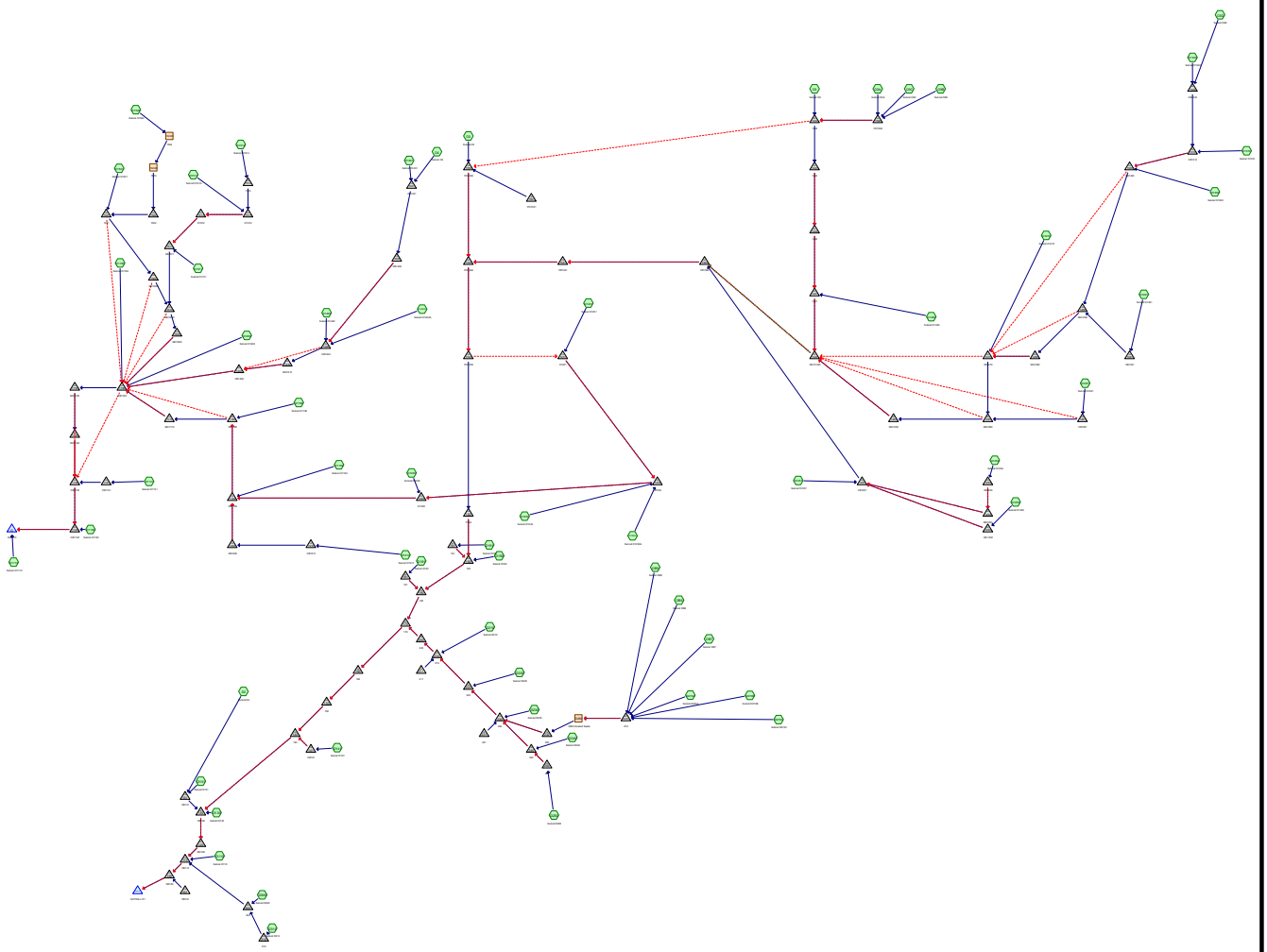
Subcat Reach Pond Link

Routing Diagram for Catchments O and D Existing
Prepared by Horsley Witten Inc, Printed 8/19/2025
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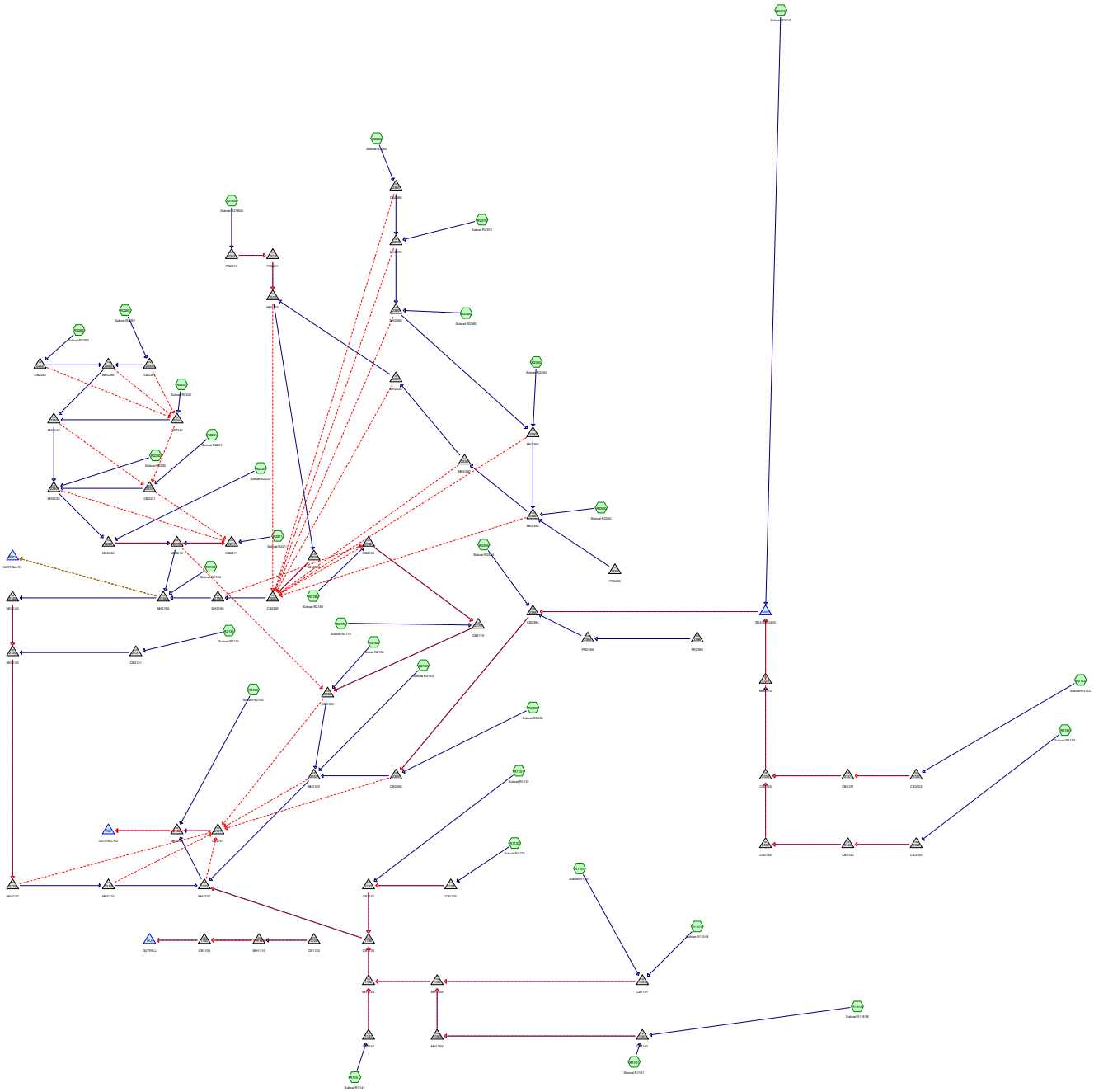
Subcat Reach Pond Link

Routing Diagram for Catchment R Existing
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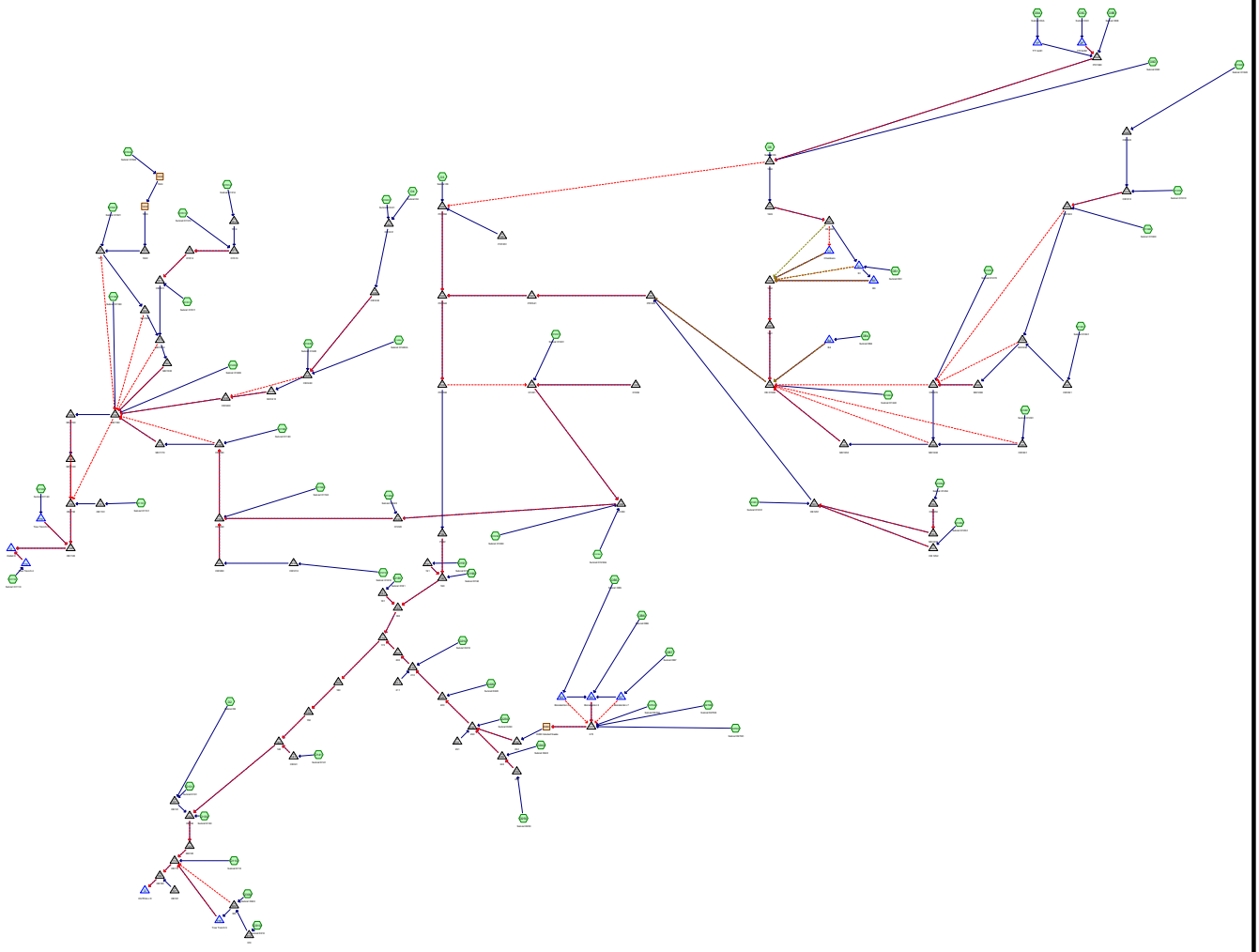
Subcat Reach Pond Link

Routing Diagram for Catchments O and D Proposed
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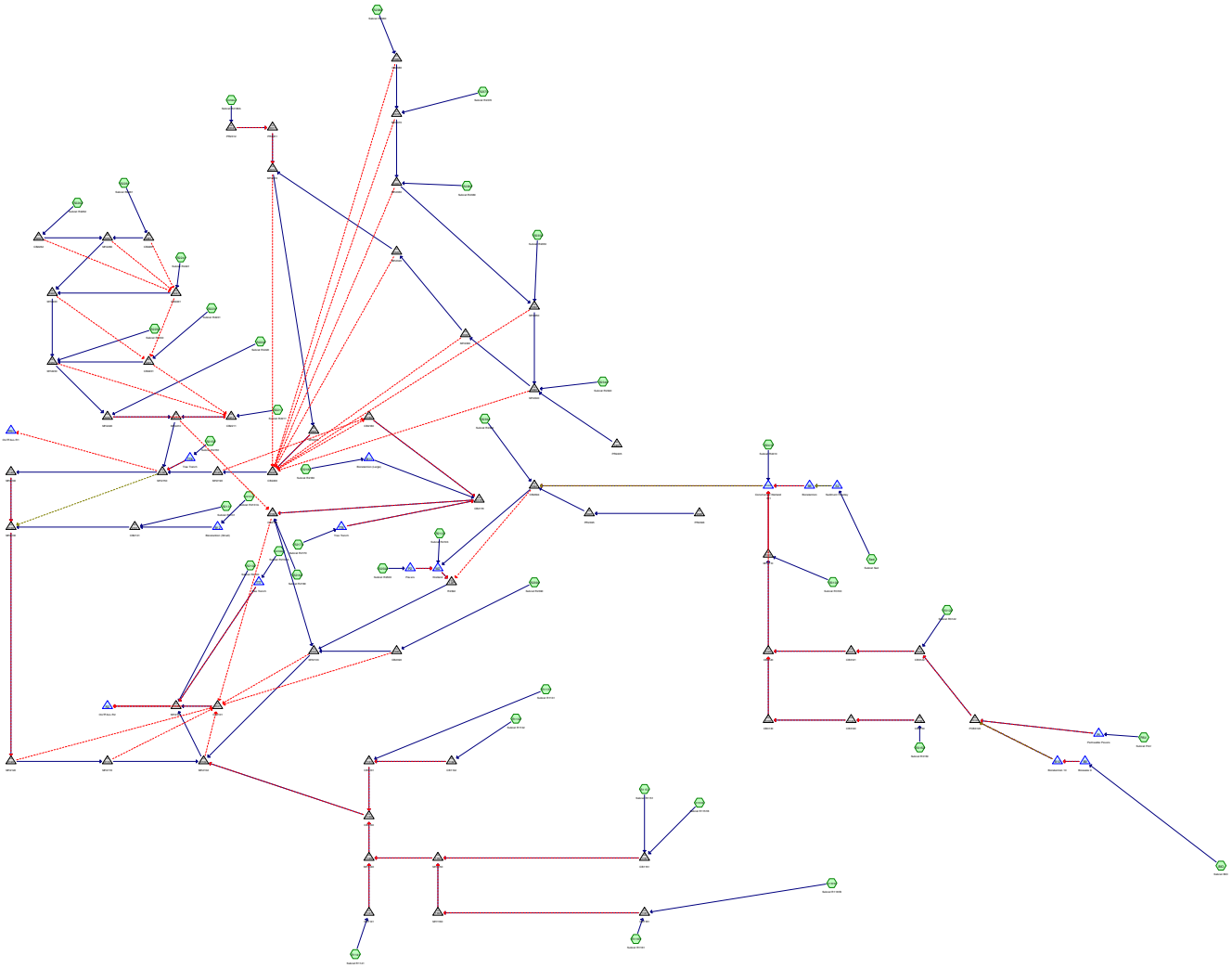
Subcat Reach Pond Link

Routing Diagram for Catchment R Proposed
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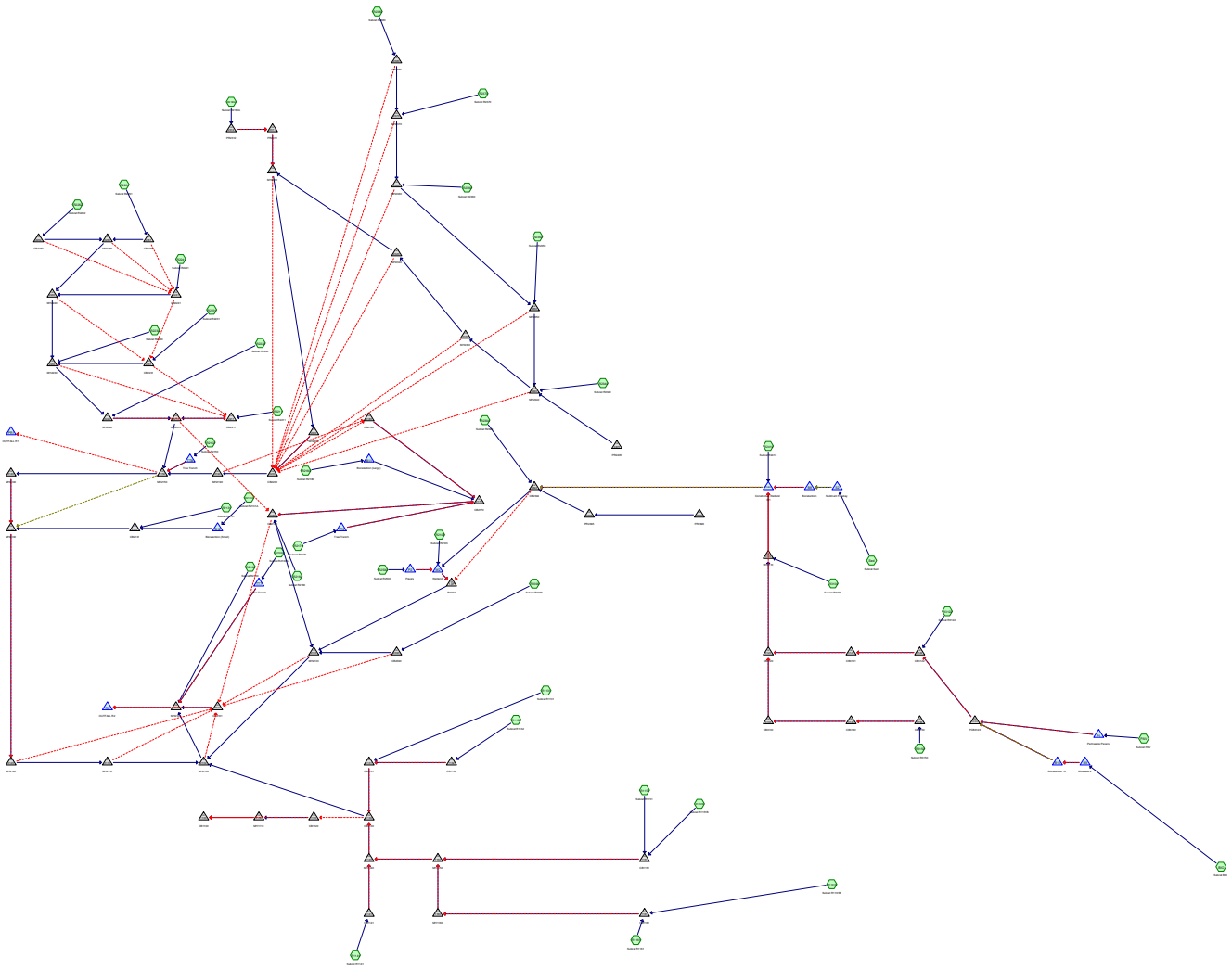
Subcat Reach Pond Link

Routing Diagram for Catchments O and D Proposed Pilot Projects
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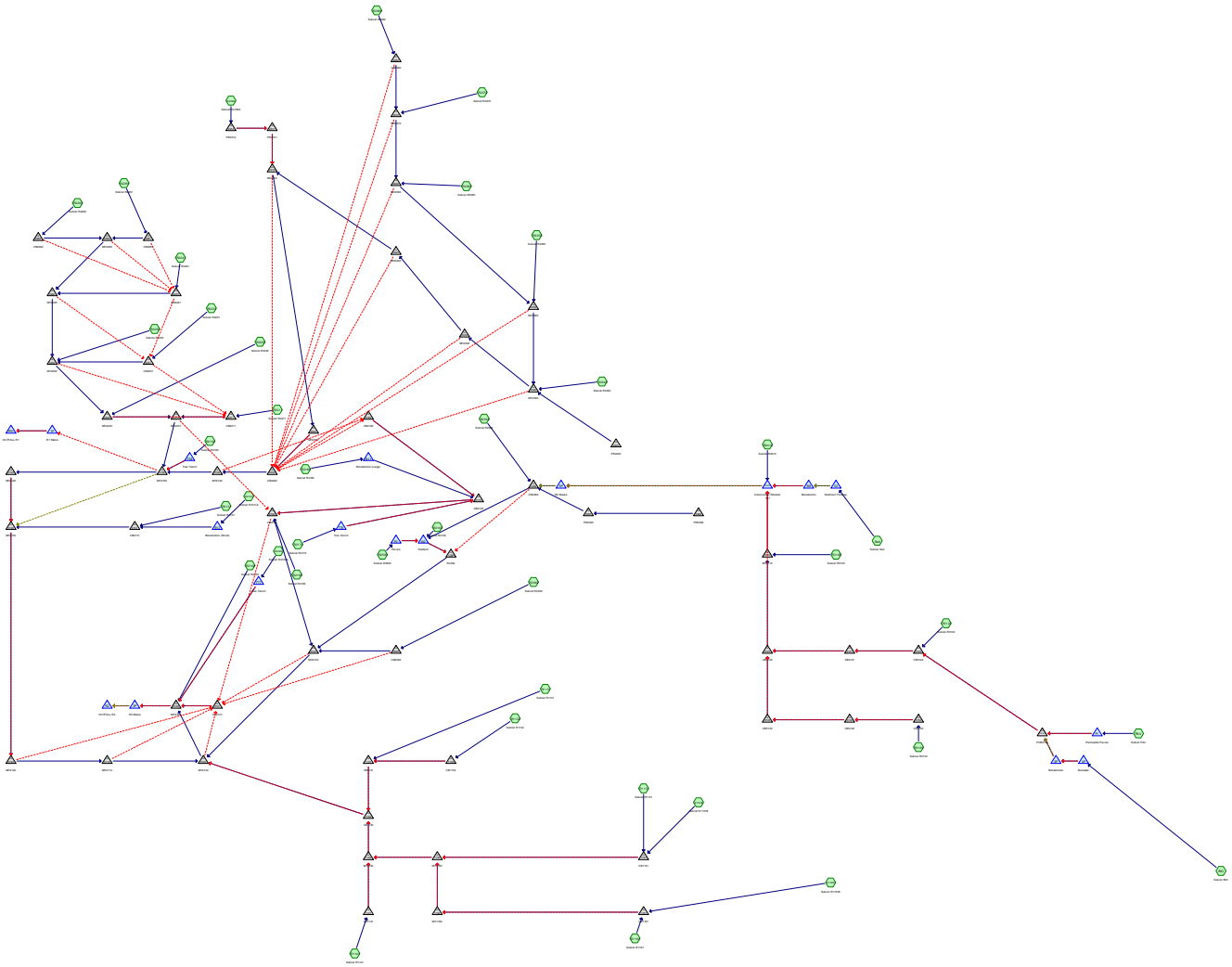
Subcat Reach Pond Link

Routing Diagram for Catchment R Proposed Pilot Projects
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ATTACHMENT D: PRE-FIRE REPORT

LAHAINA DRAINAGE AND GREEN INFRASTRUCTURE

PRE-FIRE DRAINAGE REVIEW

FINAL

May 29, 2025

Lahaina, Maui, Hawaii

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1.0 INTRODUCTION

The Horsley Witten Group, Inc. (HW) is pleased to provide this report to the United States Environmental Protection Agency (EPA) summarizing our understanding of the drainage conditions of Lahaina, Maui, Hawaii prior to the August 2023 wildfires. We used, as a starting point for this effort, the 2005 Lahaina Town Drainage Master Plan, completed by Belt Collins Hawaii, LLC, and then incorporated information about drainage improvements installed and new developments and significant land use changes that occurred, between 2005 and 2023. This report also identifies projects that had been proposed prior to August 2023, primarily within the 2005 Lahaina Town Drainage Master Plan, but were never installed. Finally, this report includes a summary of drainage improvements and watershed restoration projects that have been proposed following the 2023 fires.

2.0 WATERSHEDS AND STUDY AREA

The Lahaina moku[1] is located on the western slopes of the West Maui mountains on the mokupuni[2] of Maui. The Lahaina moku contains at least 10 ahupua'a[3]. In the 2005 Lahaina Town Drainage Master Plan, the Lahaina watershed was delineated as a 5,250-acre area comprised of 4 subwatersheds: Lahaina (2,140 acres), Lahaina Town (650 acres), Kaua'ula (2,780 acres), and a Southern subwatershed between Kaua'ula stream and Waianukole (330 acres). The Lahaina and Lahaina Town subwatersheds were the main study areas of the 2005 Lahaina Town Drainage Master Plan, as well as small areas that drain into Kahoma and Kaua'ula streams. The area north of Kahoma Stream was not included in the 2005 plan, although it is within the Lahaina municipal boundary per Maui County GIS. The study area of the 2005 Lahaina Town Drainage Master Plan, which serves as the primary study area for this report as well, is shown below in **Figure 1,** along with flood zones and wetland resources

2.1 Subwatersheds and Study Area

The study area can be divided into three main subdrainage areas. A large portion of the area drains directly to ocean outfalls. In addition, some of the study area drains to outfalls that discharge into two main streams, the Kahoma Stream on the north side of Lahaina Town and the Kaua'ula Stream on the southern side of the study area.

On the north side of Lahaina Town, the Kahoma Stream extends from the upper reaches of the West Maui mountains down through Lahaina Town and into the Pacific Ocean. One tributary to the Kahoma Stream, the Kanaha Stream, also comes from the West Maui mountains and joins the Kahoma Stream mauka of the Lahaina Bypass. Kahoma Stream is a vegetated channel until a point just makai of the Lahaina Bypass Road, at which point the stream is straightened and enters a reinforced concrete channel.

[1] Hawaiian word for island land division.
[2] Hawaiian word for island.
[3] Hawaiian word for an island land subdivision, similar in boundaries to a watershed area between mountain ridges.

On the south side of Lahaina, the Kaua'ula Stream extends from the upper reaches of the West Maui mountains down through Lahaina, discharging into the Pacific Ocean at a reinforced concrete channel at the southern end of Lahaina. Most of Kaua'ula stream is vegetated channel except for the reinforced concrete section makai of Honoapi'ilani Highway.

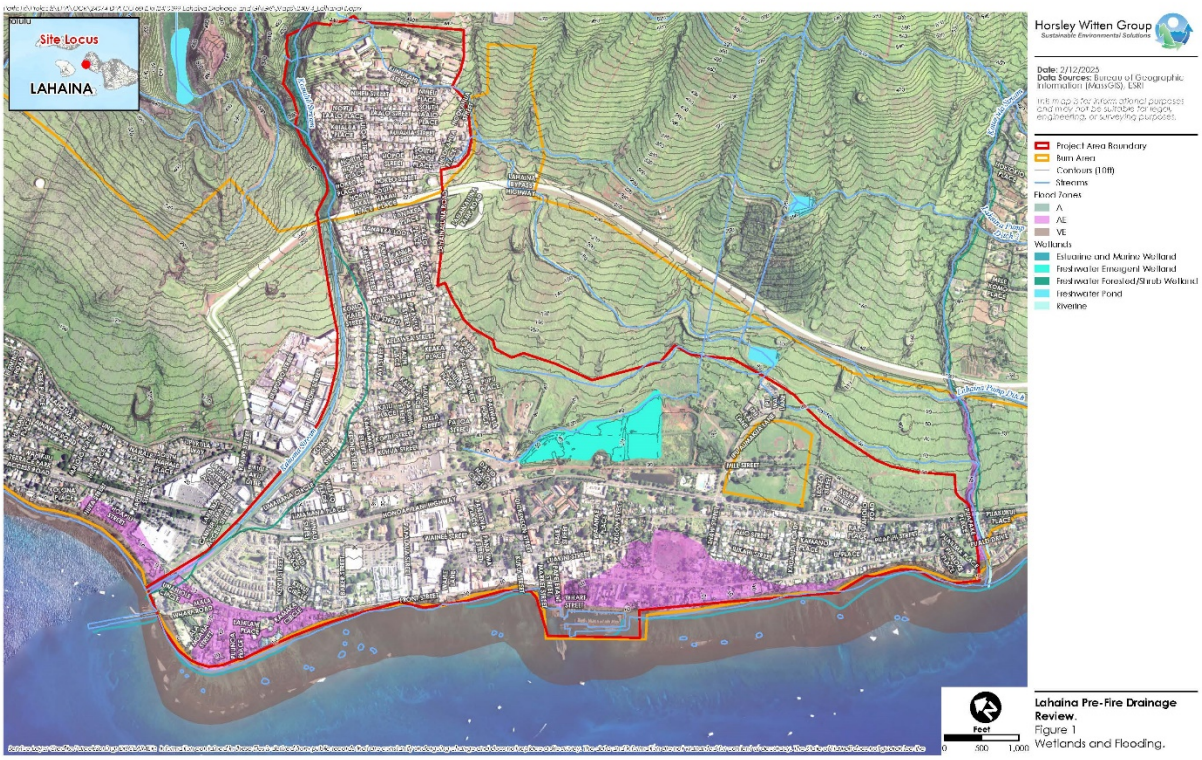


Figure 1. Study Area Boundary, Flood Zones, and Wetlands

2.2 Land Use and Land Cover

The 2005 Lahaina Town Drainage Master Plan addressed an 811-acre study area, and included a breakdown of land uses as follows (based on 2003 land use conditions):

Table 1. Land Uses within the 2005 Lahaina Town Drainage Master Plan Study Area[4]

2005 Land Use	Area (ac)	Comments/Notes
Agricultural	0	Negligible area (0.336)
Single Family Residential	212	
Multi-Family Residential	52	
Hotel	13	
Business/Commercial	53	
Light Industrial	14	
Public/Quasi-Public	80	
Park	106	
Open Space	20	
Roadway	103	
Vacant	258	Includes former mill area and fallow agricultural fields
Unaccounted	*53*	*Discrepancy between 2005 DMP and current DMP*
Total	**864**	

As shown in **Table 1** above, there is a 53-acre discrepancy between the 2005 Master Plan's study area boundary and the area of the current, 2025-delineated boundary. This is mostly attributed to inaccuracies in the 2005 Master Plan's mapping tools since the current delineation of 864 closely matched the outline of the 2005 Master Plan. Minor inconsistencies between the two study areas may come from different delineations along the shoreline and along Kahoma Stream, although these are not expected to account for the full 53-acre discrepancy.

[4] We note that the land use data used in the 2005 Lahaina Town Drainage Master Plan were derived from data that reflected conditions in 2003, and therefore, may have been partially outdated.

Land use mapping for the study area based on 2011 National Oceanographic and Atmospheric Administration (NOAA) C-CAP data is shown below in **Figure 2**. A comparison between C-CAP data from the 2005 Lahaina Town Drainage Master Plan to the most recent 2011 data is broken down as follows:

Table 2. Land Uses within the Study Area (NOAA C-CAP, 2005 & 2011)

Land Use	2005 Area (ac)	2011 Area (ac)
Barren Land	23	26
Cultivated Crops	0.4	3
Developed, High Intensity	349	380
Developed, Open Space	201	182
Evergreen Forest	91	83
Grassland	131	124
Open Water	6	5
Palustrine Emergency Wetland	20	18
Scrub/Shrub	42	40
Unconsolidated Shore	0.5	4
Total	**864**	**864**

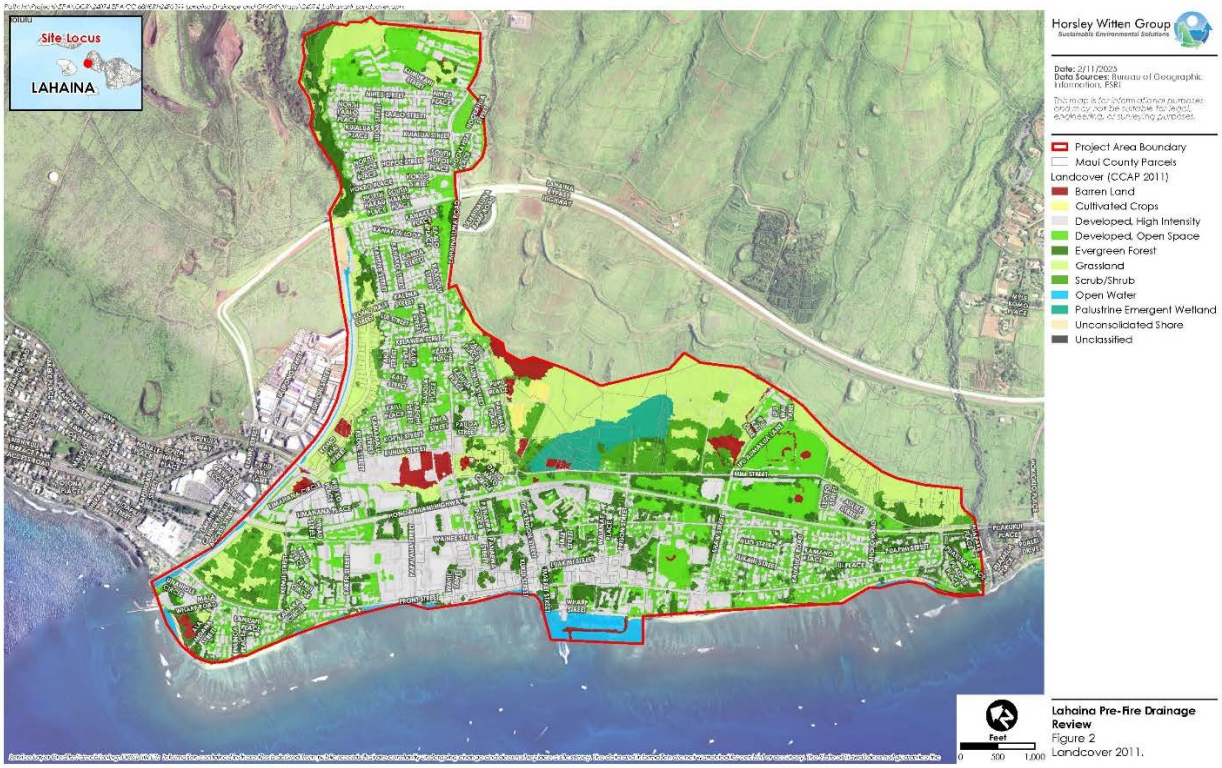


Figure 2. Land Cover (2011)

2.3 Community Resources

Prior to the 2023 wildfires, Lahaina Town had 5 preschools, 4 grade schools, 1 postsecondary school, and 8 affordable rental housing sites, the locations of which are shown below in **Figure 3**.

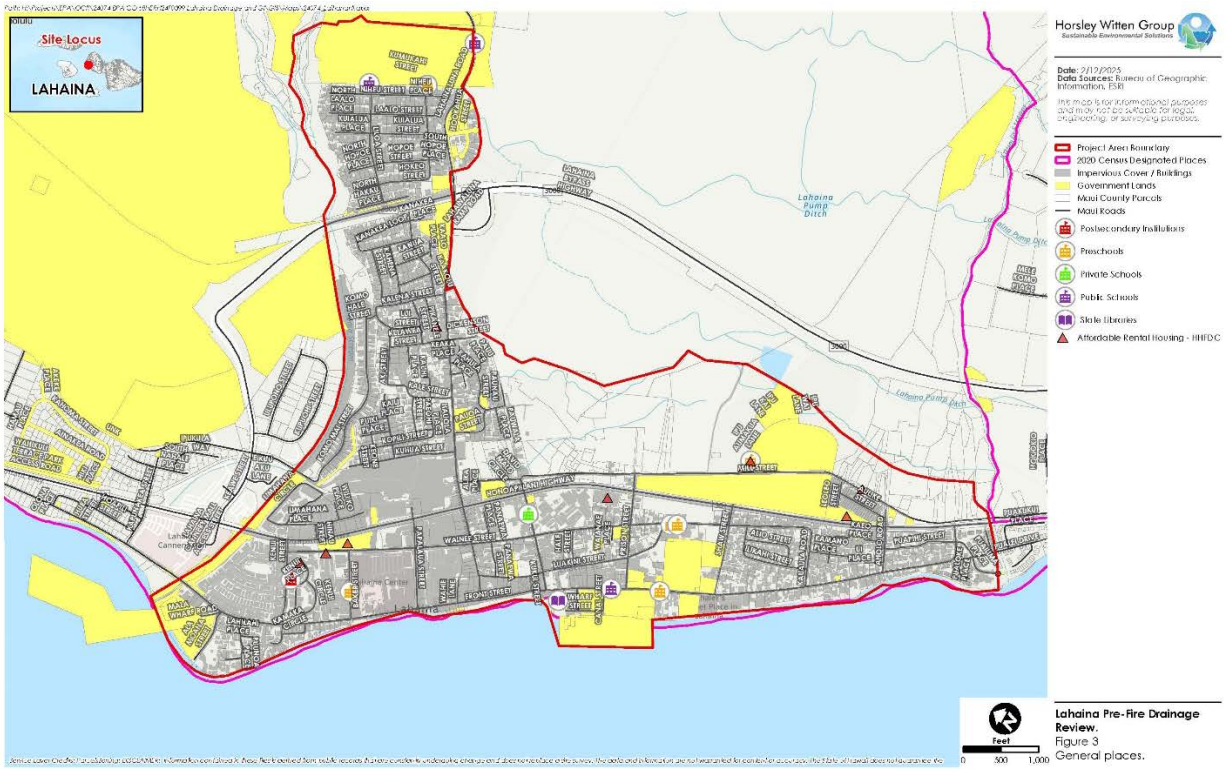


Figure 3. Lahaina Community Resources

2.4 2005 Drainage System

Stormwater drainage infrastructure within the study area is primarily comprised of short, limited-capacity culverts, catch basins, drain manholes, and pipe networks within Lahaina Town that outlet to streams and the ocean (Belt Collins, 2005). Tributary drainage areas were delineated and modeled in StormCAD for contributing drainage areas to 16 distinct outfalls in the 2005 Lahaina Town Drainage Master Plan (**Figures 4 and 5**). Drain Lines L-N discharge to Kahoma Stream, Line S discharges to Kaua'ula Stream, and all other lines discharge to the Pacific Ocean. Hydrologic and hydraulic modeling was conducted in the 2005 Master Plan to characterize runoff and flow conditions for existing drain lines and proposed drainage improvements (see Master Plan Appendix).



Figure 4. Existing Drain Lines and Contributing Areas, sketch derived from the 2005 Master Plan Description and Model

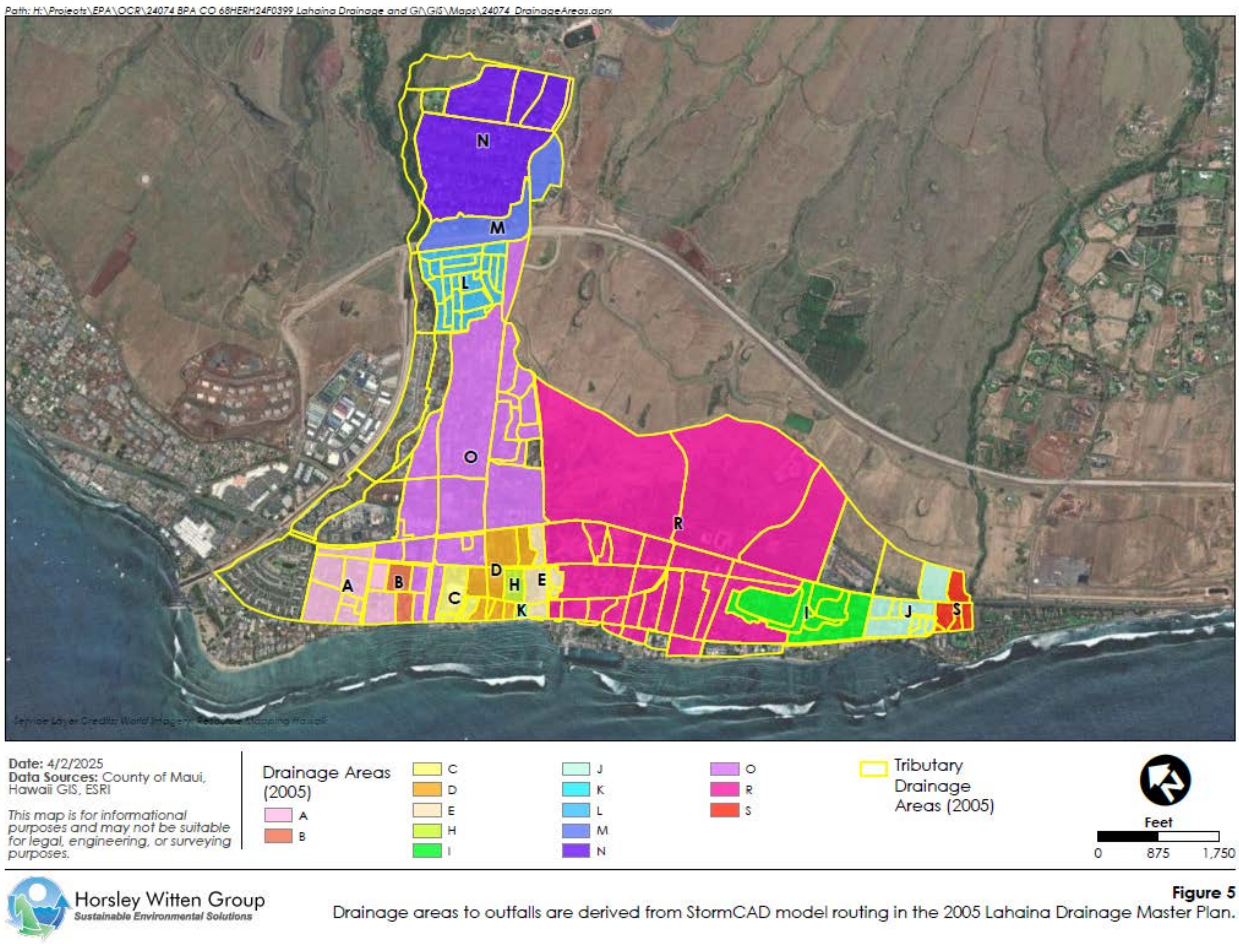


Figure 5. Existing Drainage Areas (by Line) and Contributing Tributary Areas, map derived from the 2005 Master Plan Description and Model

In addition to the drainage infrastructure described above, a temporary flood diversion system was constructed in 1997 on the former Pioneer Sugar Mill property in response to a major flood event. In 2003, the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) formalized that temporary floodway diversion system to capture flow from runoff mauka of Lahaina and direct it to Kaua'ula Stream on the southern side of Lahaina. The diversion system included three basins to store and attenuate runoff. Portions of the system, although not the entire project, were sized to retain the 25-year storm. The diversion channel was maintained by volunteers. A permanent diversion channel, mauka of the current temporary system, has been under construction in stages starting after 2005, and is described in greater detail below.

2.5 Previous Watershed Modeling

The 2005 Lahaina Town Drainage Master Plan utilized StormCAD software to develop a hydrologic and hydraulic (H&H) model of existing and proposed drainage conditions in Lahaina. StormCAD utilizes NRCS TR-55 methodology to estimate peak discharge rates for 100-year, 24-hour storm events. The software uses the Rational Method to estimate peak discharge rates for 10- and 50-year, 24-hour storm events and 1-hour storm events, and to model flow capacity in pipes.

The StormCAD model was comprised of 134 tributary drainage areas, each representing a discrete drainage area to a catch basin or waterbody. The model evaluated existing and proposed drainage conditions at 15 drain lines (A-E, H-K, M-O, R1, R2, and S). Drainage areas less than 100 acres were evaluated using a 50-year precipitation recurrence interval; drainage areas more than 100 acres used a 100-year precipitation recurrence interval.

2.6 Drainage Concerns

Lahaina has experienced at least 26 serious floods since 1879, the largest of which occurred as a result of a 21.7-inch rain event in 1960. In January 2002, a major storm event caused temporary flood control measures at the former Pioneer Sugar Mill property to fail, resulting in significant ponding on Wainee and Prisons Streets (in addition to Front Street and Malu'ulu o Lele Park). Prior to the mill's closure in 1999, cultivation of the mill property reduced the runoff that flowed down to Lahaina Town. Since then, the land has lain fallow, and runoff volumes have increased.

The 2005 Lahaina Town Drainage Master Plan identified drainage problems across the study area. The extent of the existing drainage pipe and ditch systems in Lahaina Town is limited, resulting in ponding of runoff in low spots and surface flow across roadways and through lots. One low spot, Malu'ulu o Lele Park, is the former location of a fishpond and wetland; the natural drainageway in this location has caused frequent flooding of nearby housing structures. A second low spot exists along most of Front Street. Areas of known flooding that were identified in the 2005 Lahaina Town Drainage Master Plan are shown below in **Figure 6**.

Table 3. 2005 Contributing Drainage Areas and Approximate Length of Infrastructure (Source: AutoCAD files from 2005 Lahaina Drainage Master Plan)

Drain Line Name	Contributing Drainage Area (ac)	EXISTING*		PROPOSED**	
		Length (ft)	Length (mi)	Length (ft)	Length (mi)
A	27.0	3,619	0.69	47	0.01
B	5.5	1,686	0.32		
C	7.3	231	0.04		
D	17.4	468	0.09	2,619	0.5
E	9.2	1,299	0.25	824	0.16
H	3.1	65	0.01	17	
I	27.9	2,047	0.39	620	0.12
J	16.1	2,472	0.47	1,107	0.21
K	0.9	459	0.09		
L	25.6	6,080	1.15	1,098	0.21
M	22.0	8,462	1.60	1,538	0.29
N	74.9	10,814	2.05	52	0.01
O	128.0	12,029	2.28	6,890	1.30
R	255.8	12,052	2.28	6,108	1.16
S	7.2	1,280	0.24	167	0.0
TOTAL	**627.9*** **	**63,062.92**	**11.94**	**21,088.39**	**3.99**

* This is approximate as some of the CAD lines (combined red and green) came through with outlines of catch basins as part of the geometries
** does not include infrastructure in new/proposed Drainage Lines from 2005
*** does not include areas outside of modeled existing drain lines (i.e., 60 acres makai of diversion ditch and tributary areas of direct drainage to streams)

Additional drainage problems identified by the Department of Public Works and Environmental Management (DPWEM) within the 2005 Lahaina Town Drainage Master Plan include:

Line A

- Identified by DPWEM as frequently inundated along Front Street.

Line D

- Identified by DPWEM as frequently inundated along Front Street.

Line H

- The property at Tax Map Key (TMK) (2) 4-6-09:59 on Luakini Street floods when the drainage system is backed up due to heavy rain or sedimentation from wave washed sand.
- Identified by DPWEM as frequently inundated along Front Street.

Line I

- Identified by DPWEM as frequently inundated along Kaua'ula Road, Ilikah Street, Alio Street, and Kamano Place.

Line J

- Runoff was entering the driveway of TMK (2) 4-6-003:002 from Front Street. DPWEM built a berm to prevent this from happening.
- The outlet of **Line J** of the drainage system is frequently clogged with wave washed rocks. The culvert is small diameter, limiting maintenance access to the ocean side.

Line K

- Identified by DPWEM as frequently inundated along Front Street.

Line O

- Lahainaluna Road: run-on from Lahainaluna School. Runoff is diverted to Bishop Estate property, which was undeveloped as of 2005. Runoff also flows onto Kahula Place and through private property to the Paunau Street drainage system; onto the Pioneer Mill Office property; and onto Honoapi'ilani Highway during large storms.
- DPW made a grass swale to address flooding on Kelawea Street, directing more runoff onto Lahainaluna Road.

- The hydrodynamic separator at Ka'anapali Development stopped functioning. The separator was originally installed to divert floodwater from the mill yard. Berms were constructed to capture and retain runoff on the mill site.
- Identified by DPWEM as frequently inundated along Front Street.

Line R

- The grated inlet at 505 Front Street is slow to drain, sometimes causing flooding in the underground parking lot located there. The 18-inch outlet from this inlet is buried under beach sand.
- The box culvert and channel along King Kamehameha III School is often clogged with sand at its outlet.
- The sides and bottom of the channel along Malu'ulu-o-Lele Park are deteriorating. Water is frequently stagnant and develops an odor. Many driveways cross the channel.
- Several areas identified by DPWEM as frequently inundated.

Line A/W

- Water ponds at the intersection of Kenui Street and Front Street.

Lines W, A, B, O, C, D, H, K, E, R, I and J

- Frequent clogging of all drain lines that discharge into the ocean.
- Seaweed is frequently trapped in drain lines, creating a rotten smell to occur over time.

Proposed Line U

- Significant beach erosion in the vicinity of Pu'upiha Cemetery. May impact proposed Drain **Line U**.

Public input gathered for the 2005 Lahaina Town Drainage Master Plan identified the following additional drainage problems:

Line R

- The drainage ditch adjacent to Malu'ulu o Lele Park is constantly filled with water. Outlets from the ditch to the ocean are plugged with sand.
- The open area north of the Aquatic Center is often used as a parking area for annual events including "Taste of Lahaina." The area has become compacted, resulting in increased runoff. The retention basin adjacent to the area has become partially filled to provide additional parking space, reducing storage capacity.
- Several areas of severe flooding including Wainee Street near Lahaina Hongwanji Church and the intersection of Shaw Street and Front Street.

Additional drainage problems identified by the Department of Public Works and Environmental Management (DPWEM) staff in February 2025 are presented in **Figure 7**.

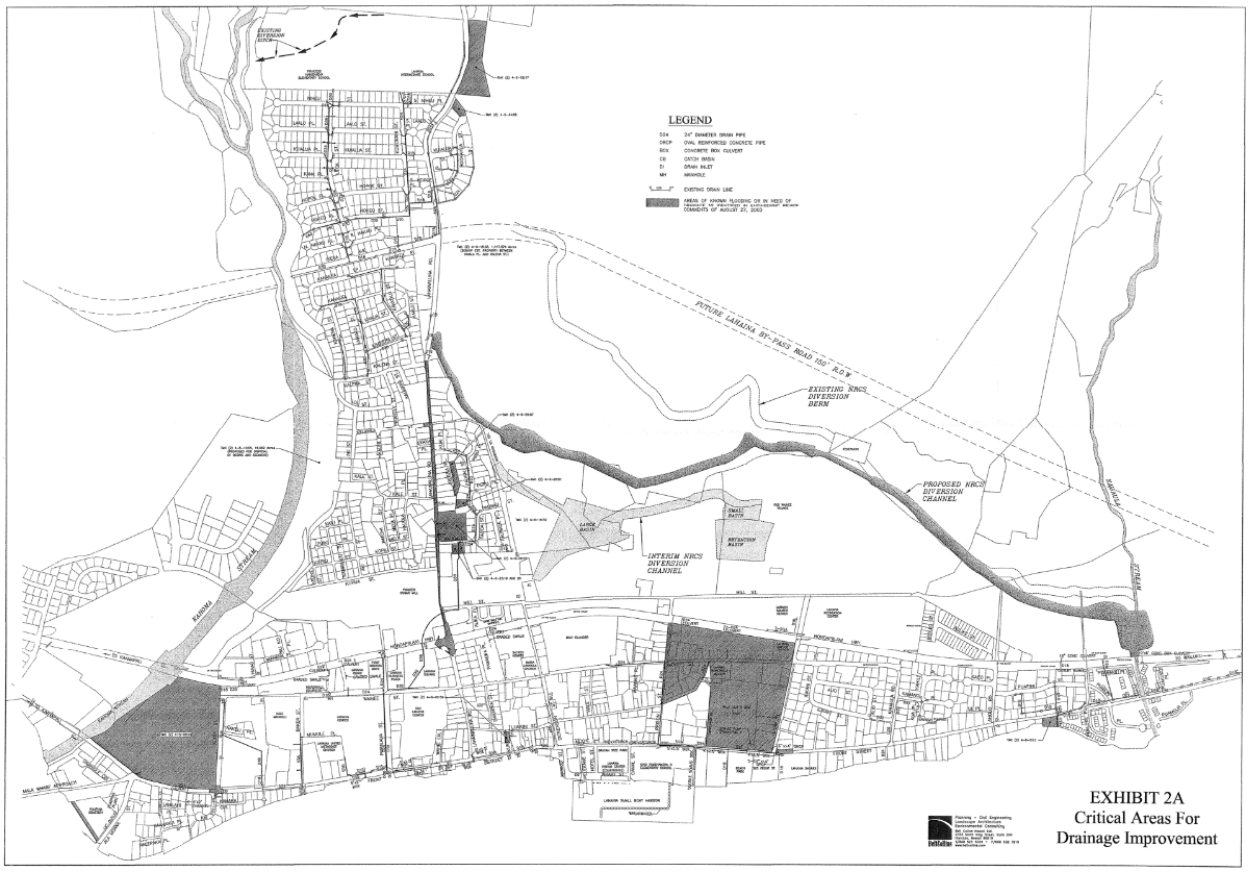


Figure 6. Critical Areas for Drainage Improvement, as presented in the 2005 Master Plan

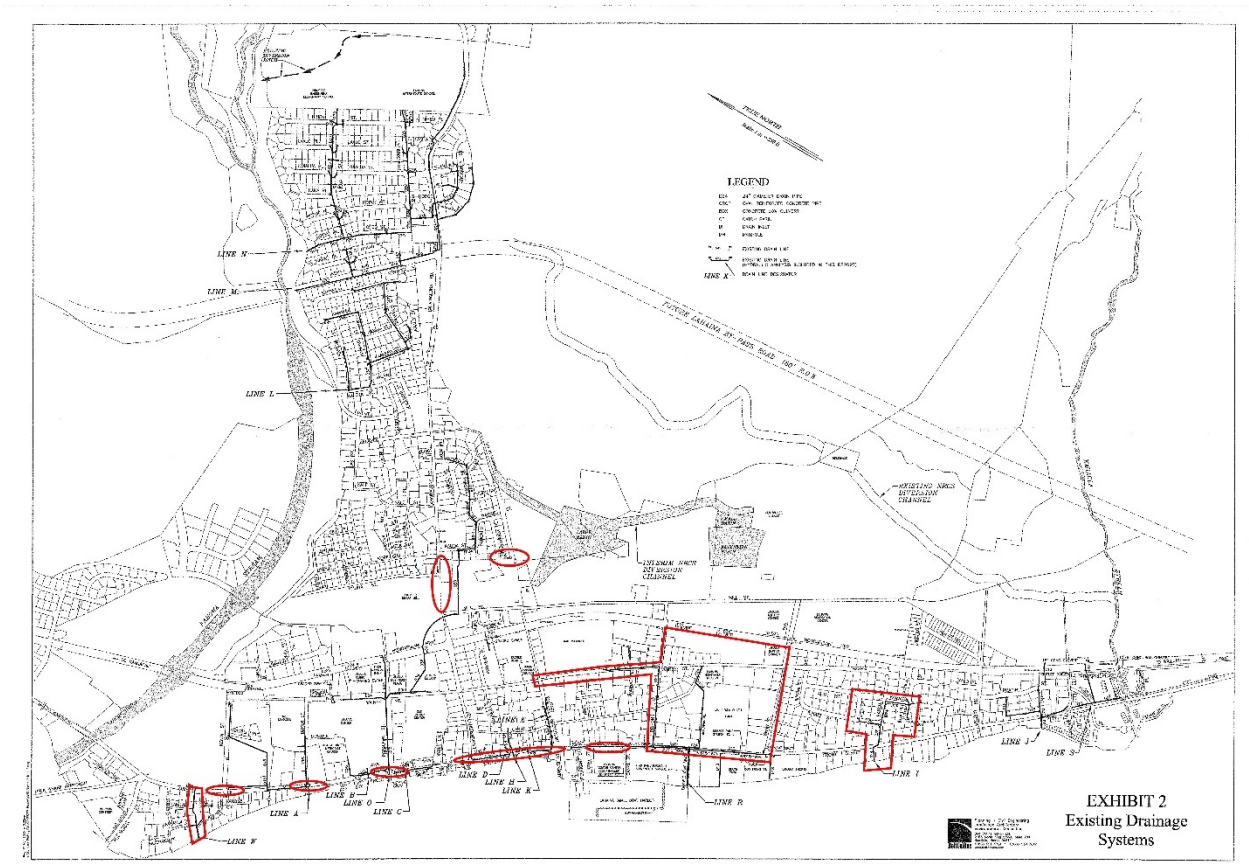


Figure 7. Critical Drainage Problem Areas, identified for discussion in February 2025 by Maui County Stormwater Management Operations and Maintenance staff

2.7 Drainage Improvements and Changes (2005-Present)

We understand from our Maui County and EPA Project Team partners that the specific recommendations presented in the 2005 Lahaina Town Drainage Master Plan have not been implemented. However, the study area has experienced updates associated with development activities, the Lahaina Watershed Flood Control Project, and other improvements pursued outside of those identified in the 2005 Lahaina Town Drainage Master Plan. After review of County provided infrastructure mapping (2024) and drainage design plans from several development projects, HW created a 2025 updated outfall drainage area map to reflect our understanding of the pre-fire drainage infrastructure. **Figure 8** shows the 2024 drainage pipe network, updated drainage areas, and direct drainage areas to streams and ocean. **Table 4** summarizes features of each drainage area, including the land area, percent impervious cover, the extent of 2023 wildfire impacts, and the length of Maui County stormwater pipes.

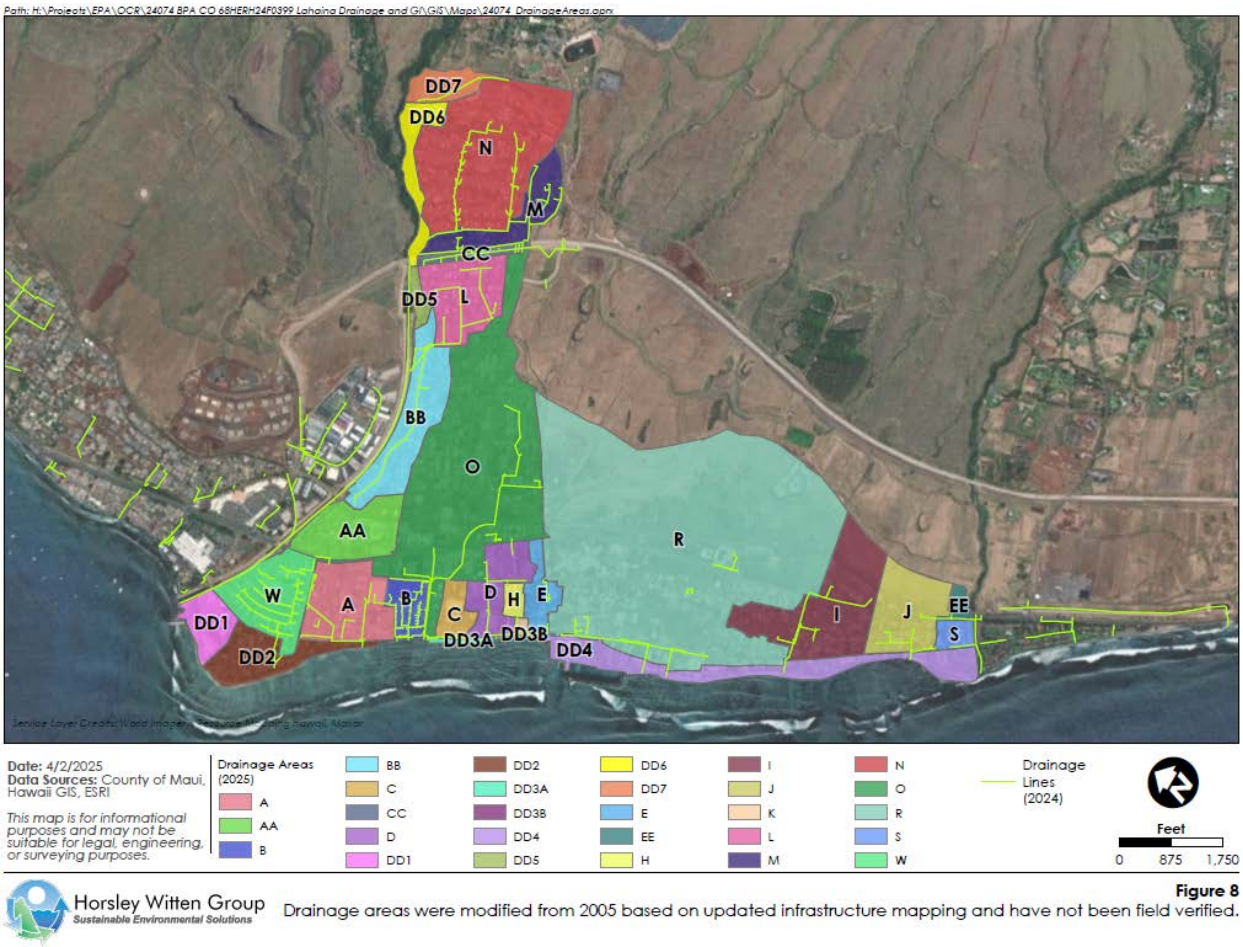


Figure 8. 2025 outfall and direct drainage areas within the project area (approximate, not field verified, includes updated infrastructure lines for bypass and Kahoma developments).

Table 4. 2025 Contributing Drainage Area Statistics

Drainage Area/Line Name	Area	2021 CCAP Impervious Cover		2023 Wildfire Extents		2024 Maui County Pipe Length + HW added*	
	acres	acres	%	acres	%	feet	miles
A	28.2	17.2	61	28.2	100	4,186	0.79
AA	24.2	19.1	79	24.2	100	250	0.05
B	9.4	8.5	90	9.4	100	4,918	0.93
BB	31.8	17.9	56	31.7	100	3,917	0.74
C	7.8	7.2	92	7.8	100	673	0.13
CC	4.5	2.6	58	0	0	2,174	00.41
D	17.9	13.2	74	17.9	100	2,358	0.45
DD1	11.3	4.1	36	10.8	95	0	0
DD2	19.9	8.9	45	19.2	96	623	0.12
DD3A	1.8	1.0	59	1.3	76	254	0.05
DD3B	0.1	0.1	86	0.1	100	91	0.02
DD4	34.0	13.7	40	30.1	89	837	0.16
DD5	3.4	0.0	1	0.8	24	0	0
DD6	12.2	0.3	3	0	0	117	0.02
DD7	9.9	0.3	3	0	0	1,317	0.25
E	9.4	6.6	70	9.4	100	793	0.15
EE	2.9	0.3	12	2.9	100	578	0.11
H	3.1	1.5	48	3.1	100	56	0.01
I	45.6	23.6	52	45.6	100	3,044	0.58
J	25.3	7.5	30	25.4	100	1,749	0.33
K	0.9	0.9	95	0.9	100	327	0.06
L	25.8	17.7	68	10.3	40	3,819	0.72
M	19.4	11.2	58	0.1	0	5,504	1.04
N	74.9	43.8	58	0	0	5,746	1.09
O	126.5	82.7	65	121.8	96	7,432	1.41
R	260.3	65.7	25	260.5	100	5,436	1.03
S	4.8	2.2	46	4.8	100	345	0.07
W	27.1	18.4	68	27.1	100	6,510	1.23
TOTAL	**842.3**	**396.1**	**47%**	**693.3**	**82%**	**63,056**	**11.94**

*HW updated the 2024 county infrastructure layer by adding digitized (approx.) stormwater drain lines for the bypass and two Kahoma residential developments.

2.7.1 Lahaina Watershed Flood Control Project

Since 2009, construction has been underway for the proposed Lahaina Watershed Flood Control Project, the permanent flood diversion system developed by NRCS. The Lahaina Watershed Flood Control Project has been identified by the West Maui Soil & Water Conservation District (WMSWCD) as the highest priority project in the watershed. Construction has not progressed significantly since 2014, due to a combination of funding hurdles and permit reapproval requirements over the project's extended timeline.

The project was broken into 5 phases. Phases 1 through 3A have been constructed, along with a debris basin included in Phase 3B, while the remainder of Phase 3B as well as Phases 4 and 5 were stalled due to a pause in funding. NRCS reinitiated the implementation planning process for these later phases just prior to the 2023 Wildfire, and field surveys are underway as of February 2025. The current project timeline estimates completion by the end of 2026. The Phases are described as follows:

- Phase 1, a sediment basin and diversion channel along a portion of the Honoapi'ilani Highway (south of Kaua'ula Stream), was completed in 2011
- Phase 2B, an extension of the diversion channel north toward Kaua'ula Stream, was completed in 2013
- Phase 3A, completion of the southern portion of the diversion channel all the way to Kaua'ula Stream, was completed in 2014
- Phase 3B, a debris basin along Kaua'ula Steam mauka of Honoapi'ilani Highway, has been designed but not yet constructed. After the installation of Phase 3A, project funding paused, and community input has led to an ongoing redesign of Phase 3B
- Phases 4 & 5, installation of the diversion channel north of Kaua'ula Stream along with installation of several sediment basins and channel reinforcement, has not been fully constructed. Aerial imagery suggests that portions of the channel have been excavated.

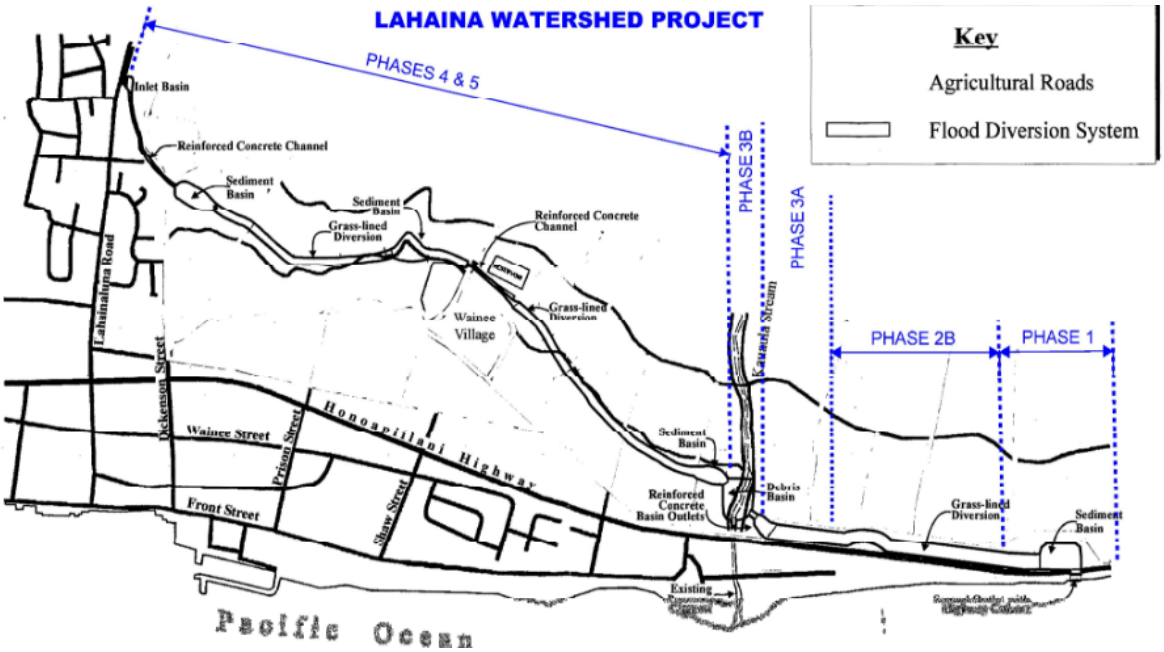


Figure 9. NRCS Lahaina Watershed Project Phasing

2.7.2 Development and Land Use Changes

In addition to the ongoing Lahaina Watershed Project, development in the watershed since 2005 has changed watershed patterns. Examples include:

- Installation of the Lahaina Bypass road changed drainage patterns significantly and included the construction of two stormwater basins: one at the intersection with Lahainaluna Rd. and another 1.6 miles further south (see Line M modification and new Line CC).
- Construction of a solar farm mauka of the Lahaina Bypass Highway, south of Lahainaluna Mission Cemetery. This development is outside of the drainage master plan study area but contributes runoff to the Lahaina Watershed Project.
- **Line N**: Line N was extended mauka to include drainage from Princess Nahienaena Elementary School and Lahaina Intermediate School
- **Line O**: Industrial development at the Pioneer Sugar Mill property.
- **New Drain Line AA**: condos and existing commercial area discharge to the stream.
- **New Drain Line BB**: The Kahoma Residential Subdivision was constructed along Kahoma Stream mauka of Front Street, converting a vacant parcel into a 70-lot subdivision. The drainage on the site shifted from overland flow into Kahoma Stream to a closed drainage system that discharges to a stormwater basin. Overflow from the basin flows to Kahoma Stream.
- **Line J**: high density residential area added to Line J.
- **Line S:** Drainage area revised to send upper portion directly to stream.
- **Drain Line W**: The Kahoma Village Residential Development was constructed along Kahoma Stream mauka of Front Street, converting a vacant parcel used for processing cane stalk waste to a village of apartment buildings and several access roadways. The drainage on the site drains to Line W, after flowing through an aboveground detention basin or a set of seven underground infiltration basins.

3.0 PREVIOUS RECOMMENDATIONS

In addition to ongoing project work identified above, multiple drainage and restoration projects have been recommended over the past 2 decades but not implemented. These recommendations came from the 2005 Lahaina Town Drainage Master Plan, the West Maui Community Plan, and other sources.

Drain line improvements recommended in the 2005 Lahaina Town Drainage Master Plan, but never implemented, are presented in **Figure 10** and described here: **Line A** - Replace the 36" **Line A** with a 42" line and a 7'x3' box structure. Raise Front Street at Kenui Street to eliminate flooding at low point. Crown the road, create concrete gutters, and add an additional inlet.

- **Line D** - Extend existing box structure of **Line D** up Lahainaluna Road to Wainee Street in order to intercept flow from the existing 24" highway culvert near Panaewa Place. Install additional inlets to capture roadway runoff. Install curb and gutter on both sides of Lahainaluna Road.
- **Line E** - Extend **Line E** up to the intersection of Wainee and Dickenson Streets to provide drainage to Wainee Street. Increase the existing Line E pipes from 30" to 36" and install a section of 4'x2' concrete box culvert.
- **Line I** - Enlarge **Line I** to 42 inches to the intersection of Kaua'ula Road and Ilikahi Street. Enlarge the Kaua'ula Road branch to 30" and the Ilikahi branch to 36".

- **Line J** - Intercept highway culvert drainage north of Front Street and convey it through Front Street in the **Line J** network. Provide an additional inlet south of the driveway of TMK (2) 4-6-003:02.
- **Line L** - Enlarge **Line L** from 30" to 36" from the outlet on Kalena Street up along Kalena and Kaakepa Streets. Replace CMP with RCP to make conveyance more efficient.
- **Line M** - Replace 24" CMP pipes of **Line M** with 36" CMP pipes in Ikena Avenue and a 5'x2' concrete box culvert at the intersection of Ikena Avenue and Lahainaluna Road. Install curb, gutter, and additional inlets along Lahainaluna Road from Kuialua Street to the Lahainaluna Intermediate School.
- **Line N** - Replace the 24" pipes of **Line N** with 36" pipes along Kumukahi and Hokeo Streets.
- **Line O** - Replace the double pipe reach of **Line O** with a 6'x4' box culvert along Papalaua Street. Install a 24" pipe to intercept flow from two highway culverts north of Papalaua Street.
- **Line R** - Install lateral lines into **Line R1** on Wainee and Luakini Streets. Install an additional 36" line along Wainee Street to Shaw Street that connects to **Line R2**. Replace the unlined channel along Malu'ulu o Lele Park with a 10' concrete box culvert. Installation of mauka retention basins (e.g., at the Pioneer Mill property) could alleviate the need to upsize **Line R**.
- **Line R** - Install a new curb inlet at the driveway to **505 Front Street**. Expose the existing outlet and construct a headwall, manhole, and flapgate.
- **Line U** – As of 2005, **Line U** did not exist. This line corresponds to the area north of Kenui Street and east of Front Street and drains toward Kahoma Stream through an 18" culvert.
- **Line U** - Replace the 18" culvert with a 24" pipe. Install a 48" drain line in Ala Moana Street. Install an inlet at the adjacent vacant property to tie future developments into the drain line.
- **Line V** – As of 2005, **Line V** did not exist. Two drain inlets have been installed at the intersection of Aholo Road and Front Street. These structures outlet directly to the ocean.
- **Line V** - Install a pipe network within Aholo Road, extending from Honoapi'ilani Highway to the ocean. Upsize the outlet pipes to 30".

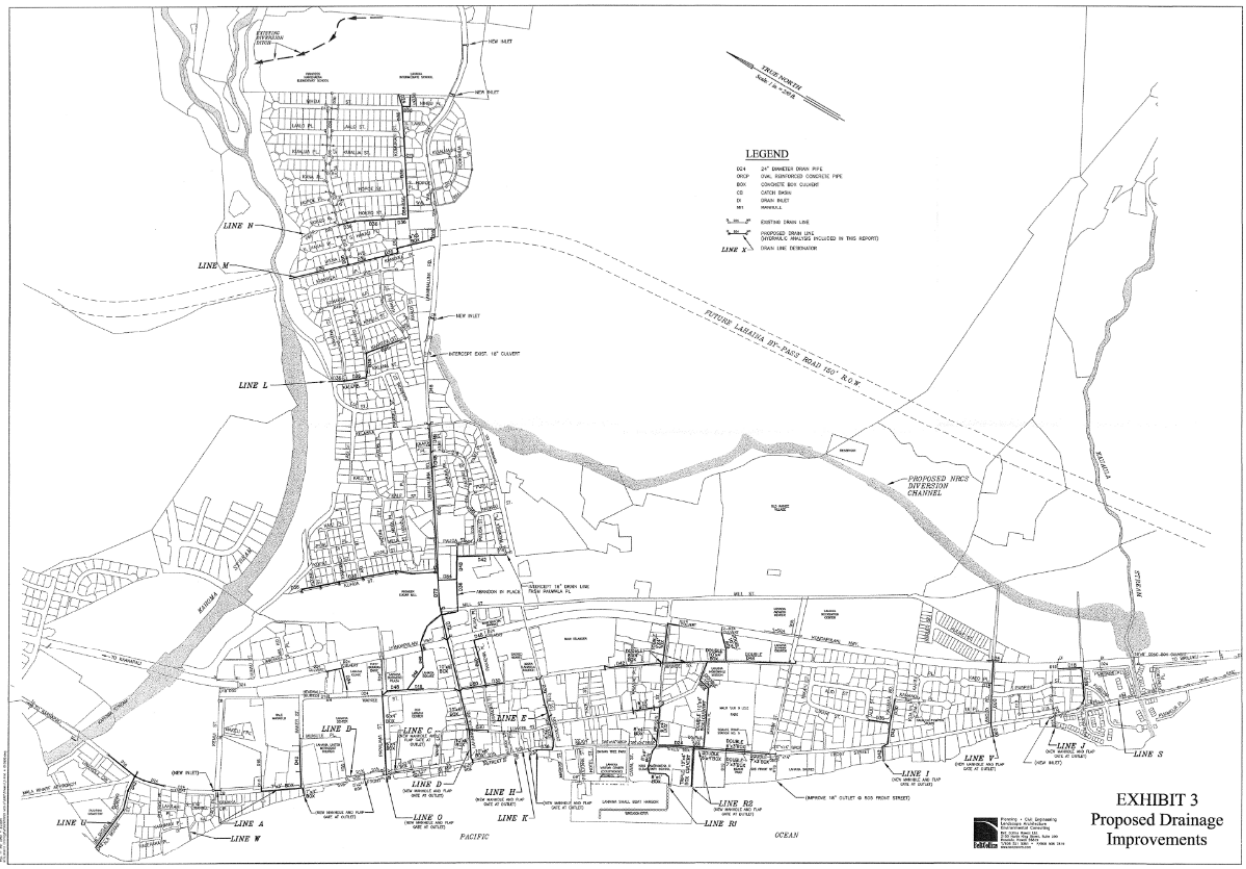


Figure 10. Proposed Drain Line Improvements per 2005 Master Plan

Drainage infrastructure improvements recommended or pursued since 2005, but not implemented, include the following:

- **Line R** - The Army Corps of Engineers developed a plan in 2012 for ecosystem restoration at **Mokuhinia/Moku'ulu o Lele Park**. The park was originally an island that served as the home of King Kamehameha III and also housed a burial ground for the royal family. The fishpond and wetland surrounding the island supported taro cultivation. The project was supported by a local group, the Friends of Moku'ula, from the early 1990s until 2017, although the Friends group dissolved in 2017. Community support for restoring the site was revived in January 2023, when Nā Aikāne o Maui held a cleanup that raised awareness of the site's history.
- DPWEM has proposed a **debris and sediment disposal site** in the vicinity of TMK (2) 4-5-010, adjacent to Kahoma Stream. The parcel originally identified in this recommendation may have been developed or subdivided since 2005, and is now being used as mostly industrial space. The next closest disposal site is the Central Maui landfill. Access from the Ka'anapali side of the stream to the Olowalu side of the stream would be required, possibly using the existing cane haul road.
- Install **flap gates/check valves** at ocean outlets and **install new manholes** to improve vacuum/vactor truck access.
- At larger box culvert outlets, **extend outlet wing walls** to reduce sediment build. Consider constructing a "sand-plug-breaking" system in which natural flow through a perforated pipe breaks up accumulated sand berms.

- **Line O**: The DPW proposed improvements to **Kuhua Street** and construction of a new roadway to extend Kuhua Street south of Lahainaluna Road. The project also proposed to extend five cross-streets from Honoapi'ilani Highway mauka: Papalaua Street, Lahainaluna Road, Dickenson Street, Shaw Street, and Aholo Street. A Final Environmental Assessment/Finding of No Significant Impact was published in 2015, but the project has been on indefinite hold.

In addition, we note the following recommendations from the 2024 West Maui Community Plan, which are relevant to stormwater and drainage management in the study area. We are not clear as to which, if any, of these recommendations have been pursued or implemented to date.

- Conduct a detailed vulnerability assessment of County infrastructure and facilities in West Maui that are within the state-recognized sea level rise exposure area (SLR-XA).
- Prepare and implement an acquisition strategy for parks in West Maui, considering potential sea level rise and climate change.
- Integrate the SLR-XA into capital improvement planning for all County departments and public facilities.
- Develop an inventory of natural and cultural resources and practices impacted by sea level rise, along with preservation plans.
- Conduct sea level rise exposure modeling incorporating local data to use in vulnerability assessments of critical infrastructure and facilities in the event of 6 feet or more of sea level rise.
- Develop basal groundwater sources in West Maui to serve planned population growth and offset decreased surface water diversions.
- Update the Lahaina Town Drainage Master Plan with consideration given to Low Impact Development solutions and develop an implementation plan.
- Support the implementation of flood control projects and siltation basins mauka of Honoapi'ilani Highway, including the remaining phases of the Lahaina Watershed Project, to address problem areas.
- Maintain a current inventory of drainage facilities in West Maui for use in developing long-term plans to address stormwater issues.
- Prioritize regular maintenance and clearing of sediment basins in West Maui.
- Implement the County's Storm Water Management Plan in West Maui with consideration of Low Impact Development objectives.
- Educate public on existing policies related to maintenance of drainage ways.
- Create open space in areas sensitive to flooding and around native forests as a protective buffer both for forest and development.
- Propose amendments to the Maui County Code to require permeable surfaces or other Low Impact Development standards to be used in new or redeveloped parking lots and streets, to mitigate runoff and help with groundwater recharge.
- Develop guidelines and incentives for landowners to retain stormwater runoff and include more permeable surfaces on their property.
- Obtain funding and install ahupua'a signs throughout West Maui.

4.0 DESIGN GUIDELINES

The following documents have been identified as relevant design guidelines for stormwater infrastructure in Lahaina:

- **Department of Public Works Maui County: Rules for the Design of Storm Drainage Facilities in the County of Maui (1995):** The document includes rules and regulations for stormwater design in Maui County. Guidance for hydrology calculations and design standards for closed drainage systems, bridges, culverts, and channels is provided.
- **Department of Public Works Maui County: Rules for the Design of Stormwater Treatment Best Management Practices (2012)**: This document includes the most recent rules and regulations for stormwater design in Maui County. Guidance of sizing stormwater quality facilities and examples of these facilities are included in the document. The design volume specified for treatment is based on 1 inch of runoff.
- **Hawaii Department of Transportation: Stormwater Post-Construction Best Management Practices Manual (2022)**: This document includes additional guidance on stormwater facility sizing. It also provides detailed design guidance on several types of stormwater facilities. The stormwater facilities identified can be considered green stormwater infrastructure.

5.0 ONGOING FIRE RECOVERY PROJECTS

Following the August 2023 wildfires, a number of drainage projects were identified by the Long-Term Recovery Plan, including:

- **Infrastructure and Drainage Improvement Studies**: a short-term (1-2 years) project to analyze the condition of existing infrastructure and identify needed improvements, including roadways and drainage
- **Stormwater Resilience and Flood Risk Management**: a mid-term (3-5 years) project to implement holistic stormwater and flood management, minimize stormwater runoff to the ocean, and manage floodwater across West Maui
- **Wai and Watershed Planning**: a mid-term project to plan for mauka to makai holistic restoration efforts. The project will include efforts to revitalize environmental and human health, reduce fire and hazard risks, increase aquifer recharge, restore native habitat, and maintain coral reef health. This project may also include restoration projects such as reforestation with native plants, reduction of invasive grasses, restoration of stream flow, establishment of agroforestry and agriculture, flood control, and erosion control. The community has also expressed interest in development and implementation of a community-led water plan, with a focus on community governance over water in West Maui.
- **Creation of a Cultural Corridor and Restoration of the Moku'ula and Loko o Mokuhinia Complex**: a long-term (6+ years) project to restore the 17-acre pond at Loko o Mokuhinia. Also discussed above.
- **Revegetating and Reforesting Lahaina and Kula**: a long-term project to revegetate the watershed with fire-resilient native plants and canoe plants to reduce fire risk and erosion. In much of Lahaina, the invasive buffelgrass has regrown in the fire impact zone, which also increases fire and wind risk for the town.

6.0 REFERENCES

Belt Collins Hawaii Ltd. March 2005. Final Lahaina Town Drainage Master Plan. DPWEM, County of Maui.

County of Maui Office of Recovery. December 2024.Lahaina Long Term Recovery Plan.

Dingeman, R., 2023. Restoring Moku'ula, Maui's Sacred Island. Honolulu Magazine.

Haley Aldrich. October 2023. Geoviewer - Lahaina Emergency Response. (https://cegis.caleng.com/projects/0209312/GeoViewer.html)

Hawaii Department of Transportation Highways Division. 2009. Plans for Honoapiilani Highway Realignment.

Maui County Department of Planning. 2022. West Maui Community Plan. January.

Maui County Soil and Water Conservation District. XXXX. Lahaina Watershed Flood Control Project. United States Department of Agriculture, Soil Conservation Service

Maui County Department of Public Works. 2019. West Maui Community Plan Meeting, Ready and Resilient Systems. August 20.

Maui County Department of Public Works. 2022. Engineering Division, Lahaina Watershed Flood Protection Project: Preliminary Project Overview.

Natural Resource Conservation Service. 2023. Lahaina Watershed Control Project.

Natural Resource Conservation Service. 2015. Lahaina Watershed Project Update.

Natural Resources and Conservation Service. 2019. Lahaina Watershed Reaffirming Feasibility Report.

Rules for the Design of Storm Water Treatment Best Management Practices. 2012. DPW, County of Maui, November 25.

Sawdey, S. 2025. NRCS Lahaina Watershed Discussion with Horsley Witten Group, Maui County staff.

SSFM International, Inc. 2016. Drainage Report for Mass Grading Permit and Civil Site Improvements: SCD Weinberg Kahoma Villages Drainage Study.

SSFM International, Inc. 2015. Kahoma Village. Stanford Carr Development Corp.

Lahaina News Staff. 2019. Staff District Stewards Want to See the Lahaina Watershed Flood Control Project Completed. Lahaina News, August 22, 2019. Accessed April 22, 2024.

Storm Water Post-Construction Best Management Practices Manual. 2022. Hawaii Department of Transportation, Highways Division, February.

Warren S. Unemori Engineering, Inc. 2013. Kahoma Residential Subdivision.

ATTACHMENT E: FIELD ASSESSMENT REPORT

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

MEMORANDUM

To: Kate Rao, Sarah Pedroza, Hudson Slay (EPA)

From: Ellie Baker, Michelle West, Jonas Procton, Sydney Stanton (HW)

Date: June 17, 2025

Re: Lahaina Drainage Master Plan & Green Infrastructure – Field Findings

cc: Kristi Ono (Maui County DPW)

Purpose

This memorandum summarizes data collection and key findings from our field investigation of the Lahaina Town Drainage Master Plan Study Area conducted by HW with support from County of Maui Department of Public Works (DPW), U.S. Environmental Protection Agency (EPA), and others on May 16 – 21, 2025. The purpose of the assessment was to map drainage infrastructure, identify problem areas (pollution sources, flooding, damage, etc.), and identify potential pilot project opportunities and other recommendations to advance green stormwater infrastructure (GSI) implementation as Lahaina rebuilds from the devastating 2023 fires. During this effort, the field team:

- Visited DPW's Priority Flooding Areas
- Mapped and added to over 20 drainage structures
- Filled in data gaps for the Hydrologic Model
- Learned about adjacent and related projects in the study area (e.g., Lahaina Watershed Flood Control Project)
- Volunteered with Maui Cultural Lands to see upper watershed and better understand cultural connections with water, land, and community
- Met with Maui County Development Administration Services (Permitting), Office of Recovery, and DPW
- Visited the Lahainaluna High School grounds at the top of the study area
- Identified pilot GSI projects in each focus drainage area

We have included the following attachments for more details.

Attachment A: Itinerary

Attachment B: Notes from field visits and meetings

Attachment C: Draft Site Concepts

Attachment D: Meeting Slides

Field Assessment

The HW Field Team explored the Lahaina Study Area with Maui County DPW and EPA staff on Friday, May 16 to get an overview of the area and to visit DPW's identified priority problem areas (**Photo 1**). DPW and EPA staff provided a great deal of institutional knowledge and background on a number of issues discussed in the field. HW also explored additional areas on our own (Monday and Tuesday, May 19 and 20).

This time on the ground in Lahaina was invaluable to this project (**Photos 2-4**). HW was able to see firsthand the impacts from the fire to land cover and infrastructure and could fill in pre-identified data gaps in mapping as well as the hydrologic model (see **Photo 5** for a screenshot of our field map). In addition, HW visited residential and commercial areas that were not burned to get a good sense of development patterns in the area. During the field assessments, we also observed additional drainage problems that we had not expected as well as GSI opportunities in a variety of public spaces.

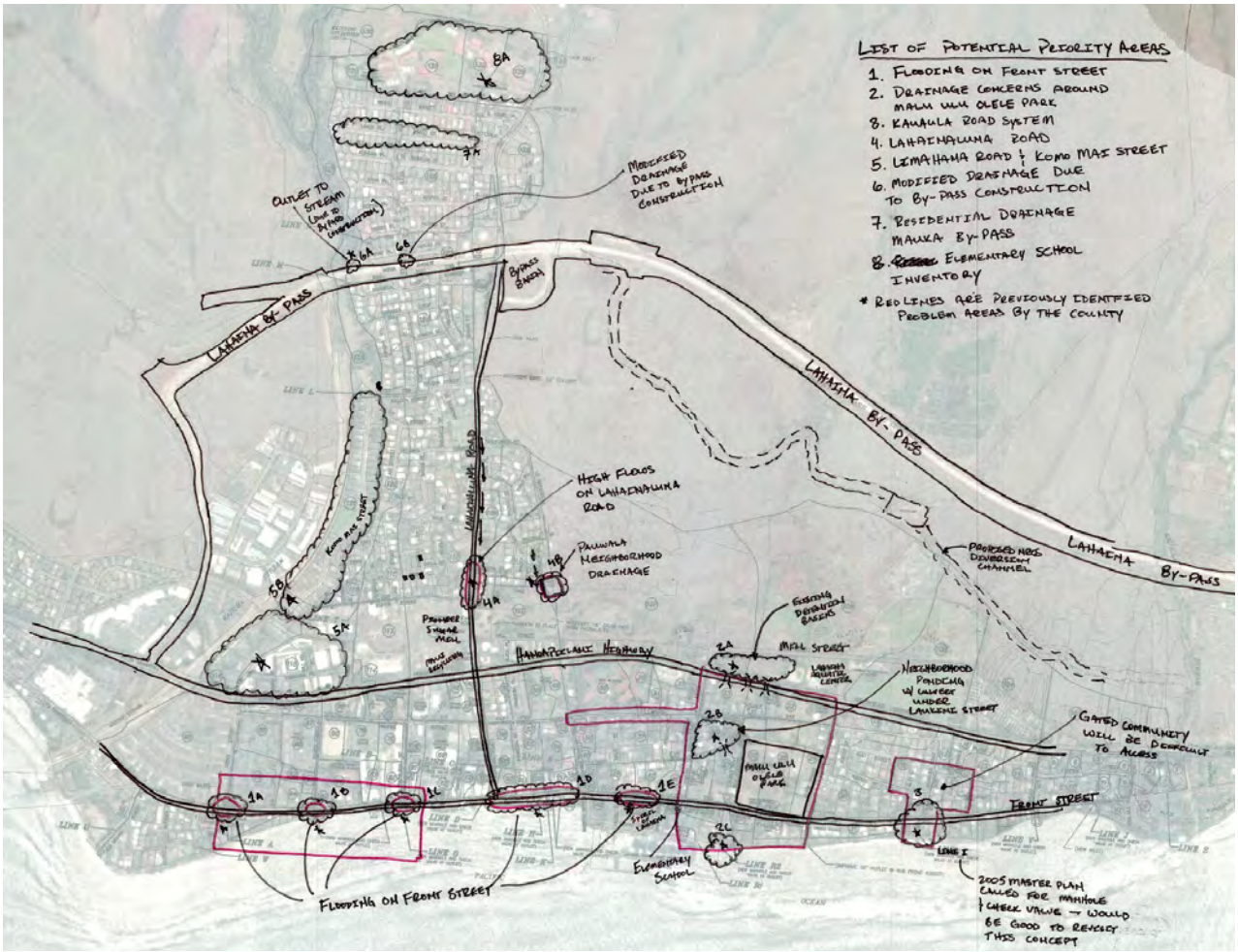


Photo 1. Sketch of DPW's priority areas where they experience frequent flooding issues.




Photo 2. HW staff collecting spatial data at priority sites along Front Street.




Photo 3. Looking at areas in Lahaina where drainage infrastructure is undersized (LEFT) or missing altogether (RIGHT)




Photo 4. DPW popping manhole covers for the field team (LEFT); HW, EPA, and DPW discussing a priority problem area.

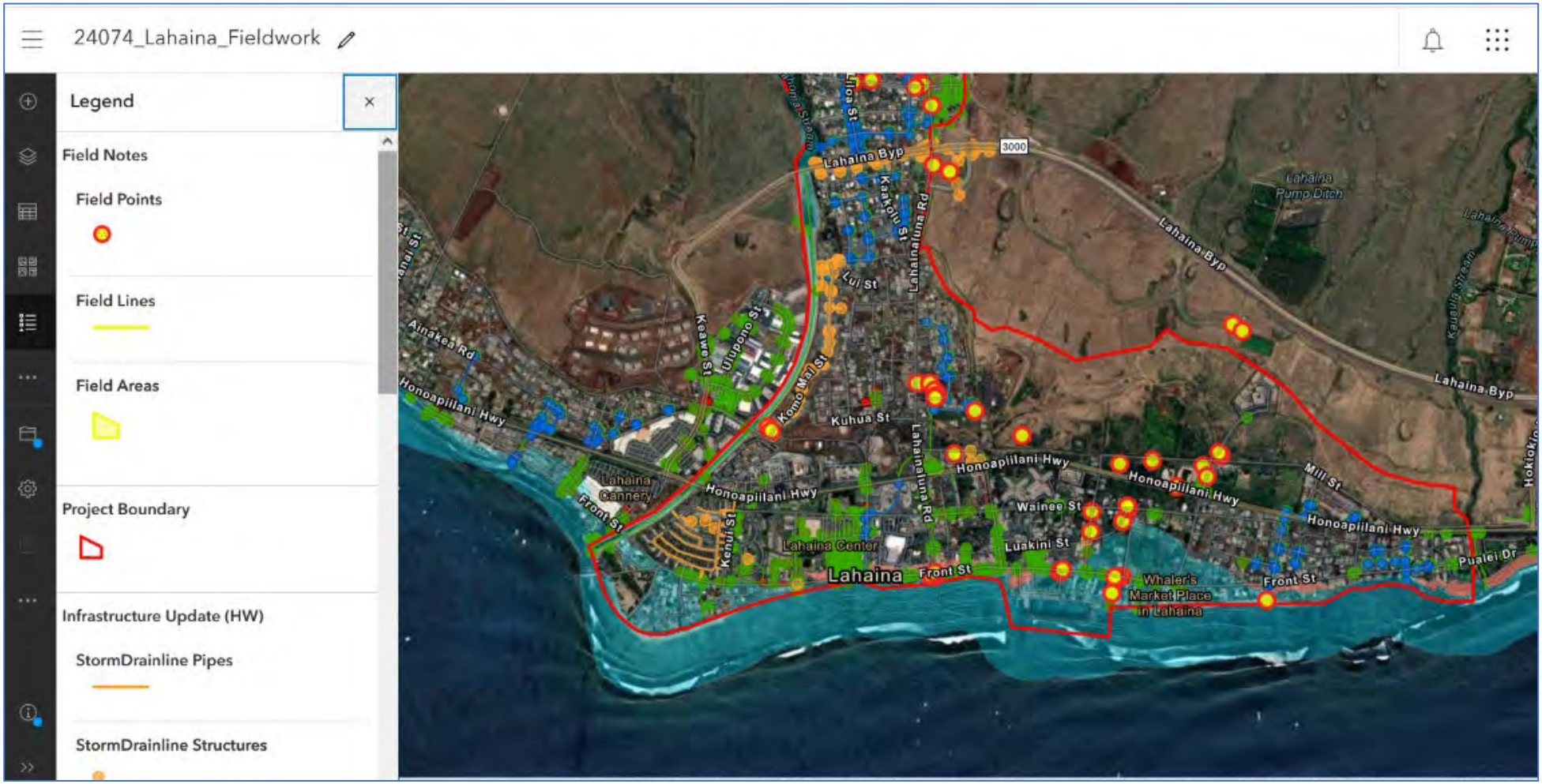


Photo 5. Screen capture of our online map used for data collection in the field.

Meetings

The HW Field Team was able to participate in a number of meetings while on Maui (see our itinerary in **Attachment A** and notes in **Attachment B**). The first was a meeting on Friday, May 16, with the West Maui Soil Conservation District to learn more about the temporary and future Lahaina Watershed flood control project. Then, on Saturday, May 17, we volunteered with Maui Cultural Lands, removing invasive plants from an important historical community site and learning about how the people who lived there understood the vital connections between water, land, and community (**Photo 6**).



Photo 6. HW field team members volunteer with Maui Cultural Lands and learn more about the area and culture.

HW also met with Maui County Development Services Administration about how permitting is being handled as Lahaina residents and businesses rebuild and how GSI can fit into that equation. Then, we met with the Office of Recovery to discuss how this project can support and enhance their many current efforts, providing more opportunities to integrate GSI. Finally, we met with DPW to discuss how to not only implement GSI in a practical, feasible way in public spaces and rights-of-way, but ensure that it can be maintained into the future.

Some major meeting takeaways include the following:

- It may be difficult to require GSI during the rebuild unless the regulations are updated, particularly for single-family homes.
- Multi-generational families are rebuilding bigger and need more parking than a single-family home typically would need.
- There are many ongoing projects or projects that are just starting that relate to this work and will be impacted by our recommendations.
- People in general want to do the right thing to improve water quality – simplified resources for residents and business owners would help encourage people to use GSI even if they are not required.

- The Office of Recovery and other agencies may be purchasing vulnerable and damaged properties in the future and would be open to recommendations about priorities and reuse, GSI, and restoration.
- There are very few cisterns used in this area currently, but rainwater harvesting may become more popular as the local One Water program is implemented.
- There is a technical gap that needs to be bridged to better implement GSI - need to have a local champion/expert/group that can help people understand the topic and install rain gardens or other practices.
- Communication will be key – need to use appropriate language and timing to avoid alienation and outreach fatigue.
- Maintenance will be a major factor for DPW – need to have simple designs that can be maintained with current equipment or get support on maintenance from other departments.

Focus Drainage Areas

The GSI Supplement to the Lahaina Drainage Master Plan will focus on implementing GSI recommendations in two drainage areas, the areas draining to outfalls labeled Line O and Line R in the 2005 Master Plan. These are the two largest drainage areas in the study area at 128 acres and 256 acres, respectively. Our data collection and investigations in the field focused on these two areas, as does our hydrologic/hydraulic (H/H) model (HydroCAD).

Line O

The Line O drainage area encompasses residential areas along Lahainaluna Rd, the former Pioneer Mill area, and the more commercial areas down to Front St. Currently, there are only a few inlets on Lahainaluna Rd from the Bypass down to Honoapiilani Highway. Those inlets were identified as a flooding priority area by DPW. The HW field team was able to see the connection from the inlets on Lahainaluna Rd into the Maui County Senior Center property and then out to Pauoa St. It was unclear if the large, curved pipe (as shown in the provided drainage maps) connecting this drainage infrastructure to the pipe network along Papalaua St exists and/or is functioning. In fact, the “outfall to nowhere” we observed at the end of Pauwala Place where there has been major flooding issues may be connected to the Lahainaluna flooding issues.

It is important to note that the 2005 Master Plan Recommendations included adding drainage infrastructure on Lahainaluna Rd and then connecting it to enlarged infrastructure for Drain Line D instead of O. A screen capture of the existing (pre-fire) conditions model of Line O is shown in **Photo 7**.

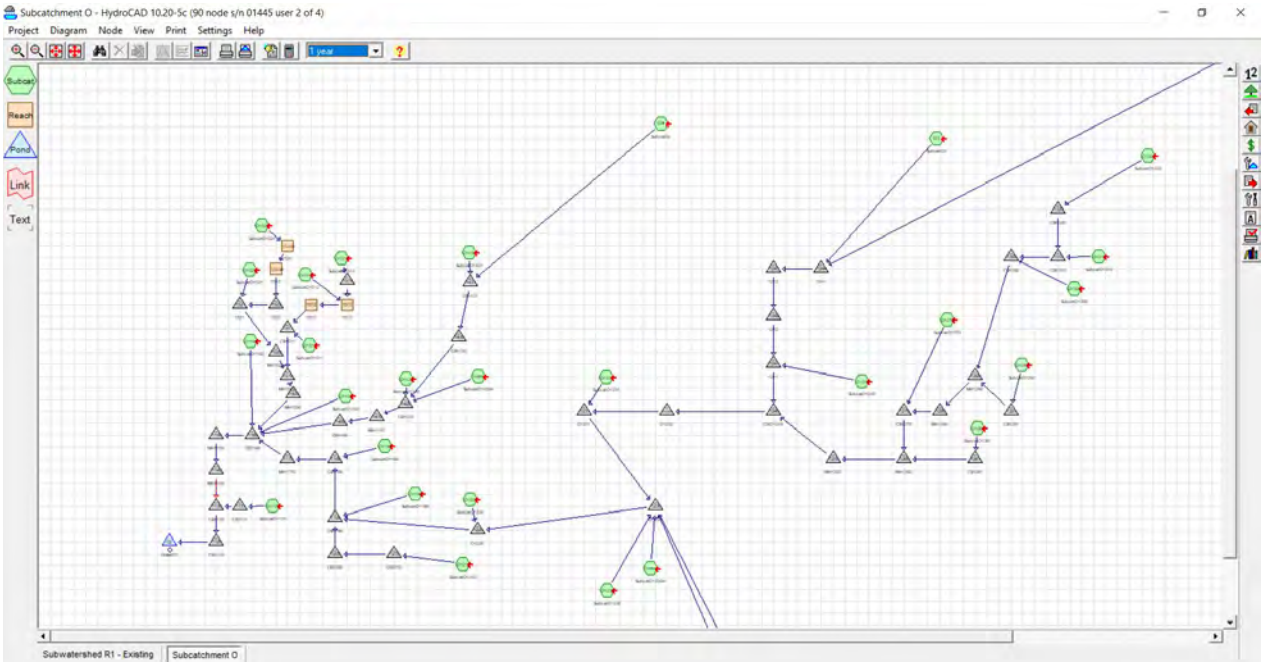


Photo 7. Screen capture of the existing HydroCAD model of Line O

Line R

The Line R drainage area encompasses public spaces (recreation and aquatic centers), residential areas, historical sites in the Royal Complex (including Mokuhinia/Moku‘ulu o Lele Park), commercial properties, and public parking. The HW field team visited all of the public spaces in this area and was able to observe the undersized infrastructure as well as the high groundwater in open ditches and wetland areas.

The 2005 Master Plan Recommendations for this drainage area included adding a new outfall and splitting the drainage areas into Line R1 and Line R2 to alleviate the pressure on the undersized infrastructure here. It also recommended additional mauka storage basins and replacing the open channel with a 10’ concrete box culvert.

Potential Pilot Projects

We identified nine sites for pilot projects – five in Drainage Area O and four in Drainage Area R. The types of pilot projects range from implementing GSI along neighborhood or commercial area roads, in community spaces, for public housing, and for large public parking lots. The types of GSI employed in these pilot project concepts include tree trenches, bioretentions, underground infiltration/storage, storage basin retrofits, permeable pavements, and constructed wetlands. This wide range of practices across different land uses will provide valuable examples for all the agencies, nonprofits, businesses, and residents working hard to rebuild Lahaina. We will be including these pilot projects in our hydrologic and hydraulic (H/H) model, as well as a pollutant loading model, to approximate expected benefits from these sites as well as if these types of practices were implemented on a larger scale.

Initial site concepts for each project are included in **Attachment C**. **Table 1** summarizes the type, site name, proposed GSI, and initial estimate of storage volume. An online map showing the locations of these sites with photos can be accessed at **24074_LahainaHI**.

Table 1. Identified Pilot Projects in the O and R Drainage Areas

Site ID	Type(s) of Pilot Projects	Site Name	Proposed GSI	Total Storage (cf)
O-1	Neighborhood ROW	Kelawea Street	Tree Trenches and Bioretentions	1,000
O-2	Community Space	West Maui Senior Center	Bioretentions and Subsurface Chambers	9,700
O-3	Public Housing	David Malo Circle Apartments	Bioretentions	1,000
O-4	Commercial ROW	Papalaua Street and Front Street	Tree Trenches	1,780
O-5	Waterfront	Lahainaluna Road and Front Street	Tree Trenches	790
R-1	Community Space	Aquatic Center Basin Retrofit	Add pretreatment to basin (forebay and bioretention), retrofit basin to increase storage and treatment	85,050
R-2	Community Space	Lahaina Recreation Center	Bioretentions and Permeable Parking	3,990
R-3	Public Parking	Prison Street Public Parking	Permeable Parking, Constructed Stormwater Wetland, Restored Natural Wetland/Hydrologic Connection	116,300
R-4	Commercial ROW	Front Street at Mokuhinia	Tree Trenches and Bioretentions	2,000

Next Steps

This memo serves to document field findings and to communicate those findings with project partners and other interested stakeholders. The next steps of this effort will be to:

1. Fill in any remaining data gaps that were identified.
2. Complete our existing (pre-fire) HydroCAD model, and then create proposed versions that include recommendations to determine benefit/impact of GSI.
3. Model pollutant load and reduction potential for pilot projects.
4. Develop the GSI Supplement for the Lahaina Drainage Master Plan.

ATTACHMENT A – Trip Itinerary

Lahaina Drainage Master Plan Update
Site Visit/Meetings
May 16-21, 2025
Itinerary (as of 5/14/2025)

Friday, May 16
8:30 AM – 12:00 PM (latest): Lahaina site visits
Contact: Kristi Ono & Darin Kahahane-Lived, Maui County Department of Public Works Highways (historic observations/maintenance perspective)
Note: Darin will need to leave ~12:00; Kristi available until ~2:00/2:30pm
Location: Meet at Lahaina Cannery Mall parking lot on stream side (1221 HI-30 (Honoapiilani Hwy.) Lahaina, HI 96761)

1:00-2:30/3:00 PM: Lahaina Watershed Flood Control Project/Temporary Berms (Wes Nohara) and Hui O Kai Wai Ola nearshore water quality monitoring (Tova Callender, Hawaii Division of Aquatic Resources)
Location: Lahaina Boys&Girls Club/Lahaina Aquatic Center
Note: hiking to the berm takes up to 45 minutes with no shade. Please bring appropriate footwear, stay hydrated and wear sunscreen.

Saturday, May 17: H-W on own
Ekolu Lindsey/Maui Cultural Lands

Option 1: 9:00 AM - 1:30 PM-Maui Cultural Lands work day. (To participate, go website Home - Maui Cultural Lands and fill out the volunteer waiver. All details get sent upon successful completion)

Sunday, May 18: H-W on own

Monday, May 19
9:00 – 10:00 AM: Meeting with Maui County Development Services Administration (DSA) and 4Leaf (consultant performing the Lahaina permit reviews)
Meeting attendees: Lance Nakamura, 4Leaf (who), others?
Location: County Services Center, 110 Alaihi Street, Kahului, HI 96732

11:00 AM: Meeting with Maui County Office of Recovery (OOR)
Meeting attendees: John Smith, Jordan Hart, Jen Maydan, Kaiea Medeiros, Fiona van Ammers (Brown & Caldwell - OOR's "One Water" consultant)
Location: Office of Recovery office-Wailuku Executive Center, 24 North Church St, Room 210, Wailuku, HI 96793

Afternoon?

Tuesday, May 20
9:00 – 10:00 AM: Meeting with Maui County Department of Public Works (Director Jordan Molina & Deputy Director Paul Barany)
Location: 200 S. High St., Room 410-DPW Engineering Division Conference Room

At/after 11:30 AM: Lahainaluna HS
H-W coordinate details directly with Vice Principal Heinlein for scheduling, etc:

Nicole Heinlein, NBCT
Vice Principal, Lahainaluna High School
nicole.heinlein@k12.hi.us
808-727-6453 (office) | 808-318-0444 (cell)
980 Lahainaluna Rd, Lahaina, HI 96761
https://www.lahainalunahs.org/

1:00 – 3:00 PM: Cultural Sensitivity Training for Sydney at @ the Sheraton in Kanapali.
Location: Sheraton in Kaanapali - 2605 Kaanapali Pkwy, Lahaina, HI 96761

Other meetings/followup site visits?

Wednesday, May 21
Final day (only early morning meeting option?)
H-W travel day (depart Maui 12:03 PM)

Pending Items:

- DPW requested contractor placard from Maui Emergency Management Agency (MEMA) which will allow HW to access restricted areas. (Contact: Everett Balmores)

EPA Team
Sarah 808-495-7749 (personal #)
Hudson 808-321-0282 (EPA #)

Horsley Witten Team
Elizabeth (Ellie) Baker: 978-270-5306 cell
Michelle West: 734-216-4617 cell
Jonas Procton
Sydney Stanton

ATTACHMENT B – Field Notes and Meeting Minutes

- Day 1 Field Notes
- Meeting with Permitting
- Meeting with Office of Recovery
- Meeting with DPW

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

MEETING MINUTES

Meeting/Re: **Field Day Notes**

Date: 5/16/25

Time: **8:30am-2:30pm HST**

Location/Call: Lahaina – Town in AM and Diversion Ditch in PM

Attendees: Ellie Baker, Michelle West, Jonas Procton, Sydney Stanton (HW)
Kristi Ono (Maui DPW)
Hudson Slay (EPA)
Darin Kahahane (Maui DPW – Lahaina Highways Division) (AM)
Wes Nohara, Kimo Falconer (NRCS - West Maui Soil Conservation District)
Fiona van Ammers, Canaan Voss (Brown and Caldwell)

Discussion Topics

1. Morning – Lahaina Town
    a. 1A Front and Kenui
        i. ***GPS points approximate***
        ii. Front Street Apartments
            1. Owned by HHFDC (Hawaii Housing and Finance Development Committee)
            2. State owned (public), working with County to come up with redevelopment plan
            3. Really good opportunity for integrated GSI with housing at bottom of watershed
            4. This would be the best place to NOT build housing, if they could keep it a park/green space
            5. Purchased before the fire by the State to avoid low rent housing increasing rental price for current residents
        iii. Existing basin
            1. Not currently maintained by County
        iv. State is working with Bowers and Kubota on the new design for this site
        v. This site is not in the existing FEMA flood zone for the most part
        vi. Darin remembers this whole site as being undeveloped and jungle as a kid. It was full of springs.

1. Original name was Kananaka, meaning mermaid, and there was a song named after the mermaid at that site

b. 1B Front and Baker
   i. ***GPS points approximate here***
   ii. Mauka CB at the intersection doesn't drain well
   iii. Outfall was perched
   iv. Raised crosswalk
c. 1C Front and Papalua
   i. ***GPS points approximate here***
   ii. 2.5'H x 5' W box
   iii. Met Hui O Ku Wai Ola group (Liz) who has been doing WQ testing at outfalls for years
      1. Of all outfalls, this site had the highest turbidity after the first flush post fire (Jan '24)
   iv. Outfall of Line O
   v. Darin popped a manhole here (first manhole he popped)
   vi. Flooding mostly focused on one CB (mauka side of the road)
      1. Outlet pipe from this CB was ~18", probably undersized
d. 1D Front and Lahainaluna
   i. ***GPS points approximate here***
   ii. Darin noted that trees in GSI have damaged outfall pipes in the past
   iii. Cool pockets in parking for GSI opportunities
      1. ACTION ITEM: Kristi to provide green streets plan
      2. Small pipes connected the parking stalls, but they would clog frequently
   iv. Lots of utilities in the tree pits, including W and E, that we would have to work around
   v. Outfall: 5'W x 1.2'H (partially filled with sand)
      1. ACOE just cleared pilings from a building over the water that has caused more sand to deposit at the outfall, creating a beach where there wasn't one previously
      2. Clogging is a new issue here
e. 1E Front Street at Harbor (Canal Street)
   i. CB at corner of Canal and Front was full of sediment
   ii. School and Park here
   iii. Discussed possibility of a certificate or credit as incentive for commercial landowners to implement GSI when they rebuild
   iv. There was once a stream here at Canal
f. 2C Ditch to Ocean from Malu Ulu O Lele Park
   i. This is a key ditch/channel
      1. DPW excavates much of the channel/plug when a storm is expected (but they don't fully excavate into the ocean based on regulations)
      2. After a flood, DPW refills the channel/plug to prevent more sand from washing further into site where they wouldn't be able to reach as easily with equipment
      3. Army Corps permitting: A "continuous surface connection" to a "relatively permanent water" or a "permanent water"

ii. What if the channel were daylighted all the way to Front Street?
    1. Darin would just want some way to access the channel still (get in with skidsteer) like a ramp
iii. Black rock nearby = vault for royal bones (ivi = bones)
iv. Mauka ditch along Park
    1. Natural, looked good, vegetated
    2. Groundwater has risen here post fire
        a. Maybe due to more infiltration
        b. Maybe due to less water usage from residents (water comes from GW withdrawal mauka)
            i. This could tie into SW reuse plans/opportunities like rain barrels/cisterns
    3. There were fish in the ditch
    4. Darin is concerned that if the plug were removed, this whole ditch and the wetland in the park would be drained out
v. Malu Ulu O Lele means "walk for miles in the shadows of breadfruit trees" per Darin. Or literally "the place where breadfruit trees spring forth"

g. 2B Flooding in Neighborhood
    i. *Would be good to return here for GIS mapping*
    ii. Very small culvert for drainage
    iii. Continues down to Malu Ulu O Lele Park channel
    iv. Gets clogged frequently
    v. Pre fire, all the homes along the highway used to flood due to the undersized pipes under Laukini Street
    vi. Up on Wainee, there was a pipe that connected in, which drained the properties mauka of Wainee
    vii. Much of these pipes were the old infrastructure from the sugar plantation
h. 3 Shark Pit Beach Outfall
    i. Hand dug to maintain outfall
    ii. Very small sand plug
    iii. Next to reef, so the waves are not very big here and there is less sand loading
    iv. From Kauala (sp?) subdivision
i. 4B Pipe to Nowhere at Pauwala Neighborhood
    i. The connection shown on GIS probably doesn't exist
    ii. Previously existing ditch has been filled in with a road for access
    iii. Property owner open to installing subsurface drainage
    iv. Easy solution…but it's all through private property
j. 4A Lahainaluna Road and Senior Center
    i. ***Would be good to return here for GIS mapping***
    ii. Lots of runoff to a single curb inlet, which is not located at the low point
        1. Invert 8.7' below grade; 3' diameter pipe
    iii. Lahainaluna Road drains toward Senior Center, then connects in on Pauoa
    iv. ACTION ITEM: Kristi to try to get us the plans from HDR for the sidewalk along Lahainaluna and the infiltration
    v. Next to Senior Center
        1. Public

2. Could be a great site to receive runoff
3. Kristi will try to get us these plans

k. 5A Kahoma Condos/Limahana Road
   i. Kristi gets complaints from property owners about lack of drainage infrastructure
   ii. No CBs/pipes
   iii. Condos are about 5 years old, but didn't consider run-on in drainage design
      1. Kristi is familiar with this issue from this particular consultant/designer

2. Afternoon – Temporary Diversion Ditch
   a. Geology
      i. Lahaina was developed at the base of the Kanaha Valley, which collapsed and formed a wide floodplain rather than a single channel to the ocean. This contributes to Lahaina's flooding issues
   b. History
      i. After Pioneer Mills sold, agriculture practice ended and fields went fallow
      ii. Fallow fields generated more runoff than sugar fields (sugar is lush greenery), so flooding worsened substantially
      iii. Temporary diversion ditch built from existing irrigation ditches
         1. Widened existing ditches, although the slope is less steep than NRCS prefers (prefers 1.5-2%)
         2. Can only hold about the 15-20 year flow
      iv. Second diversion ditch was built makai so as to catch runoff that broke through diversion ditch in too-flat sections
      v. Lahaina bypass highway was constructed, which resulted in concentrated flows entering the diversion ditch and overwhelming some locations
      vi. Soil Conservation District has always wanted to build a permanent ditch makai of temporary ditch, at a steeper slope and able to contain a larger flow
         1. Design has been complicated by pushback from downstream resort (Puamana on Front Street)
            a. Half of Puamana burned in the fire
            b. Puamana wants to restore their own drainage ditch, and wants Soil District's help
         2. EA approval lapsed and Soil Conservation District has had to repeat it (ongoing)
   c. Ownership
      i. Kamehameha School and West Maui Land Company own much of the land of the diversion ditch and former Pioneer Mills
         1. Don't do much in the way of SW management…or fire management
         2. As former ag land that is not currently used for ag, there is not much that can be done to regulate it other than (relatively weak) fire regs
         3. (Kamehameha School AKA Princess Bernice Pauahi Bishop Estate)
   d. Mauka work
      i. Fences up to keep out deer
      ii. Keeping people out is also a problem
         1. Invasives come in on people's boots
         2. Dirt bikes cause erosion

   e. 2012 Inspections by Wes
      i. Sent by Kristi
      ii. All over Lahaina and other nearby towns
   f. Hudson may have mapping of temporary diversion ditch and the terraces mauka
   g. Maintenance
      i. Trash dumping issues
      ii. Look for and remove trees on the berms
      iii. Diversion ditch is inspected annually
      iv. Ag terraces mauka are not frequently inspected
      v. Princess Nahienaena Elementary School flooded out makai of ditch
3. General Post Fire Notes
   a. Cleanup
      i. Sampled burned sites, excavated 6”, sampled again, placed gravel if clean (over the footprint of the buildings)
      ii. Once testing is approved, homeowners are allowed to rebuild on sites
   b. HDPE pipes were the main pipes that burned (not metal or concrete pipes)
      i. These were the pipes that were at risk of/did collapse
   c. A moratorium on building/rebuild makai of Front Street has been passed
4. Other
   a. There is a 1960s restoration plan for Lahaina which may include a map for all of the historical wetlands
   b. There was once a vast wetland complex between Front Street, Canal Street, Prison Street, and Malu Ulu O Lele
      i. The flood maps reflect this
5.

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MEETING MINUTES

Meeting/Re: **DPW Development Services Administration - Permitting**

Date: 5/19/25

Time: **9:00-10:15 am HST**

Location/Call: DSA Office

Attendees: Ellie Baker, Michelle West, Jonas Procton, Sydney Stanton (HW)
Hudson Slay (EPA)
Sarah Pedroza (EPA OCR)
Kristi Ono (Maui DPW)
Lance Nakamura (Maui DPW Development Services Administration – Assistant Administrator)
Kaliko Storer (Mayor's Lahaina Advisory Team)

Discussion Topics

1. Burn area: requirements for redevelopment
    a. Residential
        i. Rarely triggered
        ii. If there is any stormwater management, it's handled during the original process of subdividing lots. Doesn't affect individual property owners later on
        iii. Maximum of 65% of a lot is allowed to be impervious (zoning)
        iv. Frontage regulations
            1. If buildings/lots already are nonconforming, they are typically grandfathered in (same for the 65% rule)
        v. Building Code 60.25 Articles 3 and 4 relate to post-construction WQ (i.e. GSI) and road widening/ROW
        vi. In some cases, multi-generational families are now making their homes larger during the rebuild
            1. The County has allowed houses to add an accessory dwelling, so long as total impervious is still <65%
    b. Commercial/larger lots
        i. If impervious area is >5,000 sf, owner must sign a form saying they won't add any new connections to the closed drainage network (Form A)
            1. This is not really enforcement, more of good faith
            2. Includes guidance for possible GSI

        ii. Sites that disturb >1 acre are required to meet post-construction WQ requirements (includes GSI) and flood control (rates and volumes), documenting both in a drainage report
        iii. Requirements for road improvements adjacent to commercial lots may be required at the Department's discretion
    c. Shoreline requirements (Special Management Area – SMA)
        i. This is a State-level permitting process
        ii. Lance: thinks there is NOT a moratorium on developing makai of Front Street since the fire
        iii. Check with planning
2. Mechanisms for drainage improvements
    a. Currently, just some optional guidance for developers (see Form A discussion for commercial lots)
    b. Roof top rain capture
        i. Not much incentive for homeowners currently
        ii. Attitude of "it never rains here"
    c. Incentive Program?
        i. Would certificates or credits incentivize homeowners or commercial owners to install GSI? Commercial owners could showcase stickers/signs to market that they "built back greener" (similar to "build back fire safe")
        ii. Lance: not sure, but it would probably come down to costs
        iii. Lance: it's worth a conversation…people are very conscious of what the water looks like going into the ocean, so they might be motivated to implement WQ improvements
        iv. There are different palettes across Lahaina for going above to improve the environment
        v. Handouts during rebuilds may help. Maybe offer free rain barrels. Particularly for those that are building back larger than previous structure.
    d. Faster Permitting as an incentive?
        i. Lance: for Lahaina, a 3rd party (4Leaf) is facilitating reviews, and the process is already relatively quick
        ii. Outside of Lahaina, there are some fast track programs (like for affordable housing developments), but mostly it is a capacity issue
    e. Planning/Permitting
        i. Important to remember that the master plan is not law – need to update ordinances/regulations through long term planning to impact how things are rebuilt
        ii. Give handouts with permits with GSI recommendations
3. Example: Jake Freeman and septic messaging
    a. Local engineer who was hired to facilitate septic upgrades
    b. Became seen as a "local champion"
    c. Key was consistent presence at public meetings and events and willingness to engage with community members directly
4. Who is the touchpoint for drainage messaging?
    a. Homeowners and commercial owners must sign the building permit
    b. Contractor or architect may be more closely involved in the actual permit process

5. Parking
    a. Multigenerational households may have 12 residents but only 2 parking spaces
    b. Kaliko: set laws now to set parking codes…not when it's too late
    c. One idea under consideration: set designated parking areas for blocks/neighborhoods to park at scale…an ongoing conversation
    d. Driveway aprons must be paved (bituminous or concrete), but driveways may be pervious
6. Sites
    a. Front Street Apartments
        i. Redevelopment would trigger review thresholds
        ii. Gets at question of what is the baseline for "existing" post-fire? Is it pre-fire conditions, or is the impervious area now reduced?
7. Ideas
    a. Subsidize permeable pavement outreach and installations
    b. Hire an on-the-ground contractor for rain garden installations/designs or partner with local watershed group

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MEETING MINUTES

Meeting/Re: **Office of Recovery**

Date: 5/19/25

Time: **11:00-12:15 am HST**

Location/Call: Office of Recovery

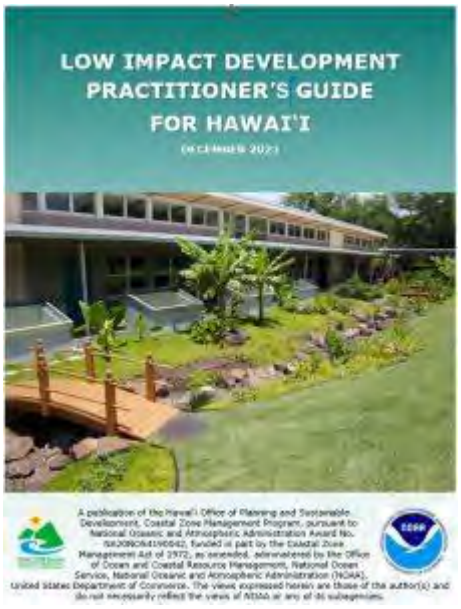
Attendees: Ellie Baker, Michelle West, Jonas Procton, Sydney Stanton (HW)
Hudson Slay (EPA)
Sarah Pedroza (EPA OCR)
Kristi Ono (Maui DPW)
John Smith, Jordan Hart, Jen Maydan (Maui OOR)
Kaiea Medeiros (Maui Dept. of Oivii)
Fiona van Ammers (Brown and Caldwell)
Virtual:
Kate Rao (EPA)
Kaliko Storer (Mayor's Lahaina Advisory Team)
Kathleen Chu (Bowers and Kubota)

Discussion Topics

1. How does drainage fit into recovery effort?
    a. Rebuild Lahaina Plan
        i. From Front Street to highway, Baker to Shaw
        ii. Looking at circulation, mobility, and GSI
        iii. Consultant team was just on-site last week, and will be back mid-July for a design charette
    b. Mokuula and Mokuhinia area
        i. Leaving this project/concept to Kaiea and the consultant that was hired for it (Group 70 International, Inc.)
    c. One Water (Brown and Caldwell)
        i. An integrated/holistic way of thinking of the entire water system (SW, WW, drinking water)
        ii. Lahaina as a case study before expanding across the island
        iii. Consider how water will inform the future vision of Lahaina

iv. Mostly internally focused at the moment
v. Engagement: be careful about how many times we (OOR/OCR) discuss water with the public. They will lose engagement if it's not a coordinated message – risk "survey fatigue"
vi. One Water will be the long-term strategy for implementation, and will fold in our plan once it's done

2. Different owners, different strategies
    a. Residential
        i. It would be helpful for homeowners (and developers) to have examples of GSI as a basis for their own properties
            1. The Office of Planning and Sustainable Development recently created a best practices document for LID



        ii. Ellie: it could be effective to meet the homeowners where they're at, walk their properties with them, and give them design guidance
            1. This could also be helpful for commercial owners
            2. Jordan: who would staff that?
            3. Maybe some of HW's recs in the DMP are "fundable" (e.g., by EPA) to contractors once they're in the DMP
        iii. The Big Question is how to make implementing GSI as easy as possible
            1. Is it with rules (i.e. clear guidance on how to develop lot) or "sticks"?
            2. Is it with community engagement and incentives or "carrots"?
        iv. One Water is a good opportunity to build GSI out into the community
    b. Commercial
        i. Thresholds for Major Grading Permit
            1. In the SMA (special management area – along shoreline): 2 feet of elevation change (this is almost always triggered)
            2. Other areas: only greater than 1 acre of disturbance
        ii. Incentives: Certifications or Credits for properties that participate in GSI programming, such as signage/logos that companies could use to market "Building Back Green"
        iii. Jordan: in the DMP, it may be helpful to include examples from existing GSI installations on commercial lots, rather than proposing GSI on a commercial lot that may receive backlash if it doesn't install to our proposal
        iv. Maui Dept. of Planning has SMA on everything makai of the highway, and could leverage that to implement design standards
    c. Public
        i. OOR has funds allocated to purchase properties for open space
            1. Engaged in an initiative for purchasing vulnerable real estate that may not be in a good spot to rebuild (e.g., FEMA flood zone)

2. Still developing this program
3. Also evaluating how SLR plays into FEMA flood zones and which properties are at risk

ii. OOR will have the opportunity to rebuild some affordable houses itself
1. Can include pervious paving and other GSI demonstration pieces
2. In some cases, OOR also subsidizes low-income housing and can require the installation of GSI as a condition
3. Locations of affordable housing that OOR will develop are not yet available

iii. Sites
1. Senior Center and Front St Apartments
2. OOR is looking at the adjacent properties, and would consider purchasing those too in order to make more space available for GSI
3. If any other sites have potential, we can notify OOR and they will investigate

3. Communications Strategy
   a. The engineering side of this work doesn't translate well…need to be able to communicate it to the public
   b. Sarah/Hudson: hopefully the findings of this DMP update will be a tool that the OOR can use for their comms
   c. John: really important how water connects everything. Water is highly valued here
      i. The current design standards are a part of the problem. They are not based on the hydrology of Hawaii, and fall apart in some parts of the watershed (especially makai near ocean)
      ii. Fiona: Honolulu/Oahu have great design guidance that is island-specific
   d. Bridging the communication gap
      i. Need to speak the language of the culture
         1. "Mauka to makai" instead of "watershed plan"
         2. Rain gardens as a version of Loi kalo
         3. Allude to land management and its impact on SW in our plan
4. Touch points for GSI messaging?
   a. There is basically a set path for how redevelopment works. The outcome can be changed based on the design standards
   b. Harder to make changes apply to residential properties

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MEETING MINUTES

Meeting/Re: **DPW Meeting**

Date: 5/21/25

Time: **9:00 – 10:00 am HST**

Location/Call: 200 High Street (DPW Office)

Attendees: Ellie Baker, Michelle West, Jonas Procton, Sydney Stanton (HW)
Jordan Molina, Kristi Ono (DPW)
Sarah Pedroza (EPA)

Virtual
Hudson Slay, Kate Rao (EPA)

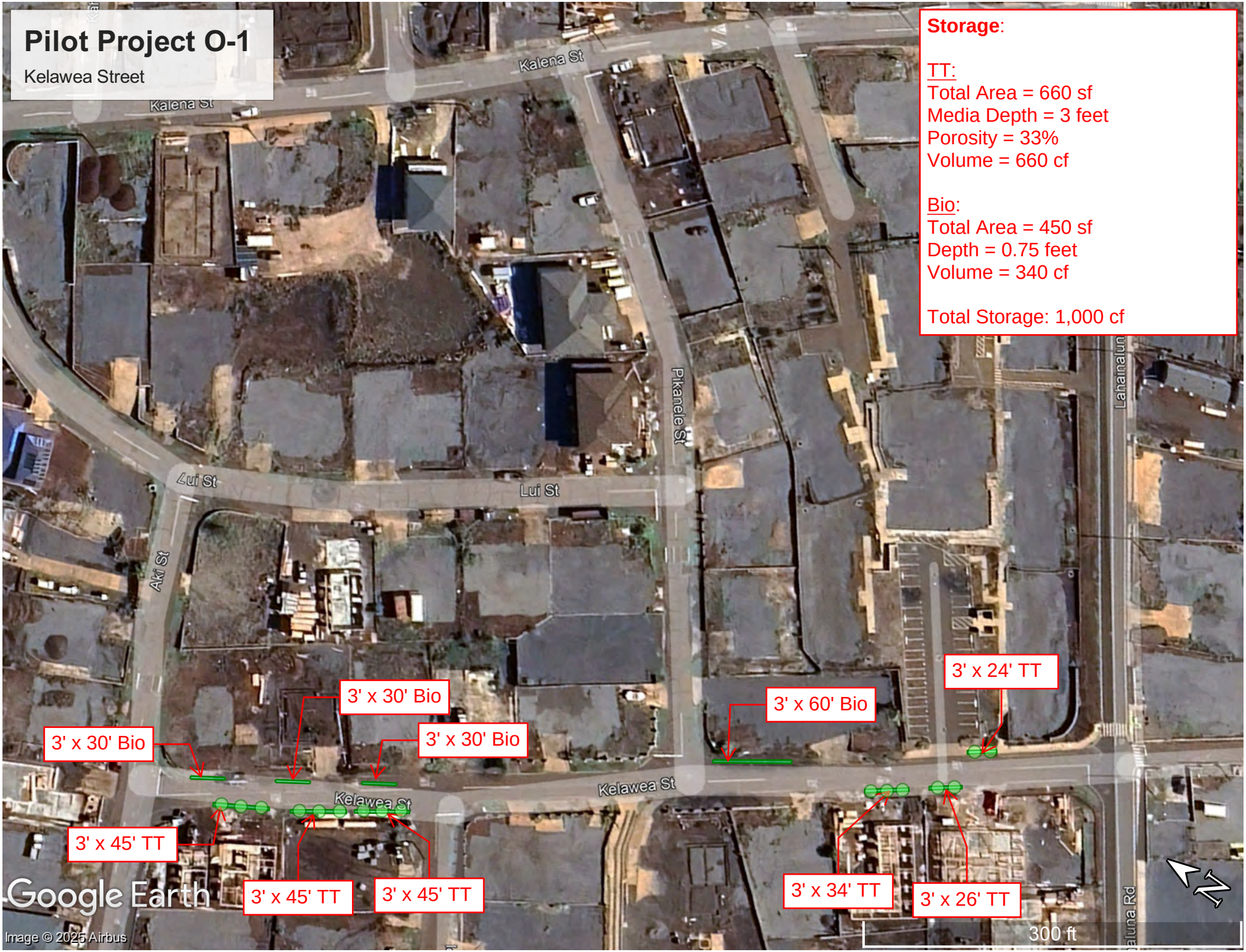
Discussion Topics

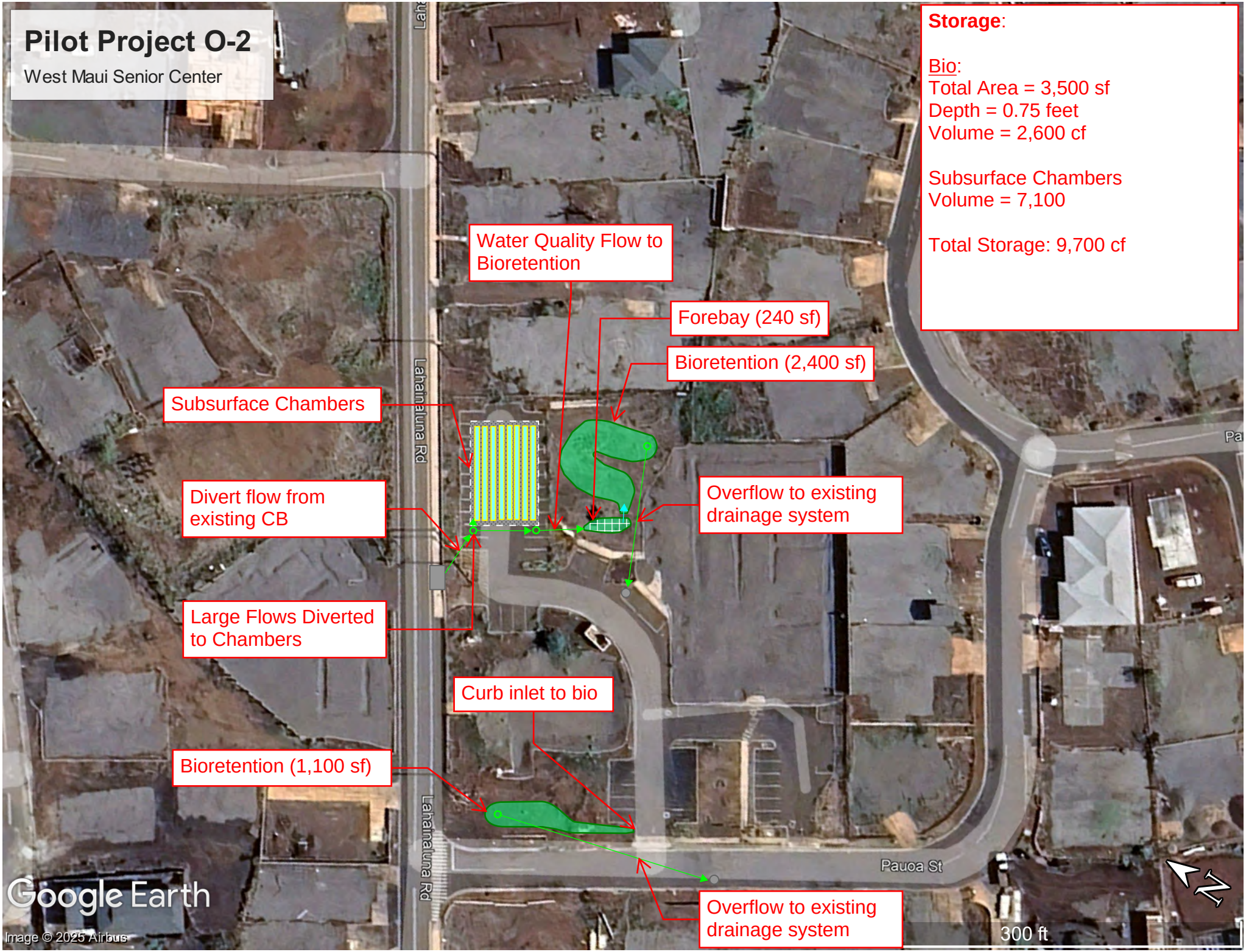
1. Various projects to coordinate
    a. NRCS Flood diversion
    b. Kamehameha School
        i. Above the bypass, Estate is planning to do ag activities and watershed restoration
            1. R-1 reuse, well water, and surface water
            2. Forestry
            3. Maybe grazing
            4. Farm plots
        ii. Below the bypass, Estate (?) is planning to…
            1. Relocate the Elementary school from near the harbor
                a. TBD what happens to the existing school's land. County may receive it, and it may be grouped with the Mokuhinia project
            2. Create a resource center
            3. Create small commercial pockets
            4. Single and multi family residential
    c. FEMA Flood maps
        i. There are new flood maps developed by Stantec that look at surface runoff and flood levels across Lahaina
        ii. The modeling did not account for the drainage system, so flooding may be exaggerated
        iii. DPW is hesitant to share this with the community

   d. Mokuhinia (Royal Complex)
      i. Restoring natural hydrology is a consideration for the cultural group – led by OOR
      ii. There is consideration of how the proposed bypass interacts with the hydrology of this area
      iii. The complex extends north into public parking area and beyond
         1. This may affect our concepts of pervious parking in the public lot with an underdrain to Mokuhinia
         2. There is a storymap of Mokuula with a lot of the historic mapping, including wetlands and hydrology: https://storymaps.arcgis.com/stories/4bd727a35fee403ea075b611016ce81d
            a. ACTION ITEM – Get Royal Complex Area GIS
2. Permitting
   a. Jordan: Recs from this project should point toward how to improve permitting/regs
   b. For residential properties, we should provide guidance on how to incorporate GSI to homeowners
   c. Commercial
      i. There are redevelopment requirements, the challenge is practicality
      ii. There could be more public parking lots developed. The County is looking at buying parcels for this purpose
         1. It would be good to provide concepts for parking lots
         2. Ideal placement of a (hypothetical) new parking lot: between Papalaua and Dickson
      iii. What about a bus/trolley?
         1. The County is looking at making a bus hub in vicinity of the Mill (intersection of Lahainaluna and 30)
         2. Parking is not yet addressed in this plan (i.e., a "park and ride")
      iv. What about a parking structure?
         1. Not yet discussed
         2. Probably an anti-structure sentiment in town…would need to be only 2-3 stories
         3. County considering purchasing private parking garage on Baker and Wainee for public parking, since it is currently underutilized as a private structure (out of the way + cost). Could incorporate solar canopy here for added benefit
3. Outcome of our plan
   a. Jordan: would like both specific sites and template examples of GSI
   b. Maybe we map out (1) residential (2) commercial and (3) public parcels
   c. Michelle: we could group recommendations into zones (i.e., near shore, middle, and mauka of bypass)
4. Maintenance capacity for DPW
   a. Jordan: we don't want to be sold strategies as a guinea pig; we want something that works. This will also be true of private property owners
   b. "Talking about maintenance will be an important part of this plan"
   c. Partners: who can help with O+M?
      i. Local groups? DPW struggles to engage with non-profits. They don't always have great longevity/continuity

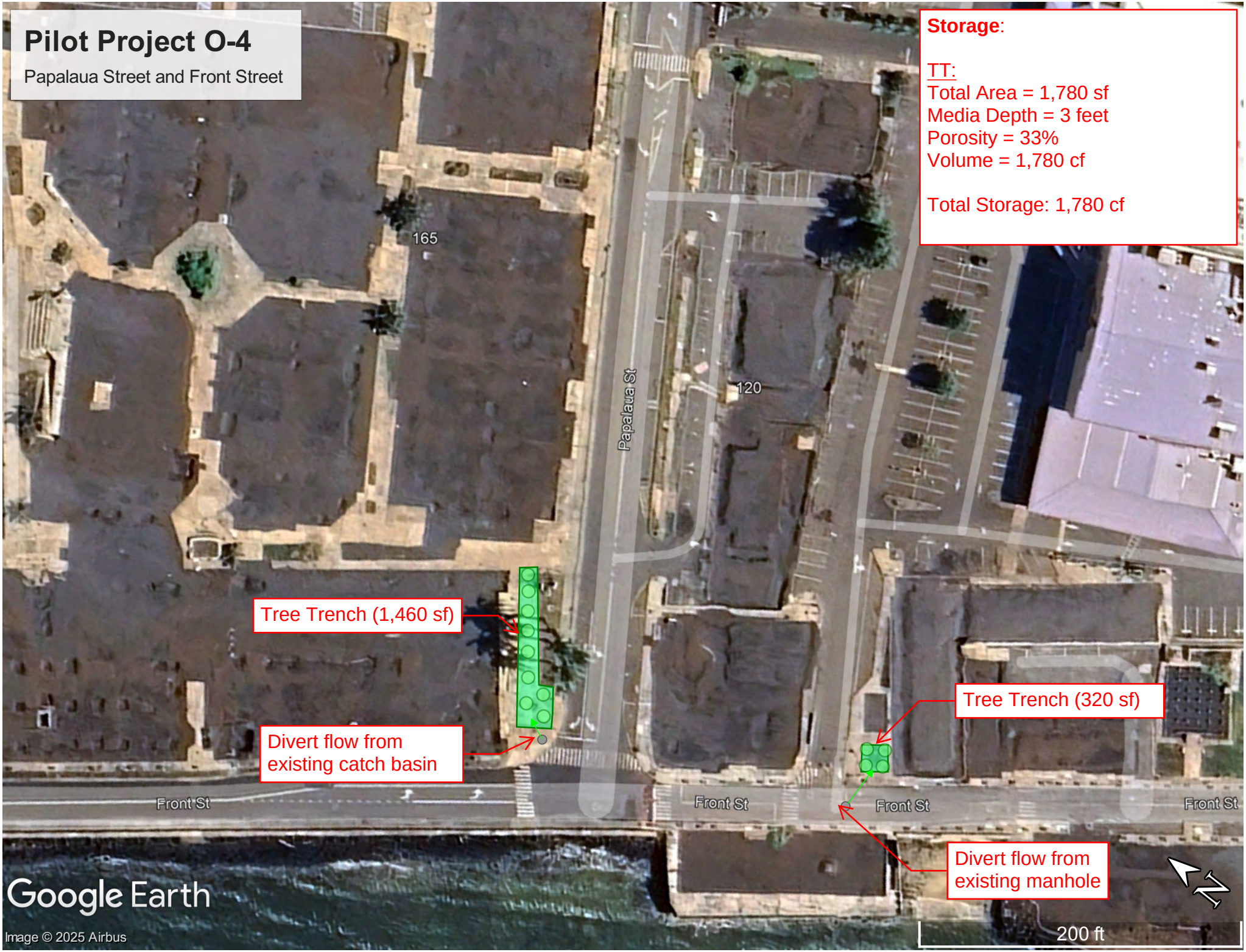
   d. What does DPW need to make maintenance happen?
      i. It is an expertise and capacity issue
      ii. Would be better to give maintenance to another department: ag or sustainability
5. Community Outreach and engagement
   a. EPA wants to provide draft docs to the community
      i. High level tentative plan
      ii. Want to share with DPW too for feedback
   b. Jordan: community outreach will end up overlapping with other projects (diversion ditch and FEMA flood update). Want to be clear on message and info
6. Constructability
   a. Can anyone on Maui install porous asphalt?
      i. There are 1-2 projects that have been installed on Maui, but they quickly clogged
      ii. 1 may have been porous concrete pavers
      iii. Maintenance is lacking
         1. DPW does have a vacuum sweeper
         2. MW: Design matters – often, designers direct a large drainage area to a small amount of porous. Key is to design flat area only receiving the rain falling on it.
         3. ACTION ITEM: Kristi to share example design plan from EcoSolutions
7. "Wetland" area mauka of highway
   a. Kamehameha was trying to buy this property, but it isn't going well
   b. County may try to buy it
   c. It seems to have a lot of archaeological sites

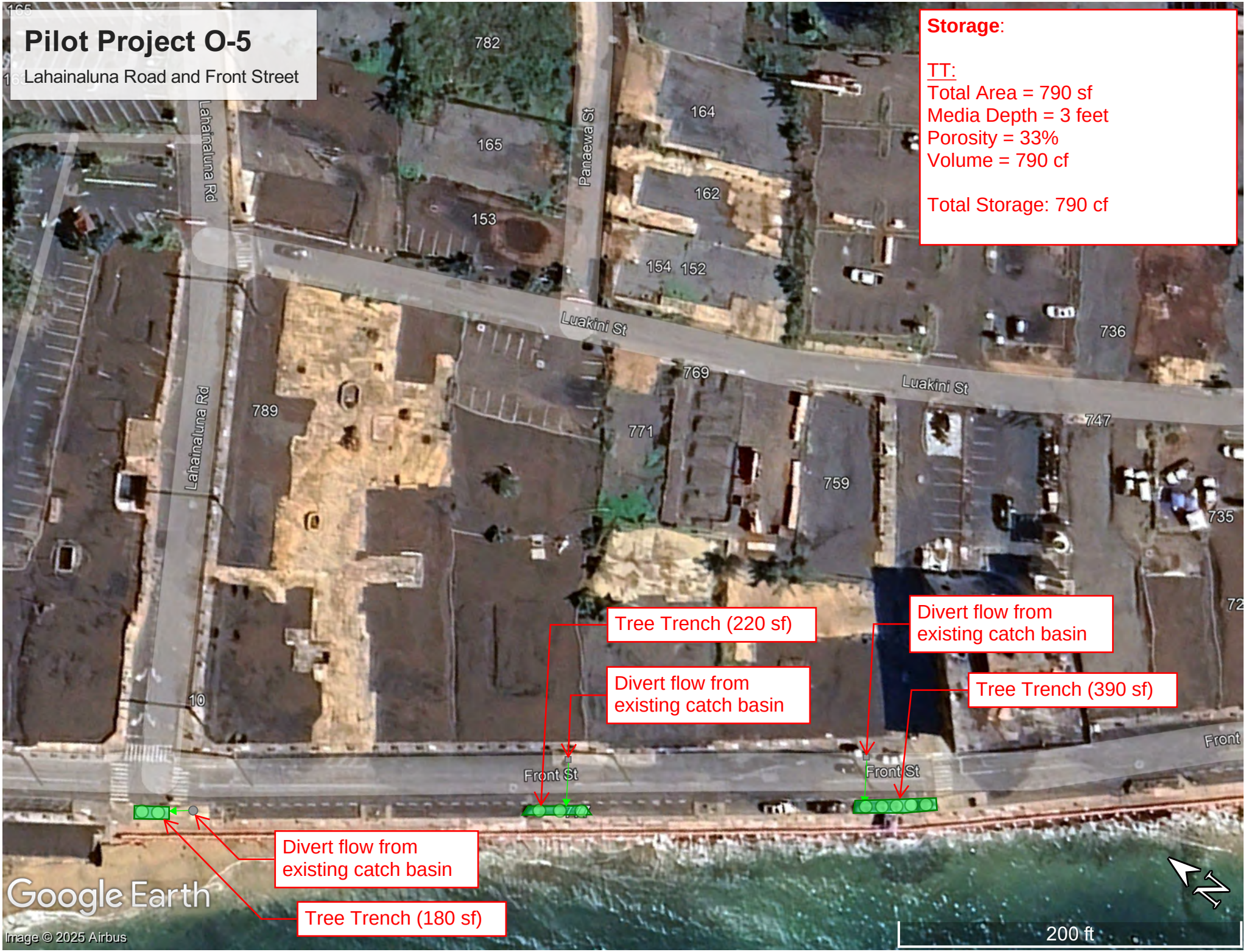
ATTACHMENT C – Site Concepts


Pilot Project O-1
Kelawea Street
Storage:
TT:
Total Area = 660 sf
Media Depth = 3 feet
Porosity = 33%
Volume = 660 cf
Bio:
Total Area = 450 sf
Depth = 0.75 feet
Volume = 340 cf
Total Storage: 1,000 cf
Kalena St
Pikanele St
Lui St
Aki St
Kelawea St
3' x 30' Bio
3' x 30' Bio
3' x 30' Bio
3' x 60' Bio
3' x 24' TT
3' x 45' TT
3' x 45' TT
3' x 45' TT
3' x 34' TT
3' x 26' TT
Google Earth
Image © 2025 Airbus
300 ft


Pilot Project O-2
West Maui Senior Center
Storage:
Bio:
Total Area = 3,500 sf
Depth = 0.75 feet
Volume = 2,600 cf
Subsurface Chambers
Volume = 7,100
Total Storage: 9,700 cf
Water Quality Flow to Bioretention
Forebay (240 sf)
Bioretention (2,400 sf)
Subsurface Chambers
Divert flow from existing CB
Overflow to existing drainage system
Large Flows Diverted to Chambers
Curb inlet to bio
Bioretention (1,100 sf)
Overflow to existing drainage system
Lahainaluna Rd
Lahainaluna Rd
Pauoa St
Google Earth
Image © 2025 Airbus
300 ft
N


Pilot Project O-3
David Malo Circle Apartments
Storage:
Bio:
Total Area = 1,690 sf
Depth = 0.75 feet
Volume = 1,260 cf
Total Storage: 1,260 cf
741
Lahainaluna Rd
Mill St
Mill St
Mill St
Mill St
737
731A
285
723
David Malo Cir
David Malo Cir
David Malo Cir
Overland flow to bioretentions
Bioretention (430 sf)
Bioretention (430 sf)
Bioretention (830 sf)
270
30
Overflow to existing drainage system
Google Earth
Image © 2025 Airbus
200 ft


Pilot Project O-4
Papalaua Street and Front Street
Storage:
TT:
Total Area = 1,780 sf
Media Depth = 3 feet
Porosity = 33%
Volume = 1,780 cf
Total Storage: 1,780 cf
165
120
Papalaua St
Tree Trench (1,460 sf)
Divert flow from existing catch basin
Tree Trench (320 sf)
Divert flow from existing manhole
Front St
Front St
Front St
Front St
Google Earth
Image © 2025 Airbus
200 ft
N


Pilot Project O-5
Lahainaluna Road and Front Street
Storage:
TT:
Total Area = 790 sf
Media Depth = 3 feet
Porosity = 33%
Volume = 790 cf
Total Storage: 790 cf
Lahainaluna Rd
Panaewa St
Luakini St
Front St
782
165
164
162
153
154
152
736
769
789
771
747
759
735
10
Tree Trench (220 sf)
Divert flow from existing catch basin
Divert flow from existing catch basin
Tree Trench (390 sf)
Divert flow from existing catch basin
Tree Trench (180 sf)
Google Earth
Image © 2025 Airbus
200 ft
N

Pilot Project R-1

Aquatic Center Basin Retrofit

Storage:

Bio:
Total Area = 4,060 sf
Depth = 0.75 feet
Volume = 3,050 cf

Infiltration Basin:
Total Area = 41,000 sf
Additional Depth = 2 feet
Volume = 82,000 cf

Total Storage: 85,050 cf

Excavate 2 feet from bottom of existing basin (41,000 sf)

Scarify bottom to improve infiltration

Bioretention (3,100 sf)

Sediment Forebay (960 sf)

Capture overland flow



Pilot Project R-2

Lahaina Recreation Center

Storage:

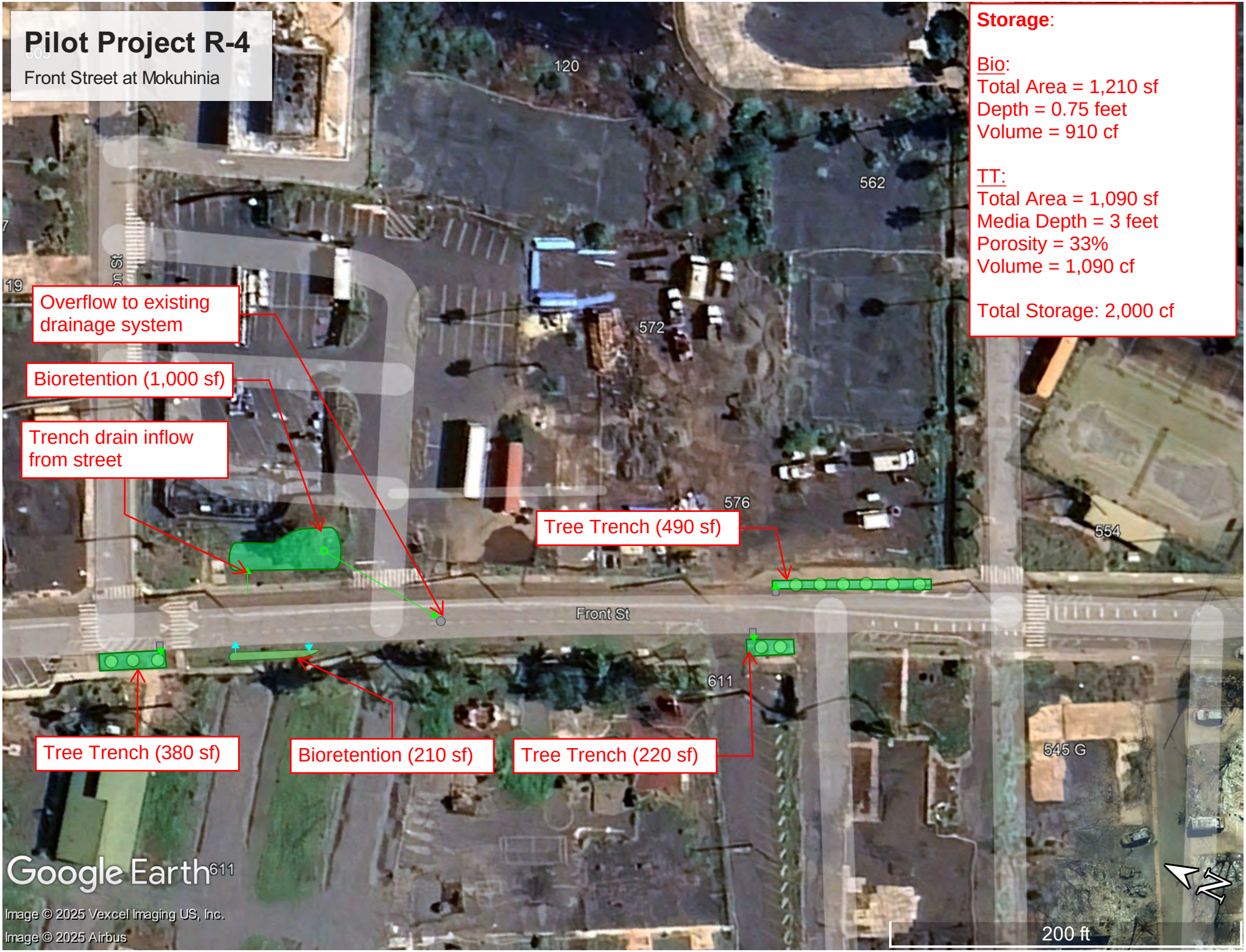
Bio:
Total Area = 650 sf
Depth = 0.75 feet
Volume = 490 cf

Pavers:
Total Area = 5,300 sf
Media Depth = 2 feet
Porosity = 33%
Volume = 3,500 cf

Total Storage: 3,990 cf




Pilot Project R-3
Public Parking and Wetland Connectivity
Wetland overflow to existing ditch
Lyakini St
Constructed Stormwater Wetland *(or restore existing wetland)* (37,500 sf)
Constructed Stormwater Wetland (10,500 sf)
Overflow from pavers and diversion from existing manhole
Permeable Pavement Parking (66,500 sf)
Prison St
Front St
Storage:
Pavers:
Total Area = 66,500 sf
Media Depth = 2 feet
Porosity = 33%
Volume = 44,300 cf
Wetlands:
Total Area = 48,000 sf
Depth = 1.5 feet
Volume = 72,000
Total Storage: 116,300 cf
Google Earth
Image © 2025 Vexcel Imaging US, Inc.
Image © 2025 Airbus
300 ft
N


Pilot Project R-4
Front Street at Mokuhinia
Storage:
Bio:
Total Area = 1,210 sf
Depth = 0.75 feet
Volume = 910 cf
TT:
Total Area = 1,090 sf
Media Depth = 3 feet
Porosity = 33%
Volume = 1,090 cf
Total Storage: 2,000 cf
Overflow to existing drainage system
Bioretention (1,000 sf)
Trench drain inflow from street
Tree Trench (490 sf)
Tree Trench (380 sf)
Bioretention (210 sf)
Tree Trench (220 sf)
Front St
120
562
572
576
554
611
545 G
Google Earth
Image © 2025 Vexcel Imaging US, Inc.
Image © 2025 Airbus
200 ft

ATTACHMENT D – Meeting Slides

Lahaina Town Drainage Master Plan Update

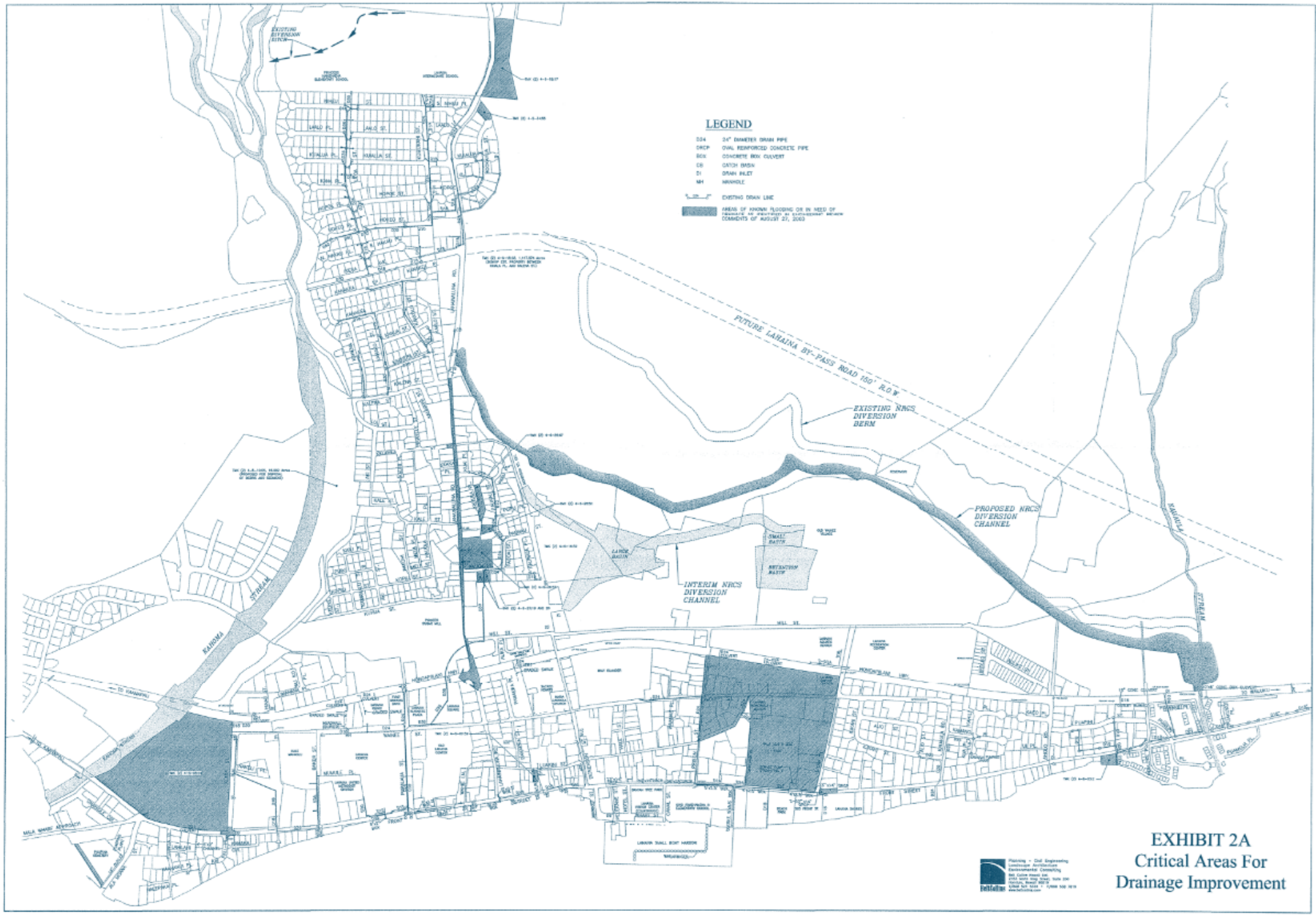
Site Visit

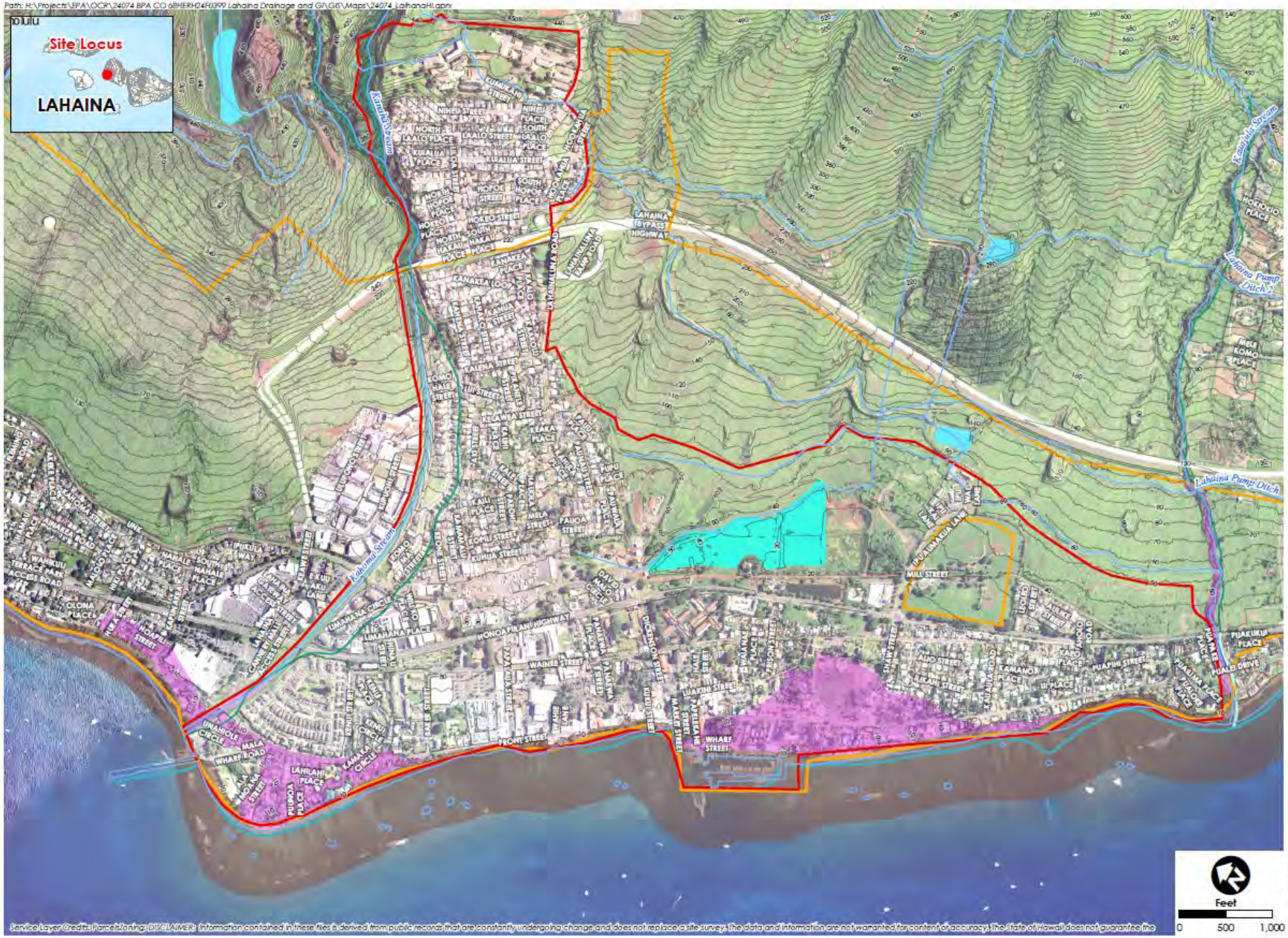
May 16-21, 2025

Project Goals:

- Update plan to reflect current conditions
- Integrate green infrastructure, LID and nature-based solutions into the Lahaina Drainage Master Plan

2005 Drainage Master Plan





Horsley Witten Group
Sustainable Environmental Solutions

Date: 2/12/2025
Data Sources: Bureau of Geographic Information (MassGIS), ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Project Area Boundary
- Burn Area
- Contours (10ft)
- Streams

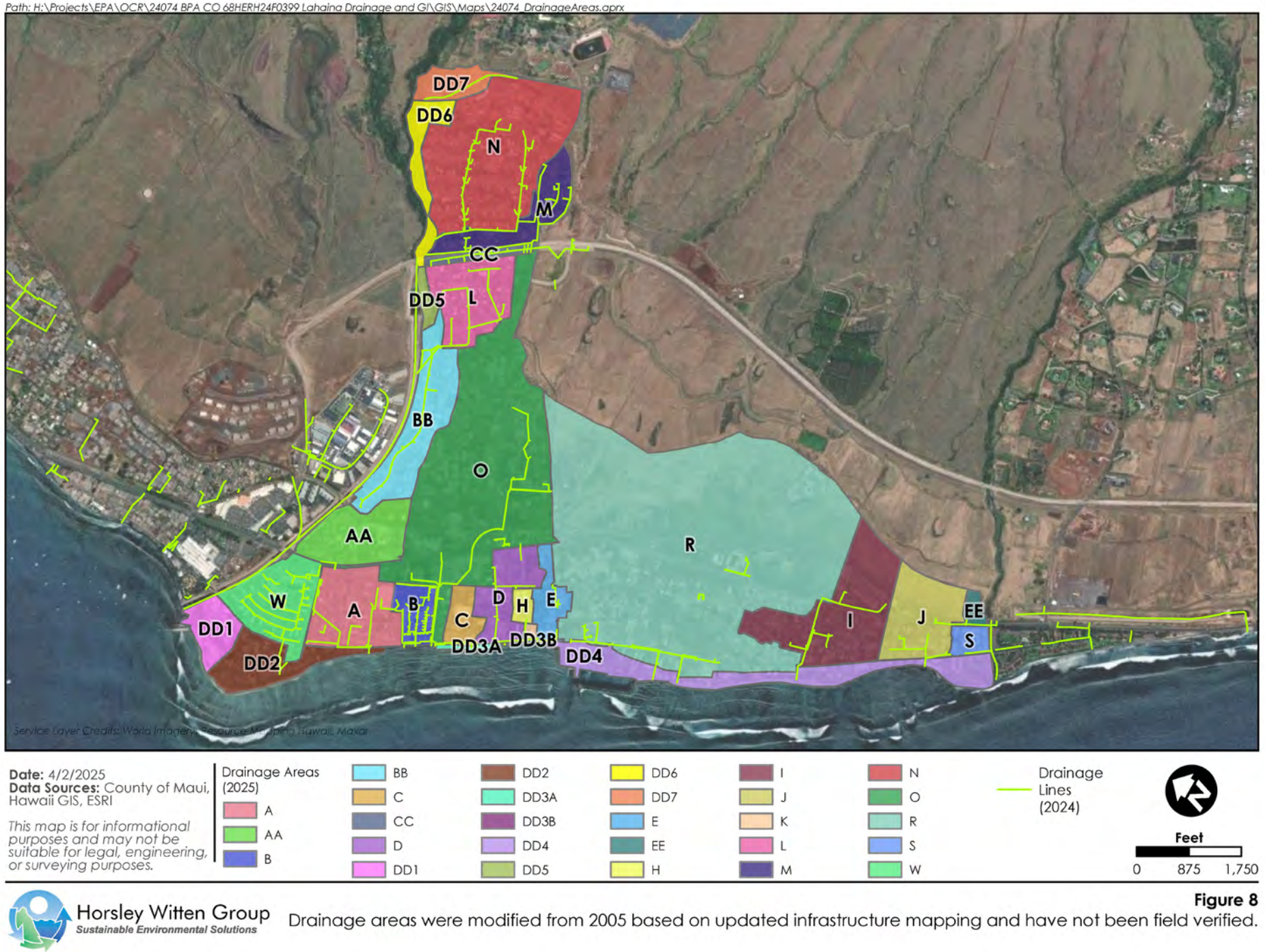
Flood Zones
- A
- AE
- VE

Wetlands
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Riverine

Feet
0 500 1,000

Lahaina Pre-Fire Drainage Review.
Figure 1
Wetlands and Flooding.

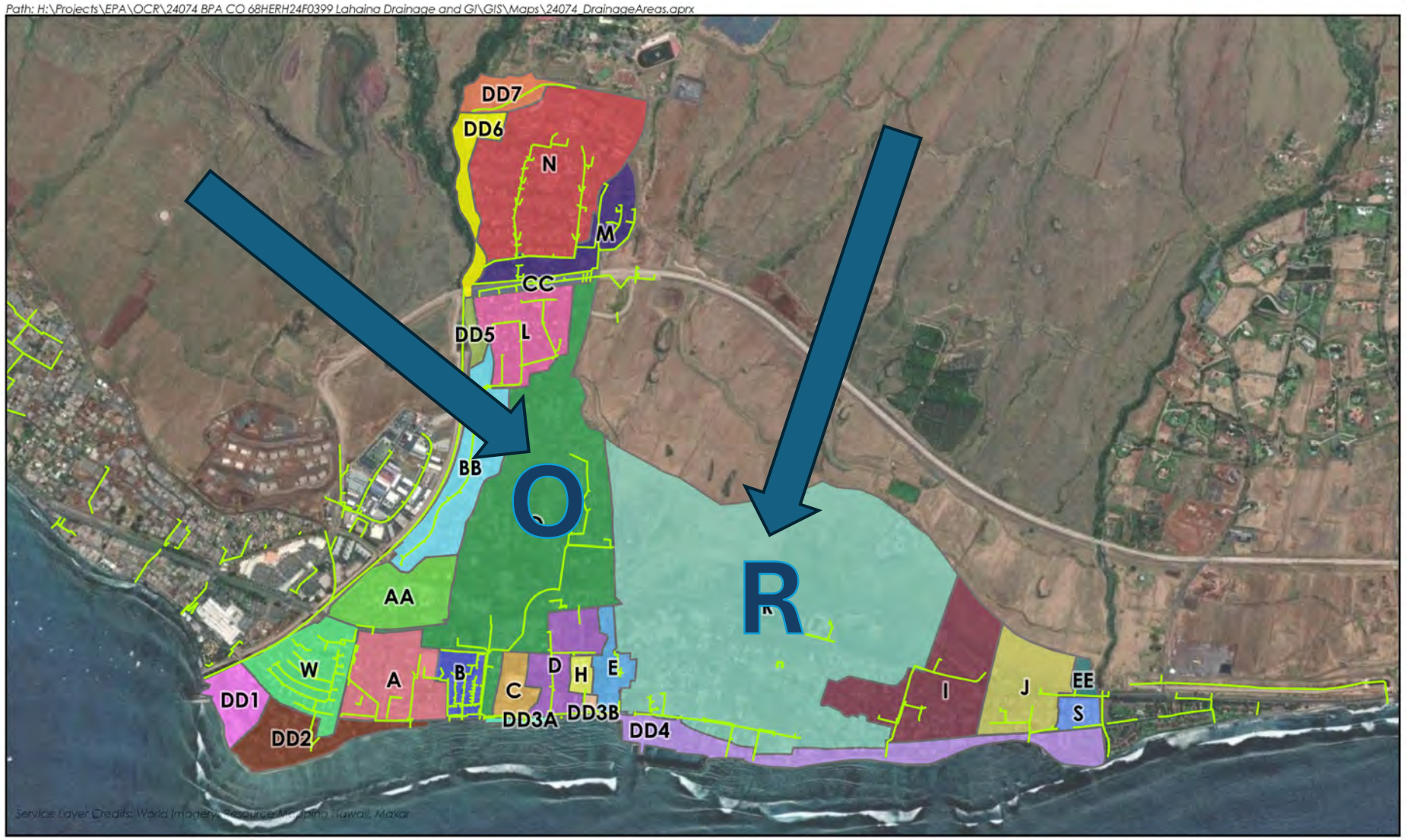
2025 Drainage Master Plan Update



Horsley Witten Group
Sustainable Environmental Solutions

Figure 8
Drainage areas were modified from 2005 based on updated infrastructure mapping and have not been field verified.

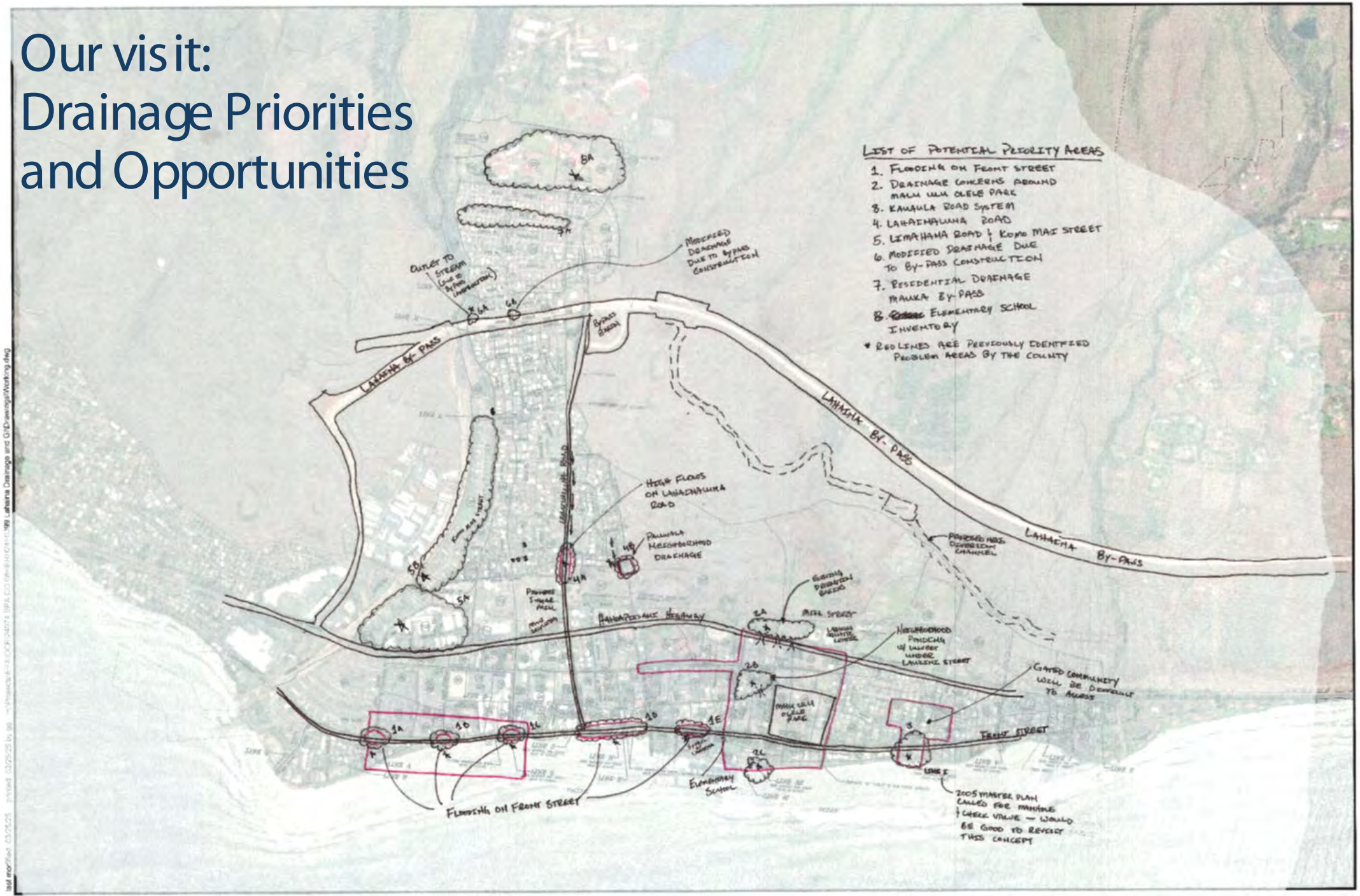
2025 Drainage Master Plan Update



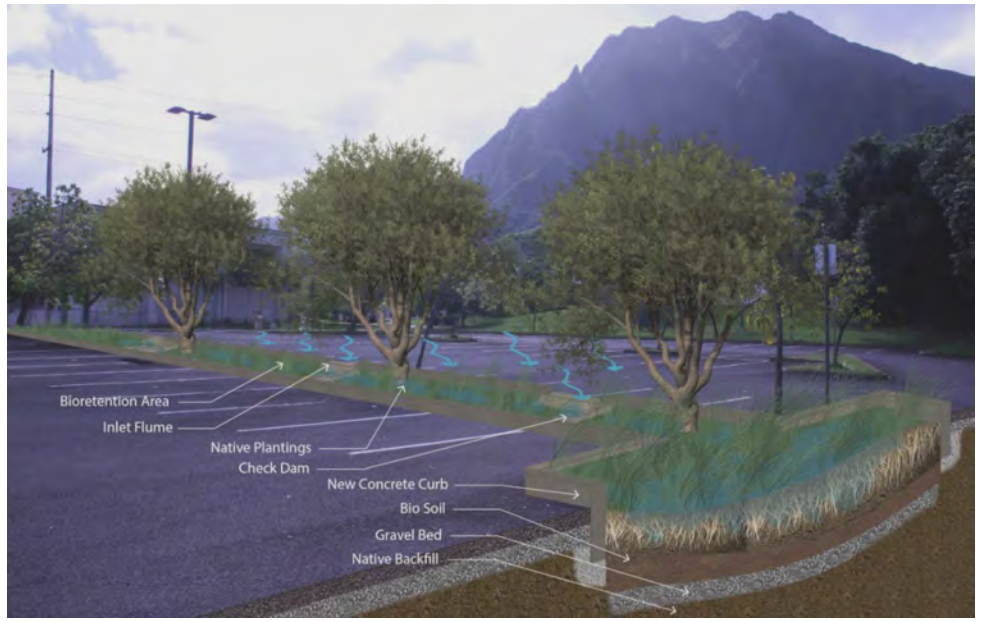
Horsley Witten Group
Sustainable Environmental Solutions

Figure 8
Drainage areas were modified from 2005 based on updated infrastructure mapping and have not been field verified.

Our visit:
Drainage Priorities and Opportunities



Green Infrastructure and Nature-Based Solutions



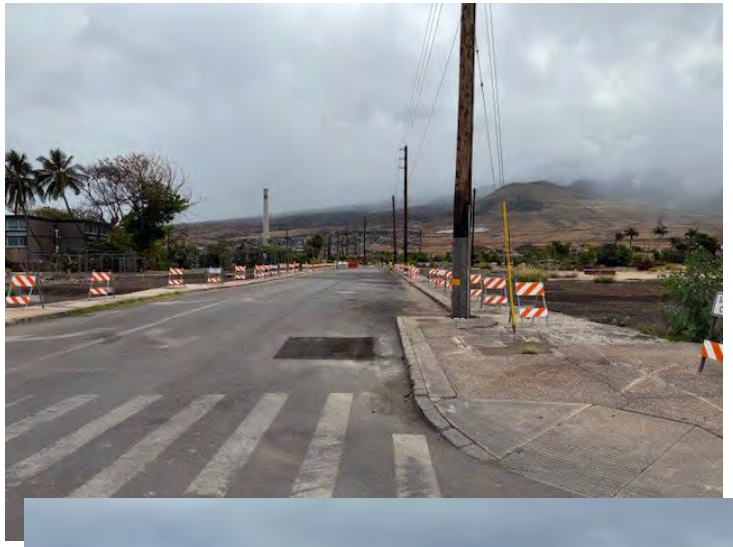








Friday in the Field















Our HW Team



Ellie Baker



Michelle West



Jonas Procton



Sydney Stanton

Project Partners:

- Maui County
- EPA
- FEMA

EPA - Lahaina Call Order ESTIMATED PROJECT SCHEDULE

4/11/2025

Task	Task Descriptions	2025				NOTES
		Apr	May	Jun	Jul	
1.0	**Project Initiation and Coordination**	⊗	⊗	⊗		3 Virtual Team Meetings Remaining
2.0	**Pre-Fire Data Review**					95% Complete
2.1	*Summary of pre-fire conditions*					
2.2	*Existing conditions map*					
2.3	*Virtual Meeting*					
2.4	*Initial Plan for Site Visit and Modeling*					
3.0	**Site Visit**					
3.1	*Site visit preparation, incl online mapping tool*					75% Complete
3.2	*Site visit*					Tentatively planned for May 15-21
3.2	*Field Report*					
4.0	**Modeling**					
4.1	*HydroCAD modeling*					Beginning HydroCAD in April
4.2	*Summary Memo*					
5.0	**Drainage Master Plan GSI Supplement**					
5.1	*Draft DMP Supplement*					
5.2	*Final GSI SUpplement*					
5.3	*Debrief call*				⊗	

⊗ *Indicates Meetings*

GSI = Need to Re-Envision the Built Environment





The evolution from *Pipe & Pond*

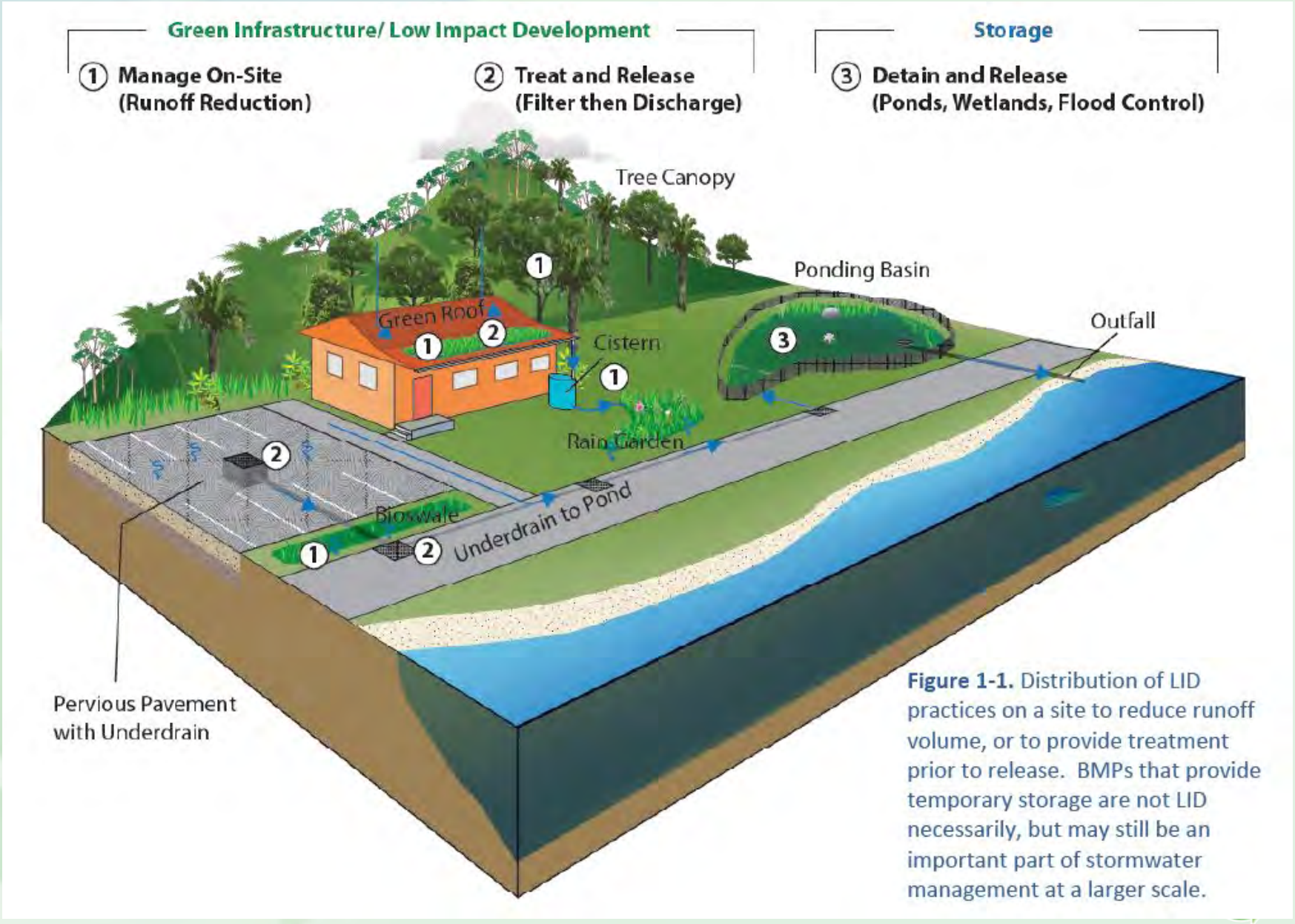


Figure 1-1. Distribution of LID practices on a site to reduce runoff volume, or to provide treatment prior to release. BMPs that provide temporary storage are not LID necessarily, but may still be an important part of stormwater management at a larger scale.

Using Vegetated Areas



- Preserve more green
- Let green areas work for you!
  - Bioretention and Rain Gardens
  - Bioswales
  - Planters & tree pits
- Upgrade turf to higher functional stormwater vegetation









Wahikuli Beach Park, West Maui







Witten Group, Inc.

Rethinking Hardscapes

- Reduce unnecessary impervious cover
- Use permeable pavers
- Use vegetated BMPs in ROW or required landscaping
- Use cisterns or storage chambers
- Disconnect remaining IC





Rethinking Hardscapes



Legend

- Study Area
- Maui Parcels

Impervious Cover

- Driveway
- Parking Lot
- Pool
- Roadway
- Rooftop
- Tennis Courts

N

0 200

1" = 200 Feet

Horsley Witten Group
Sustainable Environmental Solutions

Land Cover
Honokowai Water Quality Management Plan

Date: 2/12/2016 Figure 4

Rooftop Runoff = Water Reuse?



GSI for Roads











Tree Trench
SECTION





Conventional Cul-de-Sac

Improving Performance of Existing BMPs

- Lengthen flow paths and detention times
- Use vegetation
- Provide pretreatment
- Add filtering layers

