

APPENDIX E | CLIMATE VULNERABILITY MAPS

CONNECTING TO THE ONE WATER PLAN

This appendix provides additional detailed information that correlates to the following sections and figures.

CORRELATING SECTIONS AND INFORMATION

**5 Climate
Hotspot
Identification
Process**

5.2 Climate Exposure Mapping

App. E contains details of the GIS layers and sources used to construct the mapping tool and it features illustrative baseline maps. Also relates to **App. D Sec. 2.1**, which further explains which threats and assets were included in the geospatial analysis and the data sources for mapping layers.

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SECTION E.1: CLIMATE EXPOSURE MAPPING

E.1.1 PURPOSE

This appendix details the Climate Exposure Mapping effort undertaken to support the One Water Honolulu Plan (Plan). The primary objective of this initiative was to identify and map critical water infrastructure assets, spanning water resources, water, wastewater, recycled water, and stormwater systems, alongside vital access roads, community assets (e.g., schools, fire stations, hospitals), ecological zones, and socio-cultural resources. Developed using geographic information systems (GIS), these maps integrate and overlay eight core climate threats: wildfires, tsunamis, hurricanes, sea level rise flooding, coastal erosion, 100-year storms, extreme heat, and drought. By mapping these threats on top of key assets, these exposure maps facilitated the risk scoring and hotspot identification process described in Appendix D. This appendix documents the comprehensive GIS layers and sources utilized to construct the mapping tool (see Table E-1) and features illustrative baseline maps that informed the One Water Panel's prioritization of hotspots and recommendations for long-term climate adaptation.

Figure E-1 shows the risk scores for One Water assets islandwide, excluding very low risk assets. Assets that extend into the ocean include sewer and stormwater outfalls. Risk scores are calculated with the methodology described in Section 5.3 of the Plan, and further elaborated in Appendix D.2.2. Figure E-2 shows an example map of emergent groundwater under 3 feet of sea level rise in the Primary Urban Center, along with One Water and community assets (as described in Plan Section 5.2 and Appendix D.2.1). This example shows the dense urban layout of One Water assets. Figure E-3 shows the location of the 92 identified hotspots islandwide with callouts for the 14 Priority Hotspots. Hotspot identification and prioritization is elaborated in Appendix D.3.1 and D.3.2. Figure E-4 shows an example of the 100-year flood zones in the Hale'iwa/Waialua area, along with One Water and community assets. This example shows a country town layout of assets to compare with the dense urban example in Figure E-2.

E.1.2 GIS LAYER MAP LAYER DETAILS

Table E-1. GIS Layer Map Layer Details

MAP LAYER		DESCRIPTION	SOURCE
Climate Hazards	Coastal Erosion	Landward extent of the erosion hazard zone for lands falling within a zone with 80 percent likelihood of exposure to erosion, according to probabilistic modeling under a range of SLR levels from 0 to 10 feet.	Vitousek, S., P. L. Barnard, P. Limber, L. Erikson, and B. Cole (2017). A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change, <i>J. Geophys. Res. Earth Surf.</i> , 122, 782–806, doi:10.1002/2016JF004065.
	Sea Level Rise Wave Flooding	Wave-driven flooding for annually recurring wave conditions under a range of SLR levels using the Mean Higher High Water (MHHW) tidal datum using hydrodynamic models.	Mihami, FZ., Roeber, V. & Morichon, D. (2022). Efficient Numerical Computations of Long-Wave Run-Up and Their Sensitivity to Grid Nesting. <i>Water Waves</i> 4, 517–548. https://doi.org/10.1007/s42286-022-00070-8
	Sea Level Rise Passive Flooding	Overland, permanent coastal inundation from passive sea level rise.	Anderson, T., Fletcher, C., Barbee, M., Romine, B., & Lemmo, J. (2018). Modeling multiple sea level rise stresses reveals up to twice the land at risk compared to strictly passive flooding methods. <i>Nature Scientific Reports</i> 8: 14484 DOI:10.1038/s41598-018-32658-x
	Sea Level Rise Groundwater Inundation	Groundwater inundation includes locations where the shallow coastal groundwater table is projected to meet or exceed the ground surface elevation.	Habel, S., Fletcher, C.H., Rotzoll, K. and El-Kadi, A. (2017). Development of a model to simulate groundwater inundation induced by sea-level rise and high tides in Honolulu, Hawai'i. <i>Water Research</i> . ISSN 0043-135. http://dx.doi.org/10.1016/j.watres.2017.02.035
	Sea Level Rise Emergent Groundwater	Emergent groundwater includes locations where the groundwater is within 1 foot of, or above, the ground surface.	Habel, S., Fletcher, C., Anderson, T., & Thompson, P. (2020). Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure. <i>Nature Scientific Reports</i> , 10: 3796 DOI:10.1038/s41598-020-60762-4
	Sea Level Rise Shallow Groundwater	Shallow groundwater includes locations where the groundwater is within 1–5 feet of the ground surface and could impact buried infrastructure.	Habel, S., Fletcher, C., Anderson, T., & Thompson, P. (2020). Sea-Level Rise Induced Multi-Mechanism Flooding and Contribution to Urban Infrastructure Failure. <i>Nature Scientific Reports</i> , 10: 3796 DOI:10.1038/s41598-020-60762-4
	Sea Level Rise Passive Drainage Backflow	This layer shows flooding from passive marine flooding coupled with storm drain locations that are at or below the passive SLR scenario. The layer reveals the potential impact of urban coastal drainage infrastructure on the extent of passive SLR flooding.	Habel, S., Fletcher, C.H., Barbee, M.M., Fornace, K.L., (2024). Hidden Threat: The Influence of Sea-Level Rise on Coastal Groundwater and the Convergence of Impacts on Municipal Infrastructure. <i>Annual Review of Marine Science</i> . 16:1. https://www.annualreviews.org/doi/10.1146/annurev-marine-020923-120737
	100-Year Storm – DFIRM and FEMA Flood Hazard Zones	Digital Flood Insurance Rate Map (DFIRM) and Federal Emergency Management Agency (FEMA) Special Flood Hazard Areas (SFHA) for City and County of Honolulu. Floodplains for the 0.01 annual probability storm.	Hawai'i Statewide GIS Program. (2025). Flood Hazard Areas (DFIRM)—Honolulu County. https://geoportal.hawaii.gov/datasets/flood-hazard-areas-dfirm-honolulu-county/about
	100-Year Storm – NFHL Preliminary Hazard Zones	National Flood Hazard Layer (NFHL) Preliminary Flood Hazard Zones, based on FEMA flood mapping. These are used as secondary analysis.	Preliminary Flood Zone Changes. (n.d.). Retrieved May 15, 2026, from https://cchnl.maps.arcgis.com/apps/instant/media/index.html?appid=89832a7160374adeb2d6a89f11e25ab5
	Wildfire – Fire Risk Areas	Ratings of wildfire likelihood for major populated areas in Hawai'i from DLNR, Division of Forestry and Wildlife, Fire Management Program report <i>Communities at Risk (CAR) from Wild-Land Fires</i> .	Hawai'i Statewide GIS Program. (2024). Fire Risk Areas. https://geoportal.hawaii.gov/datasets/fire-risk-areas/about . Retrieved from: https://files.hawaii.gov/dbedt/op/gis/data/firerisk.shp.zip
	Wildfire – Fire Ignitions Heat Map 2012–2020	The number of historical ignitions per square mile per year across Hawai'i State. Used as secondary data.	Trauernicht, C. and Lucas L.P. 2016. Wildfire Ignition Density Maps for Hawai'i. College of Tropical Agriculture and Human Resources. University of Hawai'i at Mānoa. Pacific Fire Exchange. Forest and Natural Resource Management. September 2016, RM-21. Retrieved from: https://pacificfireexchange.org/maps-tools/
	Extreme Heat – One Day Heat Index – 2019	City and County of Honolulu Office of Climate Change, Sustainability & Resiliency Heat Index. One day heat index measured on August 31, 2019, temperature measurements, taken from the morning, afternoon, and evening.	CCH GIS. (2022). Afternoon Heat Index—Overview. https://www.arcgis.com/home/item.html?id=fcbce7e1873941a1a5e83d7af55e0aff . Retrieved from: https://cchnl.maps.arcgis.com/apps/MapSeries/index.html?appid=81a93d637086418f9118d8740a7e8f3c
	Extreme Heat – Heat Severity	Relative heat severity in urban areas across the United States. The urban heat island severity shows which areas of a city are hotter than average, categorized from 1 (mild) to 5 (significant).	ArcGIS REST Services Directory. (2023). NATIONAL/uhi_city_severity_2023. Retrieved from: https://server4.tplgis.org/arcgis4/rest/services/NATIONAL/uhi_city_severity_2023/ImageServer .
	Hurricane Storm Surge	NOAA SLOSH MOM layer for hurricane inundation from Categories 1–4 hurricanes.	NOAA. (2018). Hawai'i (Category 4 SLOSH MOMs) Storm Surge Inundation. https://noaa.hub.arcgis.com/maps/noaa::hawaii-category-4-slosh-moms-storm-surge-inundation/about
	Tsunami	Evacuation zone and extreme evacuation zone for tsunami inundation.	CCH, 2025. Hawai'i Statewide GIS Program: Tsunami Evacuation Zones. https://geoportal.hawaii.gov/datasets/HiStateGIS::tsunami-evacuation-zones/about
	Drought	Agriculture Drought Risk and Water Supply Drought Risk from the DLNR Revised Hawai'i Drought Plan.	DLNR. (2017). Revised Hawai'i Drought Plan Update.

MAP LAYER		DESCRIPTION	SOURCE
One Water Infrastructure Assets	Water – BWS Wells	Locations of BWS wells.	Not public data.
	Water – BWS Well Treatment Plant	Locations of BWS well treatment plants.	Not public data.
	Water – Water Pipe Prioritization	Locations of water pipelines with criticality prioritization.	Not public data.
	Groundwater Sources	Location of O’ahu aquifers.	Hawai’i Statewide GIS. (2025). DOH Aquifers. https://geoportal.hawaii.gov/datasets/a292a6aaefa148b78634b084e7a5b898_4/explore?location=21.346408%2C-157.803837%2C11
	Sewer – Submersible Pump	Locations of Honolulu Department of Environmental Services (ENV) submersible sewage pumps.	CCH GIS. (2025). Sewer—Submersible Pump. https://honolulu-cchnl.opendata.arcgis.com/datasets/6e06aa6294b14cadb82ecf0d3903fdbc_17
	Sewer – Treatment Plant	Locations of wastewater treatment plants operated by Honolulu ENV.	CCH GIS. (2025). Sewer—Treatment Plant. https://honolulu-cchnl.opendata.arcgis.com/datasets/57b9b4a63ffe4c62ae48da7b4d0c2d49_15
	Sewer – Pump Station	Point locations of sewer pump stations.	CCH GIS. (2025). Sewer—Pump Station. https://honolulu-cchnl.opendata.arcgis.com/
	Sewer – Main	Locations of Honolulu ENV main sewer lines.	CCH GIS. (2025). Sewer—Mains. https://honolulu-cchnl.opendata.arcgis.com/datasets/a732479213364d97b6fcb69ffdd86ae7_1
	Sewer – Lateral	Pipe segments running from the sewer main to the residential connection points.	CCH GIS. (2025). Sewer Laterals. https://honolulu-cchnl.opendata.arcgis.com/maps/93cdcd3f41f143bcb7b1f6dff0712415
	Sewer – Cesspools Priority	Hawai’i Cesspool Prioritization (HCPT) cesspools.	Hawai’i Statewide GIS. (2025). HCPT Cesspools. https://geoportal.hawaii.gov/maps/7a57005f120b4027977d9cdcb9451ea7
	Stormwater Structures	Point locations of stormwater structures including manholes, catch basins, inlets, outlets, and undefined structures.	CCH GIS. (2025). Storm Water—Structure. https://honolulu-cchnl.opendata.arcgis.com/datasets/b040fe5c7fd64c9c8a3fffb02798637_3
	Stormwater Conduits	Locations of stormwater conduits on O’ahu.	CCH GIS. (2025). Storm Water—Conduit. https://honolulu-cchnl.opendata.arcgis.com/datasets/4cc96099dcd94132b42393f61805e44d_4
	Streams – Perennial	Streams on O’ahu that carry flowing water continuously throughout the year, regardless of weather conditions.	CCH GIS. (2023). Streams—Perennial. https://honolulu-cchnl.opendata.arcgis.com/datasets/1eacaf6f0a8a4b809ea76b89c1300339_4
	Streams – Intermittent	Small streams, ditches, and culverts where flow generally only occurs during the wet season 50 percent of the time or less.	CCH GIS. (2023). Streams- Intermittent. https://honolulu-cchnl.opendata.arcgis.com/maps/871cfabbb99e4dbf835d6fb338d0b1fd
Community Assets	Hawai’i Department of Transportation (HDOT) Asset and Hazard Assessment	State highway assets including bridges, culverts, tunnels, and roadways, along with susceptibility to various hazards including landslide, sea level rise, coastal flood, storm surge, tsunami, wildfire, lava flow, temperature, and precipitation.	HDOT. (2021). All Hazard & Asset Overlays Map. https://histategis.maps.arcgis.com/apps/mapviewer/index.html?webmap=053180d964a04252a8ab802186e05a68
	Electrical – Transmission Lines	Electric power transmission lines. Transmission lines are the system of structures, wires, insulators, and associated hardware that carry electric energy from one point to another in an electric power system. Lines are operated at relatively high voltages varying from 69 kilovolts (kV) up to 765 kV and are capable of transmitting large quantities of electricity over long distances.	National Homeland Infrastructure Foundation Level Database (HIFLD). (2024). Electrical- Transmission Lines. https://services2.arcgis.com/LYMgRMwHfrWWEg3s/arcgis/rest/services/HIFLD_US_Electric_Power_Transmission_Lines/FeatureServer
	Electrical – Substations	Electric power substations are primarily associated with electric power transmission. In this layer, substations are considered facilities and equipment that switch, transform, or regulate electric power at voltages equal to, or greater than, 69 kV.	National Homeland Infrastructure Foundation Level Database (HIFLD). (2022). Electrical- Substations. https://services.arcgis.com/njFNhDsUCentVYJW/arcgis/rest/services/Substations/FeatureServer
	Hospitals & Clinics	Locations of hospitals and clinics across O’ahu.	CCH GIS. (2025). Hospitals and Clinics. https://honolulu-cchnl.opendata.arcgis.com/datasets/b9882f20858545c79699d5969498d5a8_2
	Police Stations	Locations of police stations within the state of Hawai’i as of August 2017.	Hawai’i Statewide GIS. (2022). Police Stations (Statewide). https://geoportal.hawaii.gov/datasets/police-stations-statewide
	Schools – Public	Public school locations for the main Hawaiian islands as of November 2024.	Hawai’i Statewide GIS. (2024). Public Schools. https://geoportal.hawaii.gov/maps/ba92e2fc0d2d4497af7289cb4ab552a7
	Schools – Private	Private school locations for the main Hawaiian islands as of November 2021 from the Hawai’i Association of Independent Schools (HAIS).	Hawai’i Statewide GIS. (2021). Private Schools. https://geoportal.hawaii.gov/datasets/95e39721d53c4319a5a4525866515458_8
	Fire Stations	Fire Stations in the state of Hawai’i (including volunteer fire stations) as of December 2025.	Hawai’i Statewide GIS. (2026). Police Stations (Statewide). https://geoportal.hawaii.gov/datasets/HiStateGIS::statewide-fire-stations-all-types/about
	Highway Bridges	National Bridge Inventory for Hawai’i as of December 2020. This data is a subset of the National Bridge Inventory from the Federal Highways Administration.	Hawai’i Statewide GIS. (2021). National Bridge Inventory. https://geoportal.hawaii.gov/datasets/9a9e1f840dc84b9a9b25775f2d7e0acf_9/
	Base Yards	Location of CCH and state base yards.	Not public data.
	Dams	Locations of regulated dams from the DLNR Engineering Branch.	Hawai’i Statewide GIS. (2019). Dams. https://geoportal.hawaii.gov/datasets/dams
	Dam Evacuation Zones	Locations of dam evacuation zones from O’ahu Dam Evacuation Planning Tool.	Hawai’i DLNR Dam Safety. O’ahu Dam Evacuation Planning Tool. https://experience.arcgis.com/experience/d9e2e0555cce49faa0917ba7fec99349
	Major Streets	Major streets on O’ahu including freeways and highways.	CCH GIS. (2024). Major Streets. https://honolulu-cchnl.opendata.arcgis.com/maps/96c6a97dd06a4cdeaff325298bb3c0a8

MAP LAYER		DESCRIPTION	SOURCE
	Street Centerlines	Street network of O’ahu, contains both non-military and military streets.	CCH GIS. (2025). O’ahu Street Centerlines. https://honolulu-cchnl.opendata.arcgis.com/datasets/oahu-street-centerlines
	Building Footprints	Building structure footprints derived from National Geospatial-Intelligence Agency LIDAR data, Underground Services, inc. Hawai’i aerial data collection, and pictometry data.	CCH GIS. (2023). Building Footprints (CCH). https://honolulu-cchnl.opendata.arcgis.com/datasets/aa444ba7c76e475f8dc54e0fa0913b34_0
Socio-Cultural Resources	Hawaiian Homelands	2020 Census Hawaiian Homeland Boundaries, with population, for the state of Hawai’i, excluding northwest Hawaiian islands and clipped to the coastline. (Source: United States Census Bureau, September 2021)	Hawai’i Statewide GIS. (2021). 2020 Census Hawaiian Homelands. https://geoportal.hawaii.gov/datasets/e7a2b95dec99477489bc3aa0b6f41017_30
	O’ahu Social Vulnerability Index	A customized social vulnerability index (SOVI) to O’ahu from the Office of Climate Change, Sustainability and Resiliency (CCSR) development of the Resilience Strategy. The index considers socioeconomic drivers of vulnerability and exposure to coastal hazards.	Social Vulnerability Map. (n.d.). Retrieved May 15, 2026, from https://cchnl.maps.arcgis.com/apps/mapviewer/index.html?webmap=2964a940b4844eff90c167b1a9dba391
	Zoning	Land use zoning designations from the City Zoning Code.	CCH GIS. (2025). Zoning. https://honolulu-cchnl.opendata.arcgis.com/datasets/b07278fbf1844df4a0ffcf5cf809fdf6_0
Ecological Features	Aquifers	Aquifer Sector Area and Aquifer System Area boundaries, as determined by the DLNR Commission on Water Resource Management.	Hawai’i Statewide GIS Program. (2022). DLNR Aquifers. https://geoportal.hawaii.gov/datasets/3bcbe7b290df40b3abf0450f52d9aebb
	Elevation Contours	Scanned contours in 40-foot intervals from the USGS Topographic Map Series.	CCH GIS. (2023). Elevation. https://honolulu-cchnl.opendata.arcgis.com/datasets/d2639cdca58d4b329f0cf25e77134e28_0
	Watersheds	Watershed unit boundaries for the major Hawaiian islands.	Hawai’i Statewide GIS Program. (2024). Watersheds. https://geoportal.hawaii.gov/maps/cfe1f5708d944a15ada695fc18f423a0
	Reserves	Significant natural landscapes, features, and places of cultural significance.	Hawai’i Statewide GIS Program. (2020). Reserves. https://geoportal.hawaii.gov/datasets/reserves
	Critical Habitat Ecosystem	O’ahu Critical Habitat – Ecosystem as of February 2017, from the U.S. Fish and Wildlife Service, Pacific Islands Office.	Hawai’i Statewide GIS Program. (2022). O’ahu Critical Habitat—Ecosystem. https://geoportal.hawaii.gov/datasets/4322d17256244da6804dfd51325a76b2
	Coral Reefs	Coral reefs located in marine waters within the vicinity of the main Hawaiian islands and recorded on the nautical charts.	Hawai’i Statewide GIS Program. (2024). Coral Reefs Hawai’i Statewide GIS Program. https://geoportal.hawaii.gov/datasets/9229d814438349948c99b5e61a084418
	Wetlands	Wetlands in the state of Hawai’i from the U.S. Fish and Wildlife Service, as of November 2024.	Hawai’i Statewide GIS Program. (2024). Wetlands. https://geoportal.hawaii.gov/datasets/2250370303ef44c8becf4fbe549e3f43_39/explore?location=21.362941%2C-157.857015%2C11
Geopolitical Boundaries	Development Plan Areas	Geographic boundaries which represent eight planning regions: Primary Urban Center, Central O’ahu, ‘Ewa, Waianae, North Shore, Ko’olau Loa, Ko’olau Poko and East Honolulu. These are now called “Sustainable Communities Plan Areas” rather than “Development Plan Areas.”	CCH GIS. (2025). Sustainable Communities Plan Areas. https://honolulu-cchnl.opendata.arcgis.com/maps/6bde9cfa4899432ba7f4c4cde8065220
	United States Congressional Districts	Hawai’i United States Congressional District Boundaries as adopted by the State of Hawai’i Reapportionment Commission in 1991.	Hawai’i Statewide GIS Program. (2024). U.S. Congressional Districts 1991. https://geoportal.hawaii.gov/datasets/f6a365be692740369d03a48344dd06c4_1
	Hawai’i State House Districts	Hawai’i State House District Boundaries as adopted by the State of Hawai’i Reapportionment Commission in 1991.	Hawai’i Statewide GIS Program. (2024). Hawai’i State House Districts 1991. https://geoportal.hawaii.gov/datasets/4116dea7b5974d508c745513a723a850_4
	Neighborhood Board Sub-District	Boundaries of the Neighborhood Board Areas, as designated in the 2008 Neighborhood Plan of the City and County of Honolulu.	CCH GIS. (2023). Neighborhood Board Subdistricts. https://honolulu-cchnl.opendata.arcgis.com/datasets/5a27e30d2816494db2aaf04729a32a90_6
	Tax Parcels	Tax Map Key (TMK) Parcels for the City and County of Honolulu.	CCH GIS. (n.d.). Parcels—Tax. Retrieved May 15, 2026, from https://honolulu-cchnl.opendata.arcgis.com/datasets/3216a20b21fd438495716a78c4642737_1

E.1.3 MAPPING INDEX SUPPLEMENTS

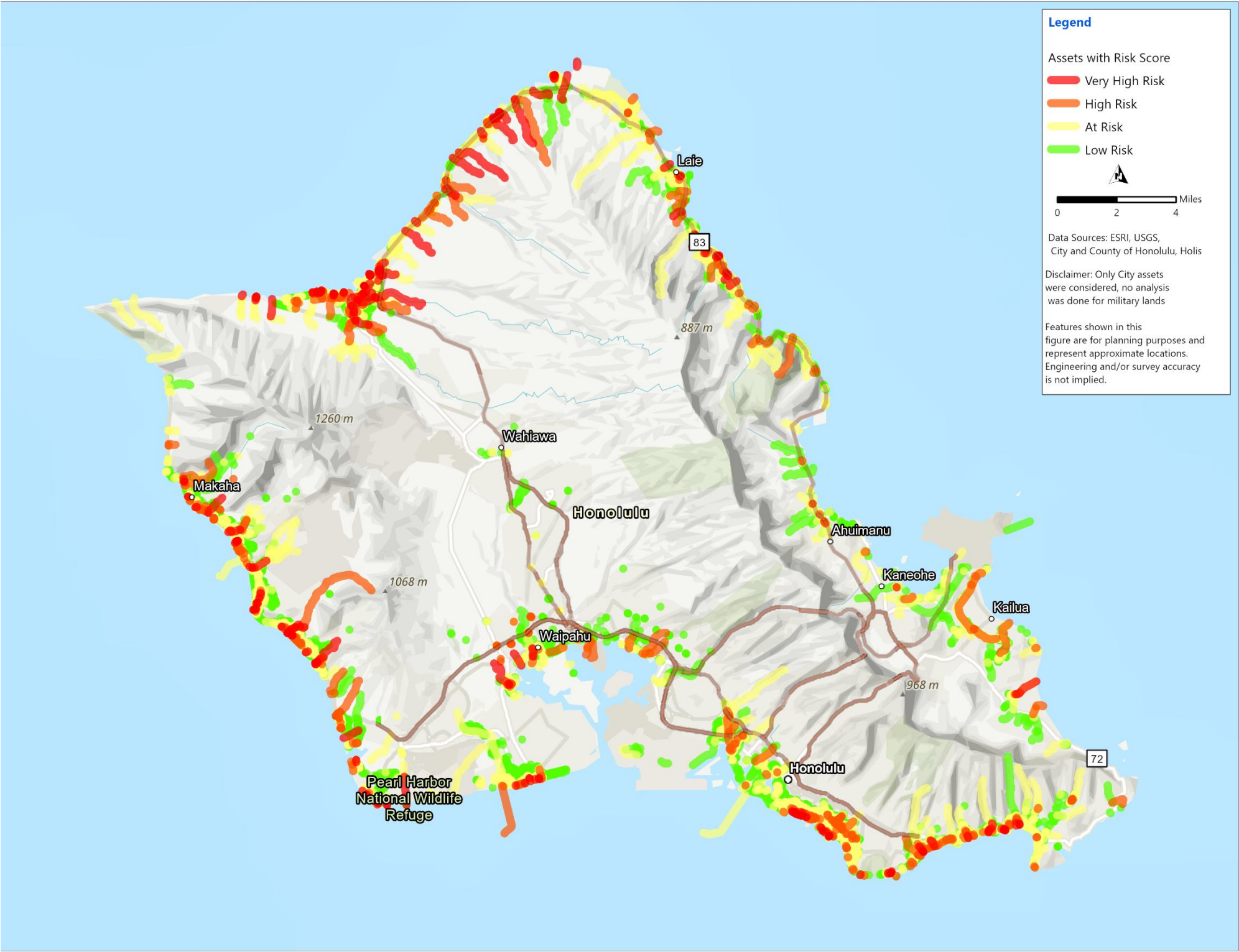


Figure E-1. Map of risk scores for OWH assets islandwide, with very low risk excluded

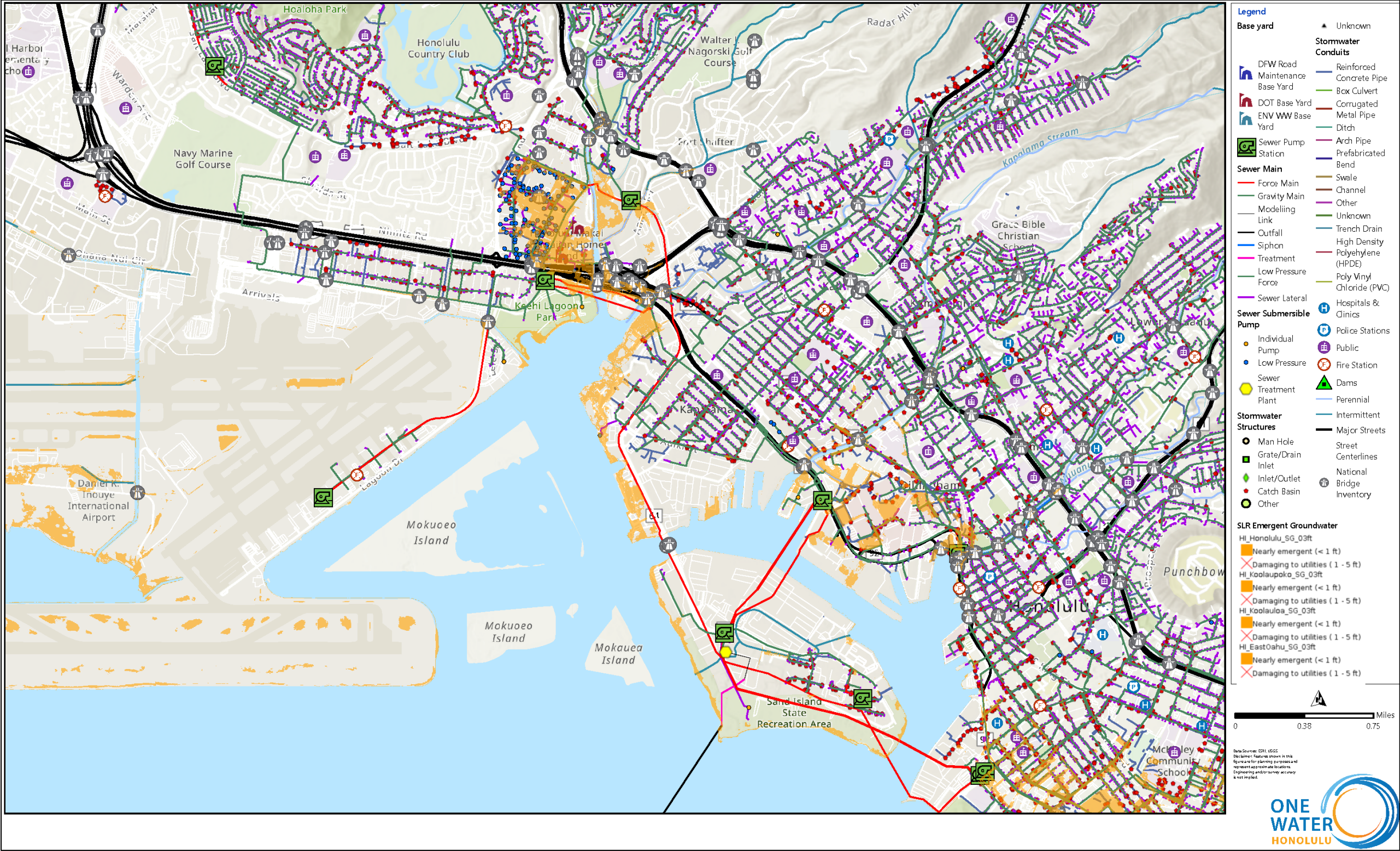


Figure E-2. Map of SLR 3-foot emergent groundwater (represented by orange shading) in the Primary Urban Center, overlaid with One Water and community assets in the area

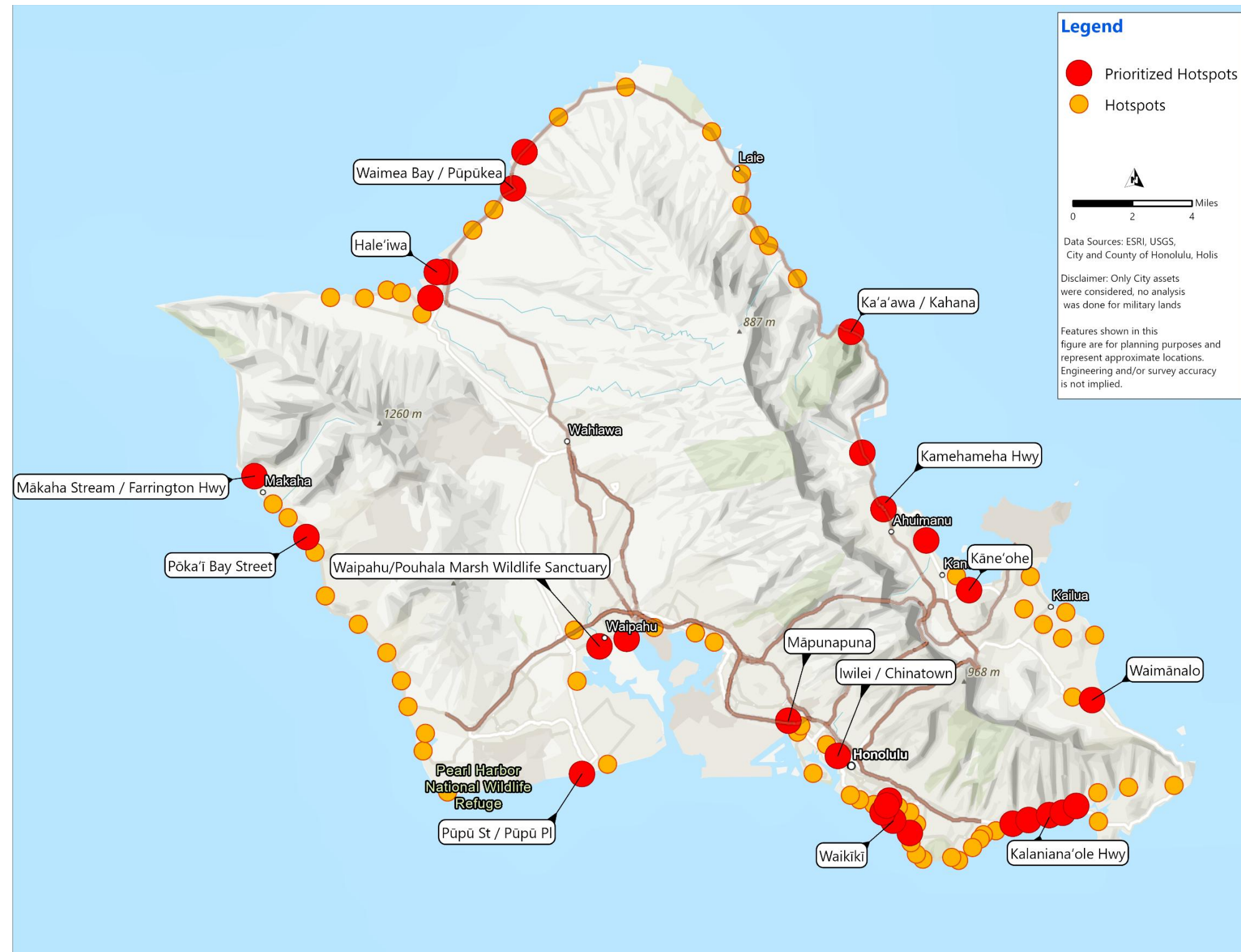


Figure E-3. Map of 92 hotspots (orange circles) around O‘ahu, with callouts for the 14 prioritized hotspots (larger red circles)

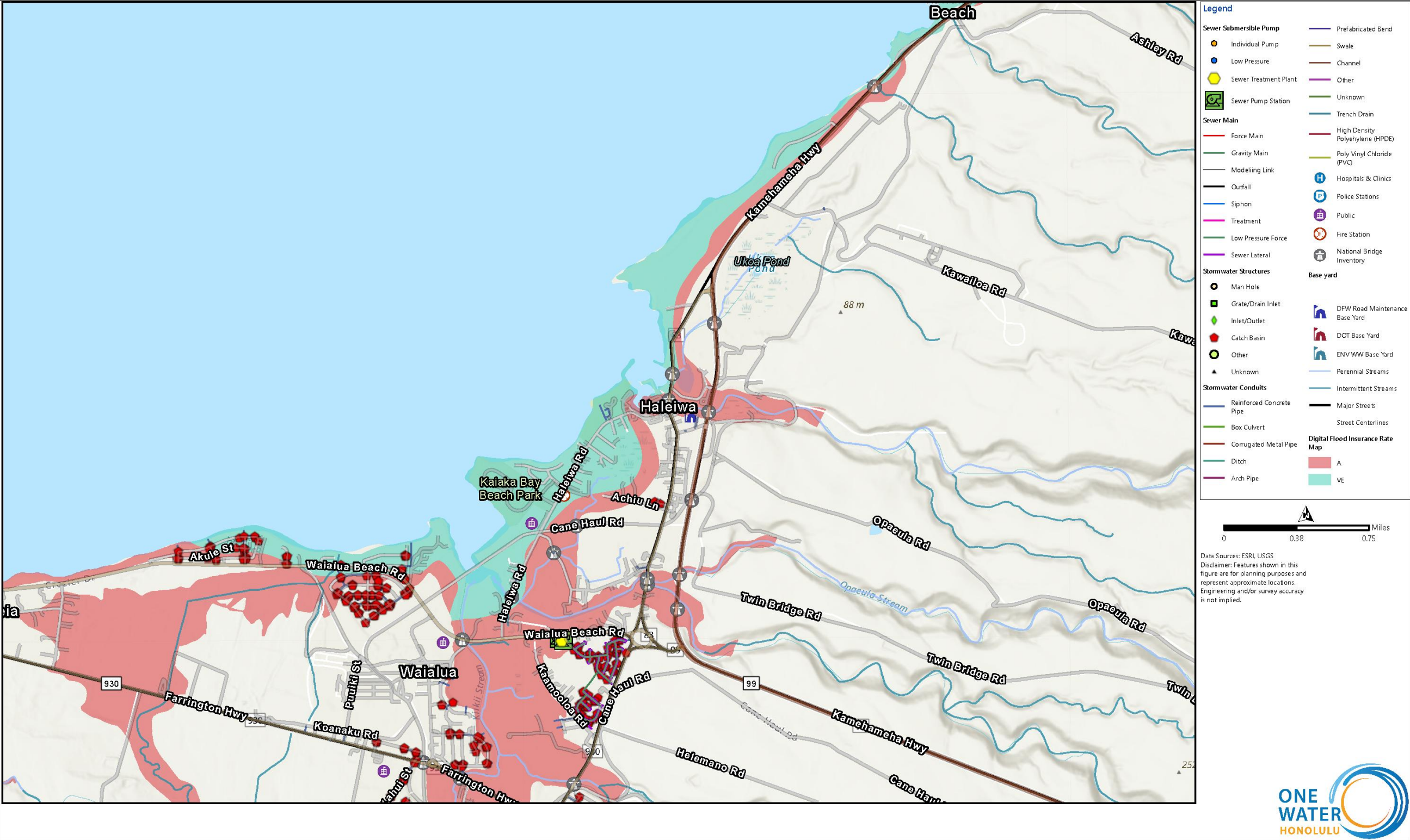


Figure E-4. Map of 100-year flood overlaid with One Water and community assets in the towns of Hale'iwa and Waialua on the North Shore