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ADDENDUM

UPDATE TO THE 2008 CULTURAL IMPACT ASSESSMENT AND KA PAʻAKAI O KA ʻĀINA ANALYSIS FOR THE PROPOSED MAKAKILO QUARRY EXPANSION, HONOULIULI AHUPUAʻA, KAPOLEI, ʻEWA MOKU, ISLAND OF OʻAHU

[TMK: (1) 9-2-003:074 (POR.)]

Exhibit "S"

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Note: *In this report, the spellings and the use of diacritical marks (glottal stops and macrons) follow conventions employed by Pukui and Elbert (1986) and Pukui et al. (1974) with limited exceptions – spellings and diacritical marks in quotations, titles, and proprietary names are given as they appear in the original sources.*

Cover Image: *View of Makakilo Quarry and surrounding landscape, taken from the northeast side of the proposed expansion project area (view to east).*

1.0 INTRODUCTION

At the request of Grace Pacific, LLC, Pacific Legacy, Inc. has prepared this addendum and Ka Paʻakai O Ka ʻĀina Analysis to update the Cultural Impact Assessment (CIA) prepared in 2008 by Pacific Legacy (Mooney and Cleghorn 2008) for the proposed expansion area at the Makakilo Quarry, Kapolei, Honouliuli Ahupuaʻa, ʻEwa District, Oʻahu [TMK: (1) 9-2-003:074 (por.)]. The proposed expansion comprises an area of approximately 15.6 acres on the west side of the current Makakilo Quarry footprint. This expansion will provide Grace Pacific, LLC with access to a seam of high-quality rock to be used in concrete and asphalt paving. In addition to the proposed expansion, Grace Pacific, LLC intends to apply for modification to their current quarry permit that would extend the permit 15 years beyond its current expiry (from 21 December 2032 to 21 December 2047) and expand hours of hot mix asphalt/concrete production and sales to 24 hours per day, 7 days per week. Mining would continue to be restricted to daytime use only.

The purpose of the 2022 update to the CIA is to evaluate potential impacts to traditional cultural practices as a result of the proposed project, in accordance with the guidelines for assessing cultural impacts, adopted by the State of Hawaiʻi Environmental Council on 19 November 1997, and to provide a Ka Paʻakai O Ka ʻĀina Analysis in accordance with Article XI, Section 7 of the Constitution of the State of Hawaiʻi. For the purposes of this addendum, Honouliuli Ahupuaʻa is considered the overall study area, while the project area is defined as the 15.6-acre proposed expansion area (Figure 1).

1.1 LEGISLATIVE CONTEXT

Article XI, Section 7 of the Constitution of the State of Hawaiʻi obligates the state to "protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupuaʻa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights." As an outcome of Ka Paʻakai O Ka ʻAina v. Land Use Commission, the Hawaiʻi State Supreme Court developed an analytical framework to "help ensure the enforcement of traditional and customary native Hawaiian rights while reasonably accommodating competing private development interests" (Case Number 94 Hawaiʻi 31, P.3d 1068). This framework has become known as the "Ka Paʻakai Analysis," and it requires the following specific findings and conclusions be addressed:

(1) The identity and scope of valued cultural, historical, or natural resources within the project area, including the extent to which traditional and customary native Hawaiian rights are exercised;
(2) The extent to which those resources, including traditional and customary native Hawaiian rights, will be affected or impaired by the proposed action; and
(3) The feasible action, if any, to be taken by the Land Use Commission to reasonably protect native Hawaiian rights if they are found to exist.

1.2 METHODS

In an effort to identify whether any valued cultural, historical, or natural resources are present within the current project area, as well as the extent to which traditional and customary native Hawaiian rights are exercised, Pacific Legacy has produced this addendum update to the 2008 CIA and conducted background research with regard to past land use in this region, reviewed previous cultural studies for the area that include consultation and oral-historical interviews, and conducted interviews with persons knowledgeable about traditional practices in the area.

In conjunction with this Ka Paʻakai Analysis and addendum update to the 2008 CIA (Mooney and Cleghorn 2008), Pacific Legacy conducted a literature review and field inspection of the proposed expansion area. The field inspection was completed on 7 June 2022 (Swift et al. 2022) and several historic properties were identified. The 15.6-acre proposed expansion area is currently undergoing an archaeological inventory survey as recommended by SHPD (Project No. 2022PR01199, Doc. No. 2210LS20).

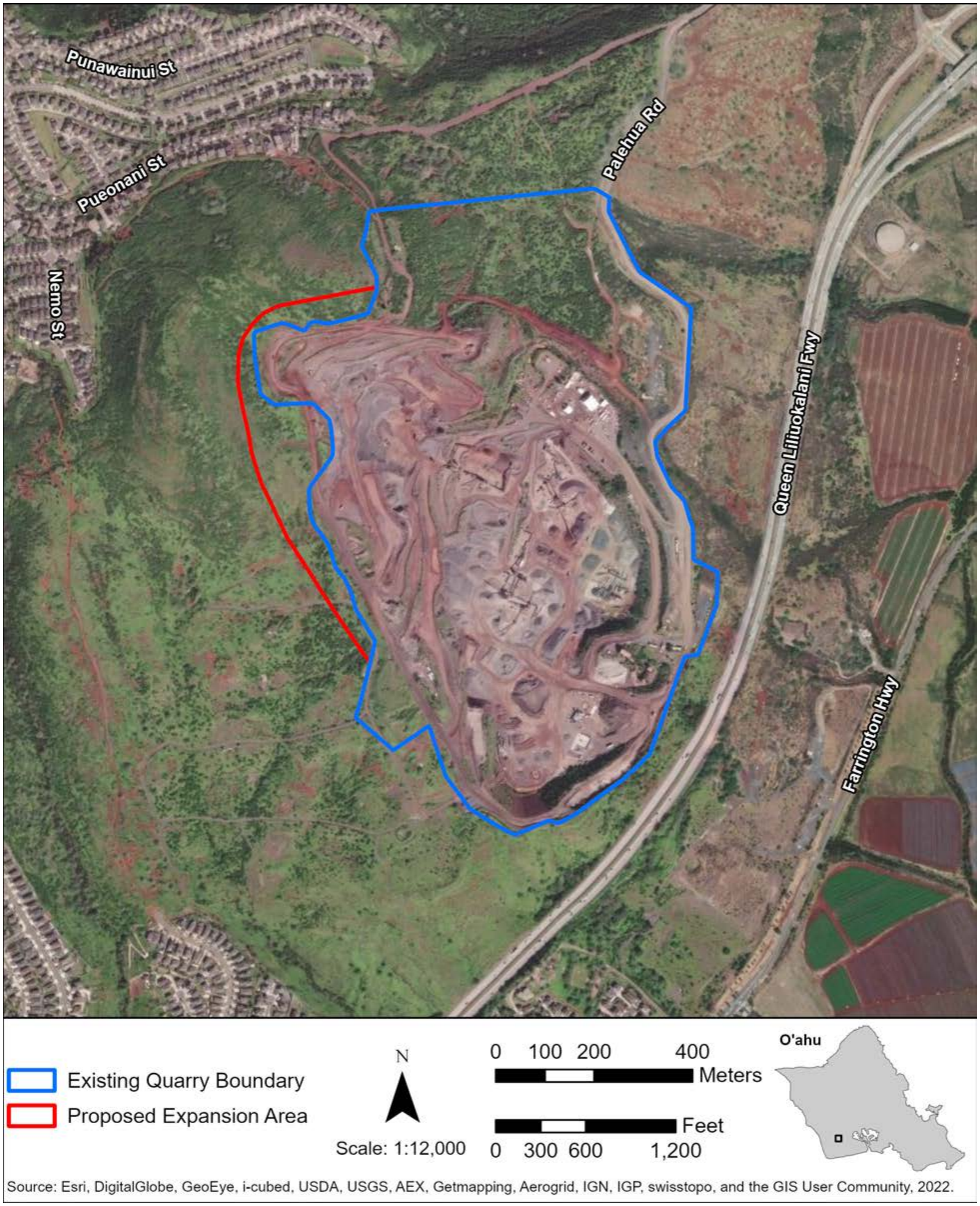

Figure 1. Location of the proposed 15.6-acre expansion to the Makakilo Quarry footprint and the project area for the Cultural Impact Assessment.

2.0 IDENTIFICATION OF VALUED CULTURAL, HISTORICAL, OR NATURAL RESOURCES

2.1 CONCISE CULTURE-HISTORICAL BACKGROUND FOR HONOULIULI AHUPUAʻA

The Makakilo Quarry Proposed Expansion Project Area is located on the southwest flank of Puʻu Makakilo, just outside the city of Kapolei and *mauka* (inland) of the H-1 Freeway. It is surrounded by Makakilo and Makalapa Gulches to the west, Kaloʻi Gulch to the north, and Hunehune Gulch to the east, all of which are seasonal drainages. Puʻu Makakilo has a steep, kidney-shaped peak that rises to ca. 950 feet above mean sea level (AMSL) and is the most prominent of several cinder cones that lie at the southern foot of the Waiʻanae Mountain Range. It lies within the traditional land division called Honouliuli Ahupuaʻa, in the ʻEwa District. Honouliuli, which translates to "dark bay" (Pukui et al. 1974:51) is the largest *ahupuaʻa* on the island of Oʻahu (approximately 40,640 acres), and it forms a portion of the ʻEwa Plain. Welser et al. (2020) suggest that the name "dark bay" may refer to the dark waters of West Loch at the mouth of Honouliuli Stream.

Most known oral historical accounts of Honouliuli focus on the eastern periphery of the ʻEwa Plain, in the area surrounding West Loch, as this was generally known to be the political and cultural center of Honouliuli Ahupuaʻa. However, a small number of accounts also pertain to central inland Honouliuli. Some of these accounts are related here, and the reader is referred to Maly (2022) for a detailed account of significant place names and *moʻolelo* of Honouliuli Ahupuaʻa.

Puʻu Makakilo literally translates as "observing eyes hill," and is located in the center of Honouliuli Ahupuaʻa within the *moku* or district of ʻEwa (Pukui et al. 1974:201). A manuscript housed in the T. Kelsey Collection at Bishop Museum (Kelsey, *Hawaiian Ethnological Notes Vol. 1*, unpublished ms, p. 820) notes that the area referred to as Makakilo or Makakilo City was once called Hanalei and was described as "a small flat land with a little gulch on either side on the right of Puuloa mauka of Puu-o-Kapolei" (as cited in Sterling and Summers 1978:34).

Puʻu o Kapolei translates to "hill of the beloved Kapo," referring to an elder sister of the goddess Pele (Pukui et al. 1974:89). Sterling and Summers (1978) note that Puʻu o Kapolei was "one of the most famous hills in the olden days" (Sterling and Summers 1978:33), and a major point of reference for travelers going east or west through Honouliuli. McAllister (1933) observed that the old government road passed behind Puʻu o Kapolei, and the area was covered in sugarcane by the late 1890s (McAllister 1933:108; however, the sugarcane fields were outside the current project area, see Figure 2). ʻĪʻī also references this trail as one of the three routes to Waiʻanae: "As mentioned before, there were three trails to Waianae, one by way of Puu o Kapolei, another by way of Pohakea, and the third by way of Kolekole" (ʻĪʻī 1959:97).

Significantly, Puʻu o Kapolei was the landmark used to mark the changing of the seasons on Oʻahu:

> When the sun reached the equator and (began to) move northward, it set right over (the islet of) Kaʻula and it moved on and set over Kawaihoa; and the Makaliʻi season when the sun set (kau) from Kaʻula to Kawaihoa was called Kau, and the Kau season was also called after the resting place of Kane (Kau-lana-a-Kane). When it set (again) at Kaʻula and turned south the season was called Hoʻoilo. In the same way the people of Oahu reckoned

> from the time when the sun set over Puʻuokapolei until it set in the hollow of Mahinaona and called this period Kau, and when it moved south again from Puʻuokapolei and it grew cold and the time came when young sprouts started, the season was called from their germination (oilo) the season of Hoʻoilo. There were therefore two seasons, the season of Makaliʻi and the season of Hoʻoilo. (Kamakau as quoted by Sterling and Summers 1978:34)

Kamaunuaniho, the grandmother of Kamapuaʻa, is said to have had a house on Puʻu o Kapolei, less than two miles south of Makakilo. However, the area around this house may have been disturbed or dismantled during post-Contact cane and sisal planting (Figure 3). A story of Kamaunuaniho is recounted in Sterling and Summers (1978):

> Kamapuaa subsequently conquered most of the island of Oahu, and, installing his grandmother as queen, took her to Puuokapolei, the lesser of the two hillocks forming the southeastern spur of the Waianae mountain range, and made her establish court there. This was to compel the people who were to pay tribute to bring all the necessities of life from a distance, to show his absolute power over all.
>
> Puuokapolei is some little distance from Sisal, towards Waianae, and is as desolate a spot as could be picked out on the whole island. It is almost equally distant from the sea, from which came the fish supplies; from the taro and potato patches of Ewa, and from the mountain ravines containing the banana and sugarcane plantations.
>
> A very short time ago the foundations of Kamaunuaniho's house could still be seen at Puuokapolei; also the remains of the stone wall surrounding her home. It has even been said that her grave could then be identified, but since the extension of cane and sisal planting to the base of Puukapolei, it is possible that the stones may have been removed for wall-making. (Nakuina as quoted by Sterling and Summers 1978: 34)

McAllister (1933) observed a large rock shelter on the side of Puʻu o Kapolei which was rumored to be this dwelling place of Kamapuaʻa and Kamaunuaniho. He also documented the Puʻu Kapolei Heiau (Site 138) in the same vicinity (McAllister 1933:108). Puʻu o Kapolei has been nominated as a traditional cultural property (TCP) (Monahan 2020).

One interviewee for the present study, McD Philpotts, noted the significance of the current project area due to its connection with the five brothers who watch over Oʻahu: Makaīwa, Makaʻike, Makaloa, Maka-Io, and Makakilo. Philpotts referenced a *moʻolelo* on this subject related by Analu Kameeiamoku Josephides in a CIA for the Waimanalo Gulch Sanitary Landfill Expansion conducted by Cultural Surveys Hawaiʻi, Inc.:

> Another concern that I may have is the place names of this particular area. A story that has been passed down to me from my kupuna is that there were five brothers who were the watchers. Their names were Makaīwa, Makaʻike, Makaloa, Maka-Io, and Makakilo. It was known that Makaīwa was to the farthest west and that Makakilo was to the farthest east. That these five brothers were the eyes of the Oʻahu people and were their protectors. They would watch for enemy intruders and relay messages to their makulu (runners). If enemy canoes were seen the makulu would run to the various districts and warn the chief and his/her people. This is why Oʻahu was a hard island to conquer in the ancient times. By the time the war canoes of the enemies would reach the shores they would be greeted by the warriors of Oʻahu, thus the enemies were never allowed to land upon the shores of Oʻahu. (Analu Kameeiamoku Josephides, in Souza et al. 2006:7–128, 129)

Josephides also related being told that in the old days, homes were not built in this region, “except for the mauka area of Makaīwa to the west, the mauka area to the east known as Makakilo, and the makai area below where in ancient time was the dwelling place of the Kamapuaʻa ʻohana” (Souza et al. 2006:7–118), as these were the paths of the Night Marchers.

Water, and often its scarcity, has been a constant theme in the history of the Makakilo area. In the 1800s, it was said that Kaloʻi (“the taro patch”), the gulch located directly north of Makakilo, was one of the few places in the area that showed any potential for procuring fresh water. William R. Castle named a spring he tapped in the gulch “Wai o Kakela,” though *kamaʻāina* (local residents) continued to refer to it as Kaloʻi (von Holt 1953 as cited in Sterling and Summers 1978:35). In 1913, the Waiāhole Water Company, a subsidiary of the Oʻahu Sugar Company, installed a water system known as the Waiāhole Ditch, which collected water from Kahana Valley in the north and transported it by tunnel through the Koʻolau Range to Waiawa, then westward to Honouliuli by ditch (Figure 4). The entire system was completed in 1916 and covered roughly 22 miles (Condé and Best 1973:37). Much of the system remains in use to this day, and portions of the Waiāhole Ditch system, State Inventory of Historic Places (SIHP) #50-80-09-02268, were identified in archaeological inventory surveys by Dega et al. (1998), Tulchin and Hammatt (2004), and Hunkin and Hammatt (2009).

World War II-era military development also brought significant change to the Honouliuli landscape, as military installations were constructed in numerous areas of the coast and the uplands. This included the Honouliuli Internment Camp, now the Honouliuli National Historic Site (SIHP 50-80-08-09068, National Register of Historic Places #90000855, and National Monument under Proclamation 9234), as well as Barber’s Point Military Reservation at Barber’s Point Beach, Camp Malakole Military Reservation, Gilbert Military Reservation, Barber’s Point Naval Air Station, Fort Barrette, and a number of other installations related to military surveillance and defense.

On top of Puʻu Makakilo, Fire Control Station A was installed (and Fire Control Station B atop Puʻu Pālailai), and the Puʻu Makakilo Training Area was used for military training from 1942 to 1945 (Environment Hawaiʻi 1992, as cited in Hunkin and Hammatt 2009). In 1945, the U.S. Army returned the Puʻu Makakilo Training Area, along with 24 other training areas in Hawaiʻi, to their original owners (*Honolulu Advertiser* 1945).

Between the end of the war and the residential boom of the early 1960s, the land in Makakilo remained primarily agricultural (Figure 5). Advertisements in local newspapers dating to the 1950s and early 1960s advertise simple, locally made terra cotta pots manufactured by Gaspro and made from “Makakilo Clay.”

In 1960, it was announced that work would start on a “Giant New Oahu City” in a 1,300-acre area of the Campbell Estate named Makakilo (Penny 1960). At the time, Makakilo was planned to be the largest residential area in the Campbell Estate 20-year master plan for Honouliuli. It would include a civic center, churches, schools, small and large shopping centers, playgrounds, parks, a cemetery, and an apartment area. Houses would be offered on a 55-year lease for $15,000 to $40,000 (Penny 1960). Ground was broken for the Makakilo development on December 11, 1961 (*Honolulu Advertiser* 1961). By the next year, Makakilo City was heavily advertised in the local newspapers as “Oahu’s First Planned City.” Since then, subdivisions have gradually replaced many of the areas previously used for ranching, sugar cultivation, or military activities.

In 1975 and in the midst of financial woes, Pacific Concrete & Rock Co., Ltd. opened the Makakilo Rock Quarry, then valued at $5 million (Smith 1975). In 1984, Grace Brothers Ltd. acquired Pacific Concrete & Rock Co., and renamed the combined entities to Grace Pacific Corp. (*Honolulu Advertiser* 1984).

In the late 1980s/early 1990s, portions of the current project area were subject to significant disturbance from the development of the 232-acre Makakilo Golf Course by Chiyoda Pacific, Inc., which included significant landform shaping for fairways and the partial construction of a two-story golf clubhouse. The grading, terracing, and other landscape modifications required for the creation of the front nine holes, which would be visible from the H-1 freeway, was nearly completed when the project encountered financial difficulties (Catterall 1993). The property was foreclosed in 1994 and purchased in a bankruptcy auction for $12.6 million by Grace Pacific, LLC (Smyser 1995).

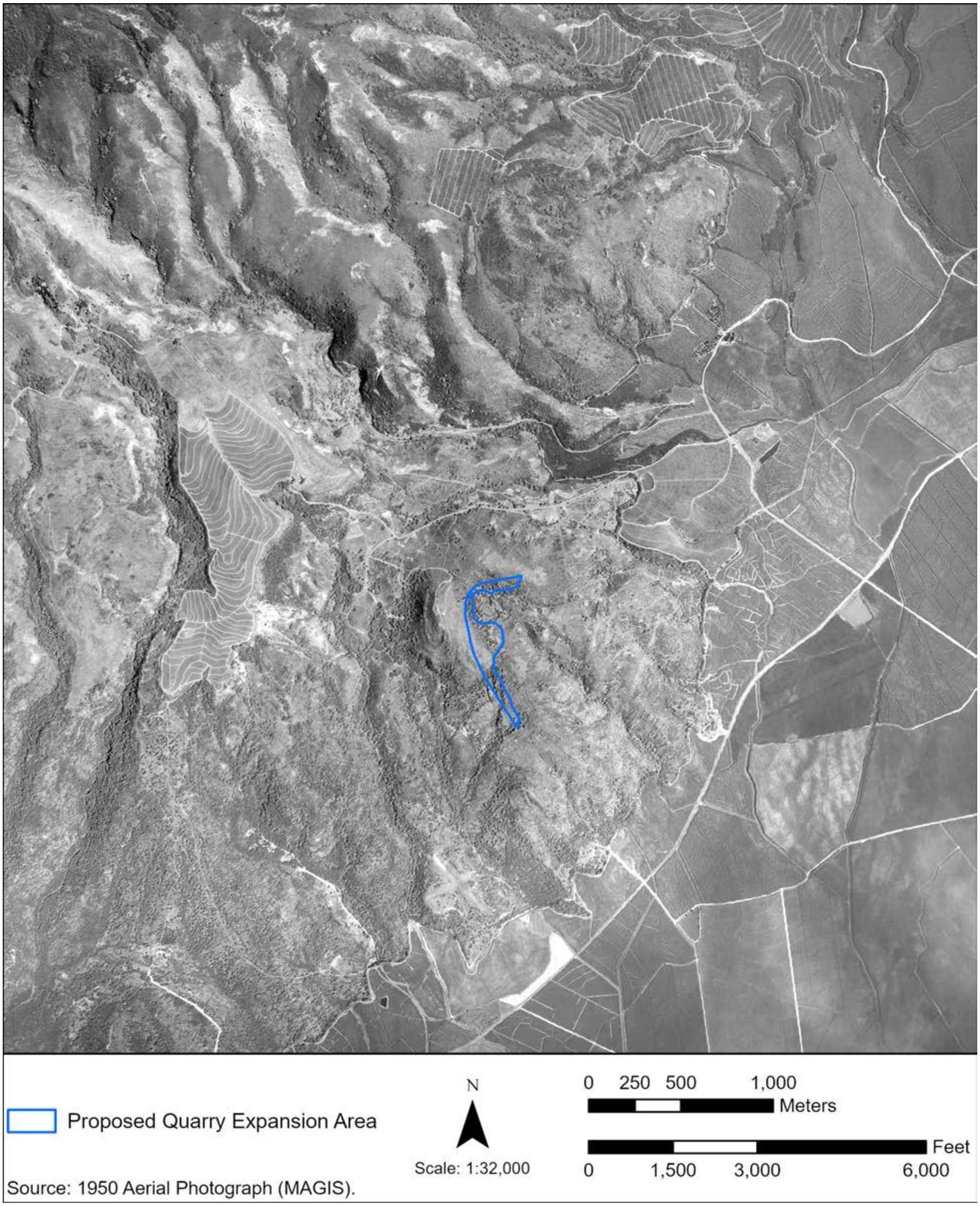

Figure 2. Aerial photograph from 1950 showing the locations of sugarcane agricultural fields.

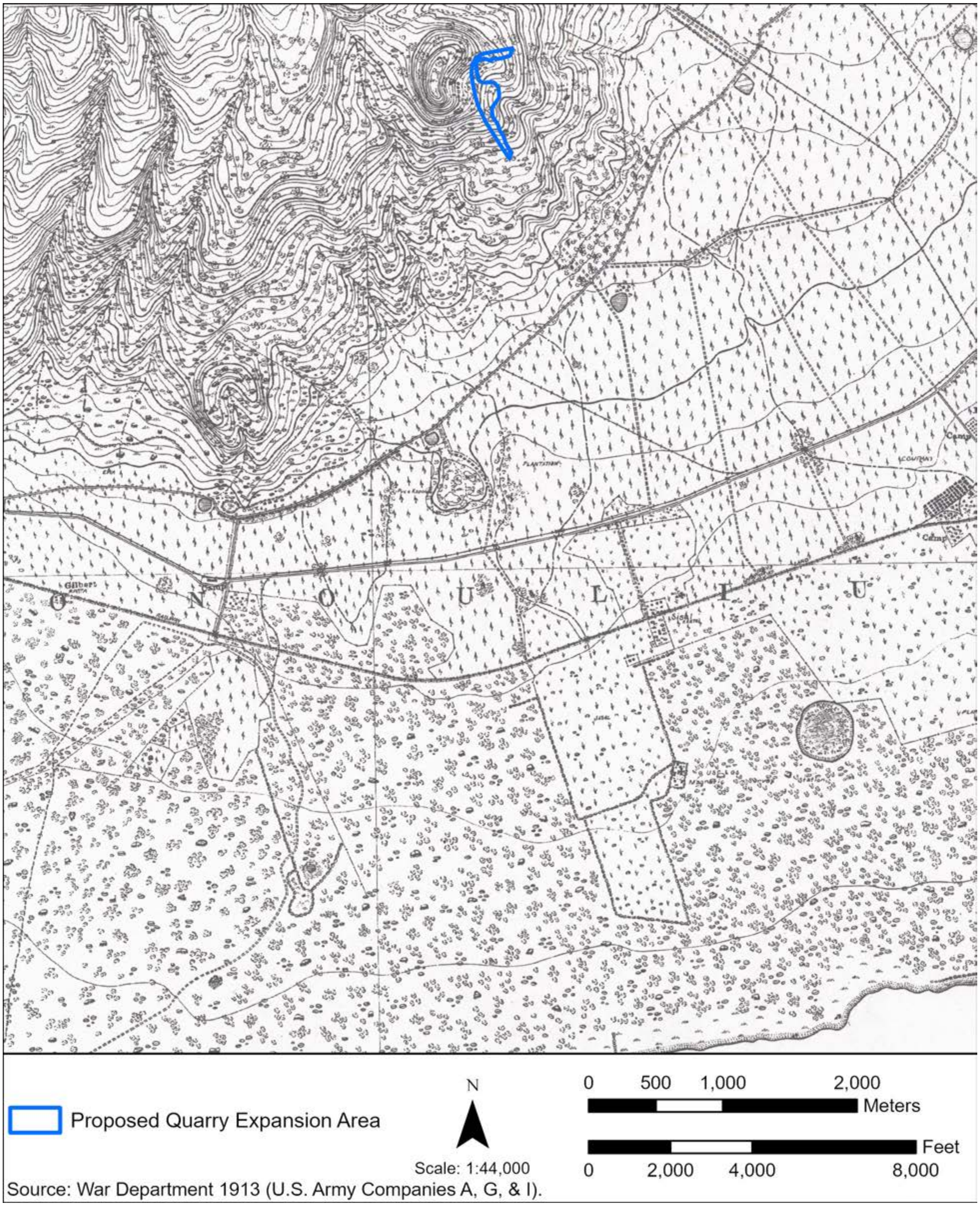

Figure 3. 1913 War Department map showing early twentieth-century landscape features such as sisal fields and plantations near the project area.

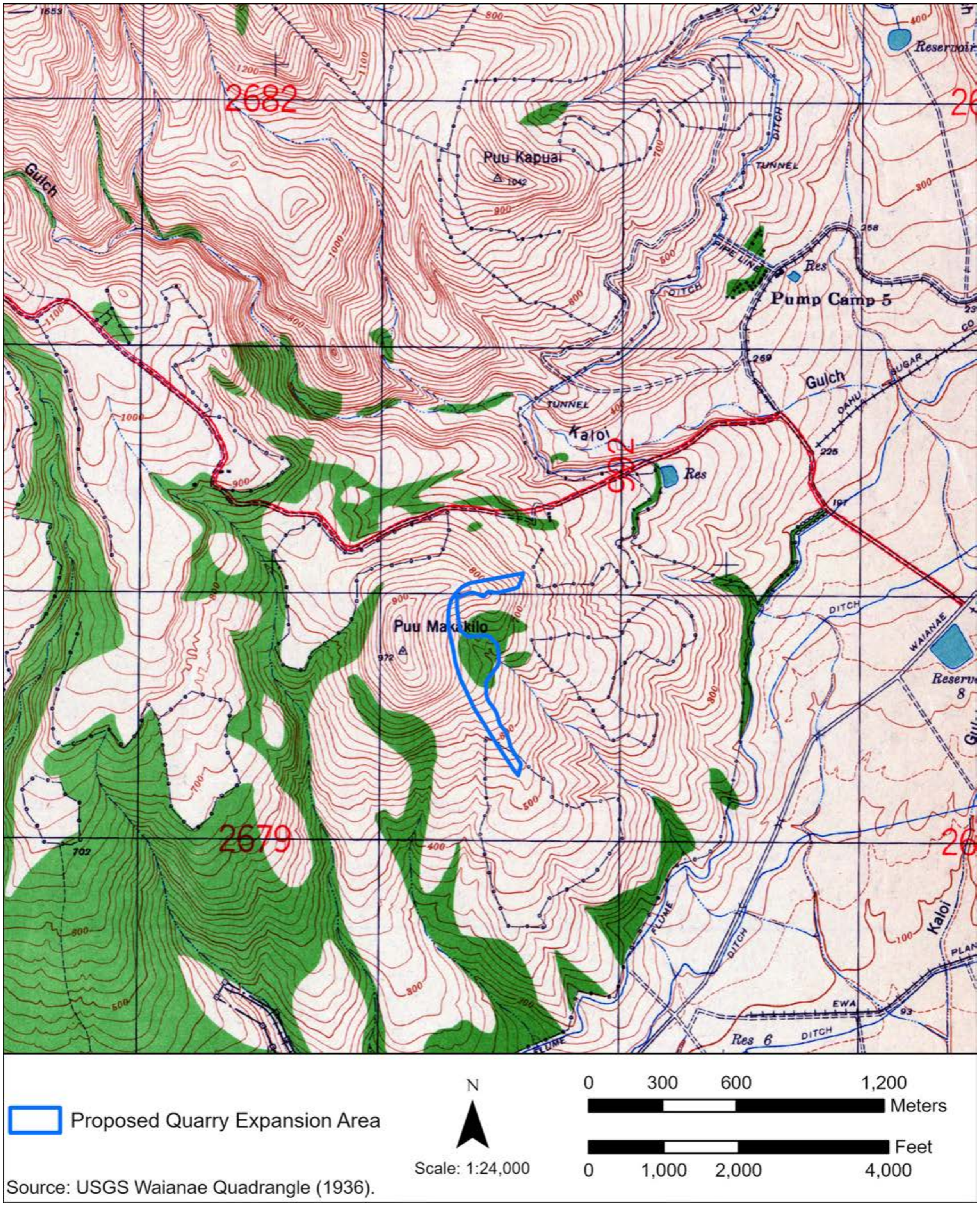

Figure 4. 1936 USGS map showing Kaloʻi Gulch and irrigation networks built in the vicinity of the current project area.

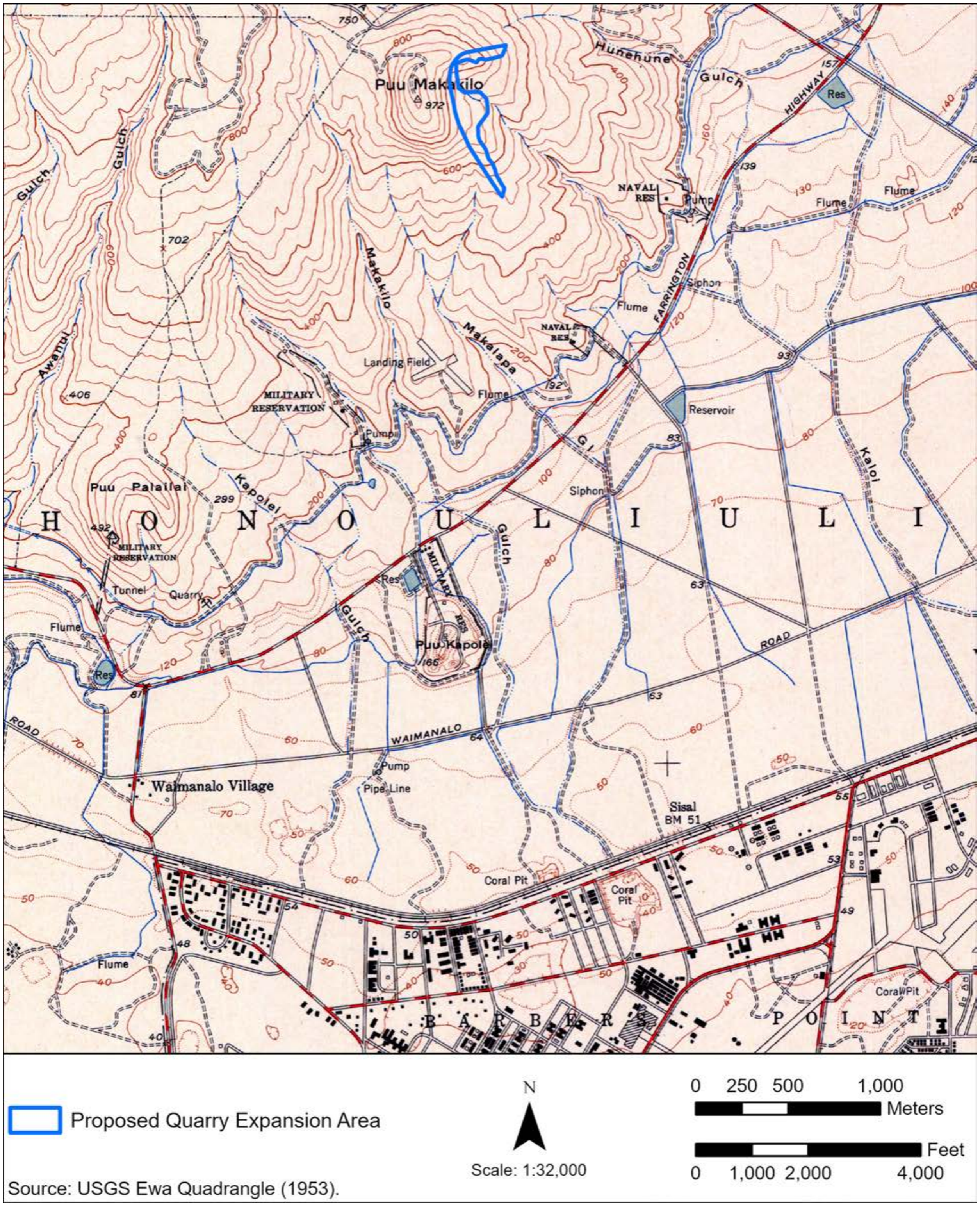

Figure 5. 1953 USGS Map showing agricultural and early settlement developments around the project area following World War II.

2.2 IDENTIFICATION OF VALUED CULTURAL, HISTORICAL, OR NATURAL RESOURCES FROM PREVIOUS ARCHAEOLOGICAL STUDIES

A number of archaeological investigations have occurred in the vicinity (defined here as within a 0.5-mile or 0.7-km radius of the current project area) of the Makakilo Quarry Proposed Expansion Area, most resulting in modest finds (Figure 6, Figure 7). Most of these studies are associated with the continued development of Makakilo within the greater Kapolei region.

The earliest archaeological investigation in the vicinity of the project area was conducted in the 1930s by Bishop Museum archaeologist J. Gilbert McAllister (1933). McAllister recorded several sites around the peripheries of Puʻu Makakilo; however, the site recording methods available to him in the early twentieth century were rudimentary by today's standards. McAllister noted that on the side of Puʻu Kapolei, a mile south of Puʻu Makakilo, was a large rock shelter rumored to be the dwelling of Kamapuaʻa and his grandmother, Kamaunuaniho. He also documented Puʻu Kapolei Heiau (Site 138) in the same vicinity (McAllister 1933:108). McAllister also described Puʻu Kuina Heiau (Site 134), located in a gulch at the foot of Mauna Kapu, 2.5 miles north of Makakilo, but which had been destroyed and reduced to "a suggestion of a terrace" (as cited in Sterling and Summers 1978:32). In the same area, McAllister recorded a four- to six-foot square basalt and coral platform (Site 136) which was purportedly a sacred Hawaiian altar (McAllister 1933:107), though apparently the site was destroyed by the late 1950s (Sterling and Summers 1978:32).

In 1977, Archaeological Research Center Hawaiʻi, Inc. (ARCH) performed an archaeological reconnaissance survey for the Kaloʻi Gulch Landfill, just north of Puʻu Makakilo. Bordner (1997) identified three walls of stacked *pāhoehoe* slabs with possible pre-Contact associations (SIHP 50-80-12-02600, 50-80-12-02601, and 50-80-12-02602), but considered them to be of marginal significance and did not recommend further work (Bordner 1977).

In 1986, Paul H. Rosendahl, Inc. (PHRI) conducted a preliminary archaeological reconnaissance survey for the ʻEwa Town Center / Secondary Urban Center, a project area of roughly 1,400 acres (Haun 1986). Haun identified an irrigation ditch that followed the 200 ft contour of Puʻu Pālalai, and noted the existence of a WWII-era structure. He recommended no further archaeological work in the project area.

In March of 1988, a letter report was written by Aki Sinoto of Bishop Museum about the pedestrian surface survey performed by Williams and Duckworth for the Makakilo Golf Course. According to this report, the survey was conducted in an area which extends beyond the Makakilo Quarry Proposed Expansion Area. Sinoto commented on the topography of the southeastern flank of Puʻu Makakilo by stating:

> As anticipated, large portions of the project area have been and still undergo severe erosion. Barren areas of exposed substrate is interspersed with areas dominated by dry grasses and small kiawe. Steep erosional gullies with vertical walled heads, bare areas of sheet wash, and pedestaled rocks attest to the severe and continuing erosion. (Sinoto 1988:1)

While no significant archaeological sites were located in the Makakilo Golf Course surface survey, Sinoto did discover a deteriorated wall segment inside of Puʻu Makakilo (Bishop Museum Site No. 50-OA-B6-276 and SIHP 50-80-12-01975). The site was located just outside (northwest) of the golf course project area's *mauka* extension. Sinoto (1988) described the 10.5

× 1.4 × 1.4-m wall as "double-faced" and "core-filled" with a north/south orientation. Sinoto speculated that the wall may have served as erosion control in historic times. However, due to its deteriorated state and the fact that the wall was not associated with any other features or structures, Sinoto determined that it did not meet the National Register criteria of significance and no further work was recommended (Sinoto 1988:1).

An AIS was conducted in 1993 on the parcels located southwest of the current project area (TMK: [1] 9-2-003:074, [1] 9-2-003:075, and [1] 9-2-003:081) by Aki Sinoto Consulting (Nakamura et al. 1993). This survey recorded a single historic site (SIHP 50-80-12-04664), described as a segment of an irrigation system constructed by the ʻEwa Plantation Company in 1941. Nakamura et al. (1993) documented the site in detail and deduced that "the significance can be considered to have been realized and no further work is necessary" (1993:32). The remaining area within the survey was also determined by Nakamura et al. to have a very low probability of subsurface remains.

In 1998, Scientific Consultant Services (SCS) conducted an AIS of the University of Hawaiʻi, West Oʻahu Campus project area (Dega et al. 1998). They identified a complex of irrigation features associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). Dega et al. (1998) assessed Site -05593 as significant under Criteria a and d, and acknowledged that SIHP -02268 was already assessed as significant. No further work was recommended for the project area (Dega et al. 1998).

In 1999, International Archaeological Research Institute, Inc. (IARII) carried out an archaeological reconnaissance survey for the Farrington Highway Expansion Project (Magnuson 1999). Magnuson identified six concrete bridges, a railroad track, and a set of unidentified concrete features. However, all features were determined to be not significant. No SIHP numbers were assigned and Magnuson recommended no further work beyond the recordation from the reconnaissance survey.

In 2004, Cultural Surveys Hawaii, Inc. (CSH; Tulchin and Hammatt 2004) carried out an AIS for the Pālehua Community Association (PCA) common areas at Makakilo, a group of discrete parcels of agricultural land, which combine to cover a total area of roughly 86 acres (TMK: [1] 9-2-003:078 [por.] and [1] 9-2-003:079). Although historic accounts point to a substantial Hawaiian population within the vicinity of the project area, Tulchin and Hammatt recorded only four new sites made up of 10 features. The sites included a complex of concrete and iron structures associated with industrial rock quarrying (SIHP 50-80-12-06680), three boulder mounds they associated with land clearing or ditch construction by the Oʻahu Sugar Co. (SIHP 50-80-12-06681), a water diversion terrace associated with the historic period (SIHP 50-80-12-06682), and a remnant portion of the Waiāhole Ditch (SIHP 50-80-09-02268). They suggested that the limited number of findings might be due to extensive land modification from ranching, commercial sugar plantations, and industrial rock quarrying, or that extensive erosion of topsoil into the project area may have concealed surface archaeological features. Sites -06680, -06681, and -06682 were evaluated as significant under Criterion d. Site -02268 was evaluated as significant under Criteria a and d. No further work was recommended for any of these sites beyond documentation that was completed for the AIS (Tulchin and Hammatt 2004).

In 2005, CSH (Tulchin and Hammatt 2005) carried out an AIS for the Pālehua East B residential development project at Makakilo, an approximately 71-acre parcel bordered by the Royal Ridge Subdivision on the west, Puʻu Makakilo on the south, and Kaloʻi Gulch on the north and east

(TMK: [1] 9-2-003:076 and [1] 9-2-003:078). They found that the area had already undergone significant erosion of topsoil, as well as substantial land modifications from development (e.g., machine grading, bulldozer clearing, excavation ditches, and landscape irrigation). They recorded three newly identified historic properties and a total of six component features, which they ascribed to agricultural or water diversion functions. These included a boulder alignment and mound (SIHP 50-80-12-06666), a basalt wall and ditch feature (SIHP 50-80-12-06667), and a boulder alignment (SIHP 50-80-12-06668). Sites -06666 and -06668 were evaluated as significant under Criterion d, and Site -06667 was evaluated as significant under Criteria c and d. They recommended no further work beyond the testing completed during the AIS (Tulchin and Hammatt 2005).

In 2006, CSH (O'Hare et al. 2006) conducted an AIS for the East Kapolei or Hoʻopili Project. They identified several previously identified historic properties, including plantation infrastructure (SIHP 50-80-12-04344), a railroad berm (SIHP 50-80-12-04345), the northern pumping station (SIHP 50-80-12-04346), central pumping station (SIHP 50-80-12-04347), and southern pumping station (SIHP 50-80-12-04348). They recorded four additional features associated with the plantation infrastructure of SIHP -04344: two linear walls, a stone-faced berm, and a concrete ditch and masonry catchment basement (Features D through G). They noted that during a 1990 survey of the West Loch Bluffs project area (Hammatt and Shideler 1990), all of these sites were evaluated as significant under Criteria c and d. However, since that time, many of the original features of Site -04344 had deteriorated, and O'Hare et al. (2006) revised their determination for SIHP -04344 to significance under Criterion d only. No further work was recommended for SIHP -04344, and SIHP -04345 through -04348 were all recommended for preservation.

In 2006, IARII (Rasmussen 2006) carried out a three-part archaeological assessment in Makakilo and Makalapa Gulches for a D.R. Horton – Schuler Division development located approximately 2 km to the west and southwest of the project area (TMK: [1] 9-2-003:081, [1] 9-2-019:003, [1] 9-2-019:072, [1] 9-2-019:081, [1] 9-2-019:084, [1] 9-2-019:085). For the project, Rasmussen (2006) conducted three separate investigations which involved two pedestrian surface surveys and one test excavation unit. The 2004 survey yielded no archaeological sites, and Rasmussen concluded that there was little chance of finding sites due to heavy disturbance from off-roading trails, bulldozing, and natural erosion. In the 2006 survey, Rasmussen recorded one new historic property (SIHP 50-80-12-04664) with eight associated features related to sugarcane cultivation, including a flume, double drain culvert, walled drainage, rock-lined ditch, plow scars, crushed coral roadbed, crushed basalt cobble foundation or paving, and a curved rock alignment. SIHP -04664, inclusive of all component features, was evaluated as significant under Criterion d, and no further work was recommended.

In 2009, CSH (Hunkin and Hammatt 2009) carried out an AIS for the Makakilo Drive Extension Project (TMK: [1] 9-2-002:006 and [1] 9-2-002:079), bound on the south by Quarry Road, which connects Old Pālehua Road with the Grace Pacific Makakilo Quarry. The AIS recorded two newly identified historic properties and documented one previously identified historic property (a portion of Waiāhole Ditch, SIHP 50-80-09-02268). The two newly identified historic properties were both irrigation ditches, likely associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-09-06950 and 50-80-09-06951). Sites -06950 and -06951 were evaluated as significant under Criterion d, and no further work was recommended for these sites. Site -02268 was evaluated as significant under Criteria a, c, and d and avoidance and mitigation of inadvertent adverse impacts were recommended.

In 2011, CSH (Runyon et al. 2011) completed archaeological monitoring for Phase 1C of the North-South Road Project (TMK: [1] 9-1-018:001, [1] 9-1-018:003, [1] 9-1-018:004, [1] 9-1-018:005; [1] 9-2-002:001, [1] 9-2-002:006). They identified one historic property previously identified by Nakamura et al. (1993), a historic water diversion structure (SIHP 50-80-12-04884), and documented one newly identified historic property, a burnt trash fill layer found under Pālehua Road, on the west edge of Ramp A (SIHP 50-80-12-07128). Both sites were evaluated as significant under Criterion d, and no further work was recommended.

In 2014, IARII (Pacheco and Rieth 2014) carried out an AIS for the East Kapolei Solar Farm (TMK: [1] 9-2-002:006 por.). They recorded one newly identified historic property, an unpaved early twentieth-century road, likely associated with either industrial ranching or sugarcane cultivation activities (SIHP 50-80-12-07433). The site was evaluated as significant under Criterion d. No further work was recommended beyond the recordation involved in the AIS.

In 2014, IARII (Rieth et al. 2014) carried out an AIS of an area including SIHP 50-80-12-07664, a site comprised of two basalt boulders carrying five petroglyph figures, and approximately 0.16 acres of the surrounding area (TMK: [1] 9-2-048:092 por.). Aside from thorough documentation of the petroglyph site, no additional historic properties were identified. The site was evaluated as significant under Criteria d and e, and relocation and passive preservation was recommended.

In 2018, CSH (Zapor et al. 2018 as cited by Welser et al. 2020) conducted a supplemental archaeological inventory survey (SAIS) for the Makakilo Drive Extension Project. They identified two historic properties: portions of the previously documented Waiāhole Ditch (SIHP 50-80-09-02268), and an irrigation ditch with associated components (SIHP 50-80-09-06951). They documented an additional component feature of the Waiāhole Ditch (SIHP -02268, Feature D) consisting of an earthen mound and stacked stone wall which are likely the remnants of a reservoir. They assessed SIHP -02268 as significant under Criteria a, c, and d (Zapor et al. 2018 as cited by Welser et al. 2020). The significance assessment for SIHP -06951 and mitigation recommendations for both sites have not been made available.

In 2020, CSH (Welser et al. 2020) conducted an AIS for the AES West Oʻahu Solar Project, (TMK: [1[9-2-002:007 por.). They identified two previously documented historic properties: a complex of irrigation features previously identified by Dega et al. (1998) and associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). SIHP -05593 was evaluated as significant under Criteria a and d, and -02268 was evaluated as significant under Criteria a, c, and d. Mitigation commitments included avoidance of adverse impact to component features within the project area, data recovery in the form of archaeological monitoring, Historic American Engineering Record (HAER) documentation of SIHP -05593, Feature 2 (mill building and Pump House 12 complex), and incorporation of the portions of -02268 within the project area to an existing Addendum to the Waiāhole Ditch Historic Context Study (Mason Architects, Inc. 2018).

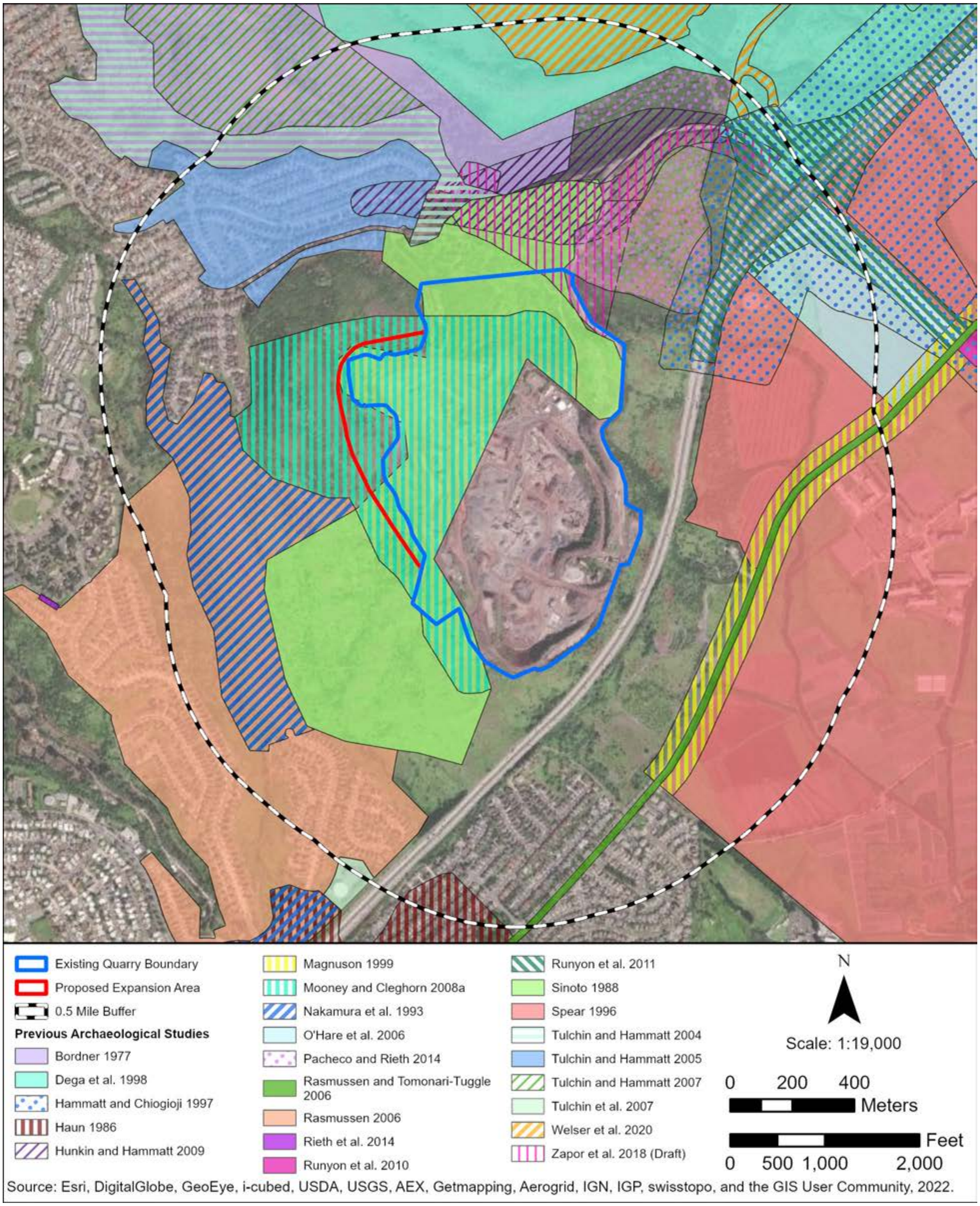

Figure 6. Locations of previous archaeological investigations in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2022).

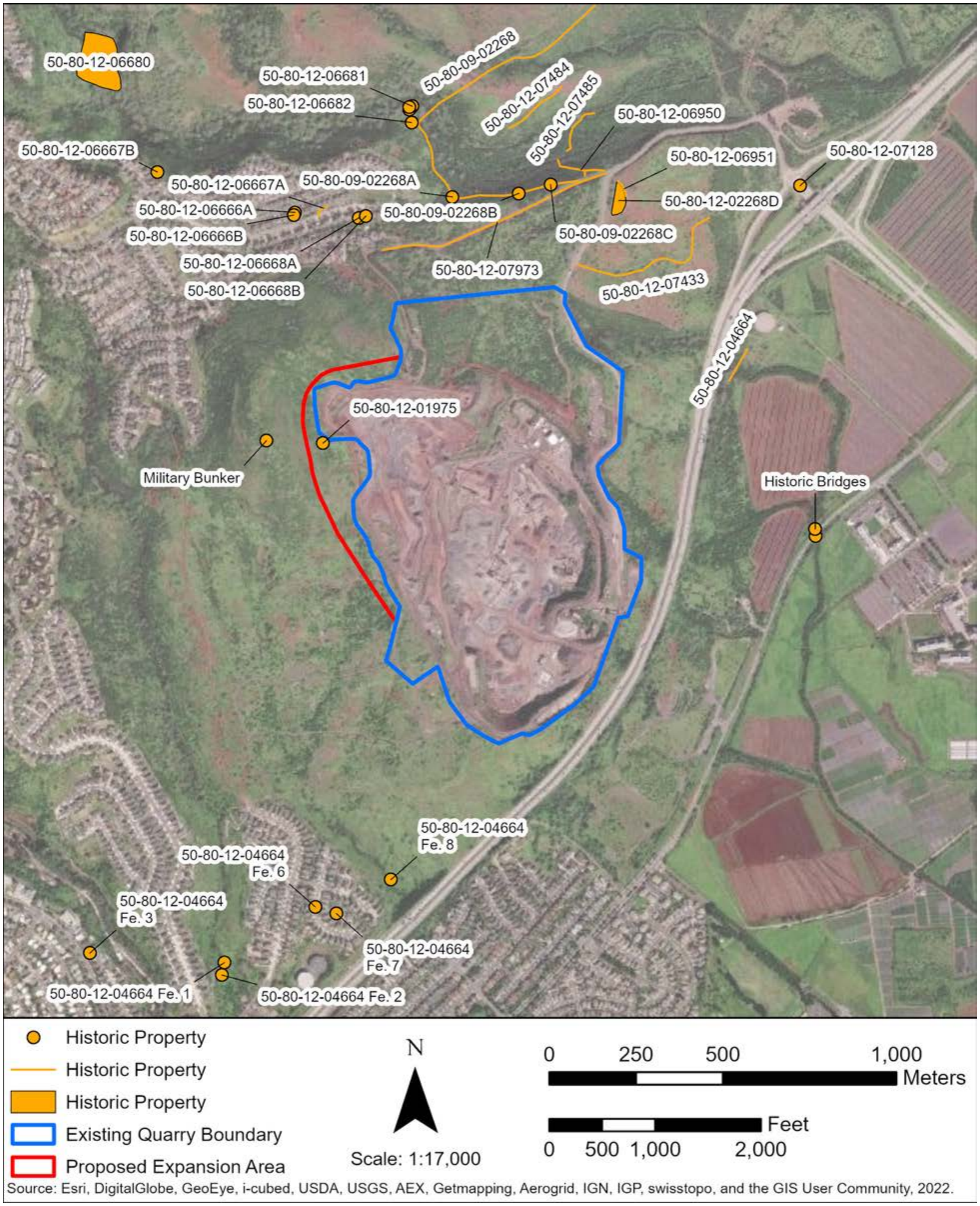

Figure 7. Map of previously identified sites in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2022).

2.3 SUMMARY OF PREVIOUS CONSULTATION AND ORAL HISTORICAL INTERVIEWS FOR PROJECT AREA

Mooney and Cleghorn (2008) conducted a Cultural Impact Assessment for a 34-acre expansion of the existing Makakilo Quarry footprint. Three individuals knowledgeable about contemporary cultural activities in the project area were interviewed. Participants recalled that the Makakilo area was used for ranching, with lower elevations also containing sugarcane fields. A number of plants were said to have grown there, including *maile* (*Alyxia stellata*), *milo* (*Thespesia populnea*), *neheleau* (*Lipochaeta spp.*), *kamani* (*Calophyllum inophyllum*), *ʻuhaloa* (*Waltheria indica*), *kaunaʻoa* (*Cuscuta sandwichiana*), *noni* (*Morinda citrifolia*), *pōpolo* (*Solanum Americanum*), *ʻaʻaliʻi* (*Dodonaea viscosa*), *wiliwili* (*Erythrina sandwicensis*), *ʻohai* (*Sesbania tomentosa*), *ʻaheahea* (*Chenopodium oahuense*), *pili* grass (*heteropogon contortus*), *ʻilima* (*Sida fallax*), *palaʻa* (*Spenomeris chinensis*), *palailai* (*Microlepia strigose*), *ʻieʻie* (*Frencinetia arboriea*), *hala* (*Pandanus tectorius*), and camphor (*Cinnamomum camphora*). The area used to also have *ʻiʻiwi* and *ʻōʻō* birds, and there was a pathway used by bird catchers to travel to the lowland springs for water.

Traditional activities in Makakilo likely included collecting plants, particularly for medicinal purposes, catching birds for featherwork, and perhaps also hunting wild pigs in the upper slopes. People also used Puʻu Makakilo to help navigate while fishing offshore, and the Puʻu also played a role in observing celestial movements and tracking calendrical time.

Kawika McKeague noted that nearly all of the Makakilo area was used for sugarcane and ranching until the late 1980s, and also emphasized the strong spiritual significance of Puʻu Makakilo as well as the broader *ahupuaʻa* of Honouliuli. According to Shad Kane, the Makakilo area north of the H-1 Freeway was once verdant with exceptional soils for cultivation. However, more recent hydrology projects and vertical plowing in Kapolei and Makakilo had significantly reduced the amount of fresh water flowing to the coast. Nettie Tiffany disclosed that her mother considered the area *kapu* (forbidden), and associated with the spirits of the deceased, that she would never reside in Makakilo, and saw the housing developments as disrespectful to the spirits (Mooney and Cleghorn 2008).

While this analysis builds on the CIA conducted by Mooney and Cleghorn (2008), previous CIAs in the uplands of Honouliuli can also help inform understanding of traditional practices carried out in the current project area. This includes CIAs completed for the Proposed Makaīwa Hills Project (Souza et al. 2006) and the Makakilo Drive Extension Project (Cruz and Hammatt 2008).

Souza et al. (2006) made efforts to contact 19 community members regarding cultural practices associated with the Makaīwa Hills project area. A number of these contacts noted the strong association of the areas around Waimānalo Gulch and Makaīwa Gulch with *ʻuhane*, or spirits. The area was identified as a pathway for the *huakaʻi pō* (procession of the night marchers) from the uplands to the ponds at Lanikūhonua. Although the landscape had been significantly altered, many also urged caution with regard to the possibility of finding *iwi kupuna*, and the importance of having a strong plan of action should they be identified. While traditional gathering of plants was likely an important pre-Contact activity in the area, the report notes that access would have been restricted during the second half of the nineteenth century, and impacts from grazing cattle, followed by commercial sugarcane agriculture, likely denuded the landscape of most of the traditional vegetation (Souza et al. 2006:55). The report concluded that although community members did not comment on ongoing cultural practices in the proposed project area, several participants emphasized the cultural importance of the area as a *wahi pana* (storied place), particularly with emphasis on the significance of the *huakaʻi pō*. They recommended that the *huakaʻi pō* be taken into account during development plans, that caution is exercised regarding the possibility of additional archaeological sites or burials within the project area, that the project should incorporate the traditional place names of the surrounding area into the proposed development as much as possible, and that community members be consulted throughout the planning process (Souza et al. 2006:69–71).

Cruz et al. (2008) made efforts to contact 23 community contacts, including government agency or community organization representatives and individuals, and conducted five formal "talk story" interviews for the Makakilo Drive Extension Project. An ancient Hawaiian Trail within the project area was highlighted as a major concern for community members, particularly as much of the trail had already been destroyed by previous development projects. The interviews also reinforced previous statements about the strong spiritual significance of the area, particularly the southwest portion of Honouliuli known as Kaupeʻa. This area was referred to as "*ao kuewa*," the realm of homeless spirits or purgatory, and is the site of a number of ghost stories and strange occurrences. Keoni Nunes noted that the *ʻuhane* were said to reside in the *wiliwili* trees, and suggested there were likely many burials in the Kaupeʻa area (Cruz et al. 2008:58–59). The report also noted that the open, drier forest and woodlands of upper Honouliuli was ideal for growing *ʻiliahi aloʻe* (sandalwood, or *Santalum ellipticum*). Based on the results of their research and consultation, Cruz et al. (2008) recommended that the old Hawaiian trail be preserved in its entirety and protected from potential harm during project construction, that all Native Hawaiian trees, including *wiliwili* and *ʻiliahi*, be preserved within the project area in perpetuity and protected from harm during construction, that cultural monitoring of trail and native tree protection be conducted by qualified and interested individuals or organizations, and that consultation with community members continue throughout the project (Cruz et al. 2008).

3.0 ADDENDUM INTERVIEWS

Concerted attempts were made to identify and locate additional persons knowledgeable about traditional practices that took place in the past, or that are currently taking place, in the area potentially impacted by the project. Pacific Legacy reached out to the three individuals who were previously interviewed for the 2008 CIA (Ms. Nettie Tiffany, Mr. Shad Kane, and Mr. Kawika McKeague), as well as representatives from two additional organizations (the Kalaeloa Heritage and Legacy Foundation and the Ewa Pu‘uloa Hawaiian Civic Club). Fifteen additional individual stakeholders with a range of affiliations were also contacted (including the Kapolei Hawaiian Civic Club, University of Hawai‘i West O‘ahu, University of Hawai‘i Leeward Community College, and the ‘Ewa Representative for the O‘ahu Island Burial Council). In addition, Ka‘ahiki Solis (SHPD Cultural Historian for O‘ahu, Kaua‘i, and Ni‘ihau) was contacted to identify additional consulting parties. In total, 21 individuals were contacted as part of the current consultation effort (Table 1).

Table 1. Names and Affiliations of All Individuals and Organizations Contacted for This Addendum Update to the 2008 CIA

Name	Affiliation/Project Area Familiarity	Contact Method	Participation
Thomas Anuhealii	Pālehua Ranger; Cultural Ambassador to Four Seasons Ko Olina	Email	Responded to initial inquiry via email; did not respond to follow-up scheduling request
John Bond	Kanehili Cultural Hui	Email	Provided information via email
Mana Caceres	O‘ahu Island Burial Council, ‘Ewa Representative	Email	Did not respond
Ross Cordy	University of Hawai‘i – West O‘ahu	Email	Did not respond
Pi‘ikea Hardy-Kahaleoumi	Leeward Community College	Email; Phone conversation	Provided information via telephone conversation
Kimberly Kalama	Hoakalei Cultural Foundation	Email	Did not respond
Momiala Kamahele	Leeward Community College	Email	Declined to participate
Shad Kane	Makakilo resident; retired police officer; local historian; OHA/OEQC Cultural Assessment Provider	Email; phone conversation	Provided information via telephone conversation
Kepo‘o Keli‘ipa‘akaua	‘Ohana Keaweamahi	Email	Did not respond
Sa‘iliemanu Lilomaiva-Doktor	University of Hawai‘i – West O‘ahu	Email	Did not respond
Melissa Lyman	Ahahui Siwila Hawaii o Kapolei (Kapolei Hawaiian Civic Club)	Email	Did not respond
Kepā Maly	Hoakalei Cultural Foundation; produced several ethnohistoric studies for Honouliuli	Email	Declined to be interviewed; provided materials for further reference
Kai Markell	Office of Hawaiian Affairs	Email	Did not respond
Kawika McKeague	Makakilo resident from 1967–2006	Email	Unable to provide feedback within project timeframe

Name	Affiliation/Project Area Familiarity	Contact Method	Participation
Kaimana Namihira	Leeward Community College	Email	Responded via email; was unable to provide feedback within project timeframe
Keala Norman	ʻOhana Keaweamahi	Email	Provided information via email
McD Philpotts	Current resident of Pālehua	Email; phone conversation	Provided information via telephone conversation
Kaʻahiki Solis	SHPD Cultural Historian (Oʻahu, Kauaʻi, Niʻihau)	Email	Did not respond
Nettie Tiffany	Kapolei resident; *kahu* and *kupuna*	Email	Did not respond
—	Kalaeloa Heritage and Legacy Foundation	Email	Did not respond
—	Ewa Puʻuloa Hawaiian Civic Club	Email	Did not respond

All individuals and organizations were contacted with a formal letter sent via email (Appendix A). Letters requested any updated information with regard to the following components of the study:

- Cultural associations of Honouliuli Ahupuaʻa, such as *moʻolelo* or connections to legendary accounts.
- Knowledge of past and present land use within and near the project area.
- Knowledge of past and present traditional gathering practices in Honouliuli.
- Knowledge of cultural resources which may be impacted by the proposed project, including traditional plant and animal gathering sites, traditional access trails, archaeological sites, historic sites, and burials.
- Any other cultural concerns that community members may have in relation to traditional Hawaiian or other cultural practices within or near the proposed project area.
- Referrals to other knowledgeable individuals who may be willing to share their cultural knowledge of the proposed project area and the wider region of Honouliuli Ahupuaʻa.

Of the 21 individuals and organizations contacted for this update, six provided additional information. Of the three individuals who were previously interviewed regarding the expansion area, two responded to our request for updated information. Ms. Nettie Tiffany did not respond to our request. Mr. Kawika McKeague responded to our request, and stated that he was interested in speaking with us but was too busy to do so within the project timeframe. Mr. Shad Kane agreed to speak with us and provided input through a telephone conversation that occurred on 25 May 2022.

3.1 Interviews of Previous Cultural Assessment Consultation Participants

Commentary by the authors is signified by parentheticals within the body of the interview sections. All other text is paraphrased from direct communication with the named participant.

3.1.1 Shad Kane

Mr. Kane provided an update to his previous testimony via telephone on 25 May 2022. He was previously interviewed by Kimberly Mooney of Pacific Legacy on 30 January 2008 (Mooney and Cleghorn 2008). In this interview, he described Makakilo as a verdant area with exceptional soils for cultivation, and home to a number of native or Polynesian-introduced plant and animal species including *milo* (*Thespesia populnea*), *neheleau* (*Lipochaeta spp*.), *kamani* (*Calophyllum inophyllum*), and *iʻiwi* (*Drepanis coccinea*).

In the previous 2008 CIA, Mr. Kane expressed cultural concerns about the quarry due to its entrance being in the vicinity of Puʻu Makakilo. However, he noted he does not have the same concerns for the current proposed expansion, as this project area is not in the same vicinity. Because the expansion area has been previously disturbed by military use, he also does not have concern for disturbance of Hawaiian sites. He noted the military formerly had an airport, and some bunkers, between the top and bottom of Makakilo Gulch, and that they may still exist in the area.

Mr. Kane's primary concern about the proposed expansion is regarding the homes below the quarry and the people who live there. He is concerned about how the expansion might affect them.

3.2 INTERVIEWS OF NEWLY CONTACTED CULTURAL ASSESSMENT CONSULTATION PARTICIPANTS

Commentary by the authors is signified by parentheticals within the body of the interview sections. All other text is paraphrased from direct communication with the named participant.

3.2.1 John Bond

Mr. Bond responded to our inquiry via email on 1 June 2022. He noted that Makakilo means "observing eyes," and was an important place for priests and *kahuna* to gather to view the sky, stars, and planets to make predictions about the future and interpret the will of the gods. He added that because the *aliʻi* depended on priests who would make such observations in almost every aspect of their lives, Makakilo played a central role in Oʻahu daily life and politics for centuries. As Mr. Bond described it, "when this hillside spoke, the Island listened."

Mr. Bond also mentioned a large cave site, and World War II-era observation posts in the vicinity of the quarry that are likely to be National Register-eligible and should not be disturbed. (The Literature Review and Field Inspection for the proposed expansion area did not identify any of these historic properties within the bounds of the current project area; see Swift et al. 2022).

3.2.2 Piʻikea Hardy-Kahaleoumi

Professor Hardy-Kahaleoumi responded to our inquiry via telephone call on 2 June 2022. She expressed that although she is a current Makakilo resident and does cultural work, she would not say that in terms of Honouliuli specifically that she had extensive expertise. However, as a current resident and cultural practitioner, she did have concerns about the proposed expansion. Prof. Hardy-Kahaleoumi expressed concerns about the history of contracted archaeological work in Hawaiʻi, in particular that it has been the case in the past that archaeologists on projects did not have expertise in culturally significant sites, and that this in turn led to the unnecessary destruction of important cultural resources. She expressed that it was inappropriate for anyone without that knowledge to be making preservation determinations in Hawaiʻi and that she hoped there would be concerted effort to preserve any sites in the project area. She also expressed a concern that there may be *iwi kūpuna* in the project area who would be disturbed in mining activities, and that this may not be reported or handled appropriately. As a resident of the area, Prof. Hardy-Kahaleoumi is also concerned about the environmental and personal health impacts of extending hot mix asphalt production to 24 hour per day, 7 days a week.

3.2.3 Kepā Maly

Mr. Maly responded to our inquiry via email on 24 May 2022. He stated that he did not have real personal knowledge of the project area, but that he had done research and interviewed some elder *kamaʻāina* of Honouliuli. While he has prepared a number of ethnohistorical studies for the greater Honouliuli region, he did not have any specific knowledge of the project area or features which might occur there. Mr. Maly shared a recent document that was prepared to support curricula for the Honouliuli area, *Honouliuli – He Ala Mēheuheu A Nā Hānauna (A Customary Path Traveled Over the Generations)*. The reader is referred to this document, which contains a rich cultural history of Honouliuli Ahupuaʻa, for additional information and resources on the overall study area (Maly 2022).

3.2.4 Keala Norman

Ms. Norman responded to our inquiry via email on 1 June 2022. She mentioned that the Honouliuli Japanese Internment Camp lies in the valley to the north of the existing quarry. She also noted that a friend told her that on *Pō Kāne* nights, he would see paddlers in a canoe traveling from Pālehua down towards the ocean, and that they were similar to the Night Marchers except paddling a canoe. (Honouliuli Ahupuaʻa is well known for spiritual, ghostly, or otherworldly sightings, including other incidences of Night Marchers; see also Cruz and Hammatt 2008).

In her personal experience, Ms. Norman recounted that she observed *akualele* (ʻflying godʼ) flying down from Pālehua on two separate occasions. She could tell that they were *akualele* because they were too close to the tops of the *kiawe* (*Prosopis pallida*) trees to be a falling star. They looked like a fireball with a flaming tail streaming behind it, and then suddenly disappeared. She was unable to tell where they came from, because at that time none of the homes in that area had been built yet.

3.2.5 McD Philpotts

Mr. Philpotts responded to our inquiry via telephone call on 27 May 2022. He noted that his main concern is a historically significant house site located on the rim of the northwest corner of the quarry. Although the site may not be in the current project area, Mr. Philpotts is concerned that the expansion could compromise the ground surface and lead to erosion that will destabilize the site. He suggests the expansion should maintain an adequate distance from the site so that it is not further disturbed. (The Literature Review and Field Inspection for the proposed expansion area did not identify this historic property within the bounds of the current project area; see Swift et al. 2022).

Mr. Philpotts noted that the site was also significant due to its connection with the five brothers who watched over Oʻahu: Makaīwa, Makaʻike, Makaloa, Maka-Io, and Makakilo. He referenced a *moʻolelo* on this subject related by Analu Kameeiamoku Josephides in a CIA for the Waimanalo Gulch Sanitary Landfill Expansion conducted by Cultural Surveys Hawaiʻi, Inc.:

> Another concern that I may have is the place names of this particular area. A story that has been passed down to me from my kupuna is that there were five brothers who were the watchers. Their names were Makaīwa, Maka‘ike, Makaloa, Maka-Io, and Makakilo. It was known that Makaīwa was to the farthest west and that Makakilo was to the farthest east. That these five brothers were the eyes of the O‘ahu people and were their protectors. They would watch for enemy intruders and relay messages to their makulu (runners). If enemy canoes were seen the makulu would run to the various districts and warn the chief and his/her people. This is why O‘ahu was a hard island to conquer in the ancient times. By the time the war canoes of the enemies would reach the shores they would be greeted by the warriors of O‘ahu, thus the enemies were never allowed to land upon the shores of O‘ahu. (Analu Kameeiamoku Josephides, in Souza et al. 2006:7–128, 129)

(In the same report, Josephides also relates being told that in the old days, homes were not built in this region, "except for the mauka area of Makaīwa to the west, the mauka area to the east known as Makakilo, and the makai area below where in ancient time was the dwelling place of the Kamapua‘a ‘ohana" [Souza et al. 2006:7–118], as these were the paths of the Night Marchers.)

3.3 SUMMARY OF INTERVIEW FINDINGS

The 2008 CIA found limited evidence to support past and contemporary cultural use of the 2008 Makakilo Quarry expansion area (Mooney and Cleghorn 2008). However, it did note that there were numerous cultural features in the surrounding area and that Makakilo had spiritual significance. It posited that events and stories from Makakilo either did not survive into current times or might exist clandestinely. The report concluded that quarrying activities would not have any effect on ongoing cultural activities, such as ritual activities or traditional plant gathering. However, it did note that the land should be respected as a spiritual and cultural landscape and that mitigation to address interviewee concerns prior to initiating the proposed project could help maintain positive relationships between the quarry and the community of Makakilo.

The house site mentioned by Mr. Philpotts in this addendum was not located during the 2022 field inspection, nor was it identified through a literature review that included previous archaeological reports in the vicinity of the project area (see Section 2.2). It is possible that more information on the location and condition of this site could be obtained through the more detailed investigation of the project area and surroundings entailed by an AIS.

One participant in the current survey noted concern regarding the possible disturbance of *iwi kūpuna* from expanded quarrying. Given the significant disturbance that has already occurred within the project area from past industrial sugarcane agriculture and golf course construction, it is likely that if there were *iwi kūpuna* within the project area, they would have already been disturbed by previous activities. The project-specific AIS required by the State Historic Preservation Division (SHPD) for this proposed expansion may offer an opportunity to conduct a more thorough investigation of potential historic properties (including potential burials) within the project area.

Finally, a key concern from many who live(d) or have spent significant time in the area is the range of potential impacts that expanded and more intensive mining activities will have on residents and the local environment.

4.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

4.1 IDENTIFICATION OF CULTURAL, HISTORICAL, OR NATURAL RESOURCES WITHIN THE PROJECT AREA

A review of historical background information, previous archaeological studies, consultation, and oral historical interviews, combined with updated consultation in the present study, identifies several consistent themes regarding the cultural, historical, and natural resources within the project area.

During the pre-Contact period, the uplands of Honouliuli were likely rich in biocultural resources including native plants, animals, water resources, and fertile soils. The area is consistently identified as a place for gathering traditional resources, particularly medicinal plants, birds and bird feathers, and hunting pigs. Puʻu Makakilo played an important role in celestial observations, marking calendrical time, and as a navigational landmark for offshore fishing. Additionally, this area is consistently noted for its strong spiritual significance. The presence of *ʻuhane*, a pathway for the *huakaʻi pō*, observations of *akualele*, and the spiritual significance of native plants like the *wiliwili* were mentioned across multiple reports and interviews. Participants in the present study were also concerned about the potential presence of *iwi kūpuna* in the project area (this concern was also shared across other CIAs for the Honouliuli uplands, e.g., Souza et al. 2006), and the health and environmental impacts of quarrying on the contemporary inhabitants of Makakilo.

4.2 IMPACT TO RESOURCES AND TRADITIONAL AND CUSTOMARY NATIVE HAWAIIAN RIGHTS

As noted above, the uplands of Honouliuli were likely an important area for pre-Contact activities that included the gathering of traditional plants for medicinal and other uses, catching birds for featherwork, and hunting pigs in the uplands. However, starting in the nineteenth century, access to this area became restricted, and the impacts of grazing cattle followed by intensive commercial sugarcane agriculture likely denuded the landscape of many of these traditional resources. Community members interviewed in the current addendum and previous CIAs in the uplands of Honouliuli (e.g., Cruz et al. 2008; Mooney and Cleghorn 2008; Souza et al. 2006) did not comment on ongoing cultural practices in the proposed project area. However, several participants in these CIAs emphasized the cultural importance of the area as a *wahi pana* (storied place), particularly with emphasis on spiritual activities and the significance of the *huakaʻi pō*.

Given the Makakilo Quarry expansion area has seen significant post-Contact and modern disturbance to the landscape and natural environment, as well as the limited evidence for contemporary cultural use of the Makakilo Quarry expansion area, there is no anticipated impact to resources and traditional and customary Native Hawaiian rights.

4.3 Feasible Action to be Taken to Reasonably Protect Native Hawaiian Rights

Although this addendum has identified no potential impact to resources and traditional and customary Native Hawaiian rights, it does recommend that Grace Pacific LLC endeavor to address interviewee concerns prior to initiating the proposed project in order to maintain positive relationships with the communities of Makakilo and the wider region encompassing Honouliuli Ahupuaʻa.

Concerns from those who offered feedback in the current study broadly fell within three categories:

- Potential disturbance of historic properties both within and around the project area
- Disturbance of *iwi kūpuna* during quarrying activities
- Impacts of expanded mining activities on current residents

Recommended actions could include:

- Development of an established protocol should disturbance of *iwi kūpuna* occur during quarrying activities, which includes immediate notification of the SHPD Oʻahu Island Burial Sites Specialist and development of a burial treatment plan in consultation with SHPD, Oʻahu Island Burial Council, Office of Hawaiian Affairs, identified cultural and/or lineal descendants, and community stakeholders.
- Dissemination of information to community members regarding other required environmental testing (and their results) for the proposed expansion and planned changes to operations.
- Continued community consultation regarding potential impacts and mitigation plans for historic properties (e.g., through the AIS process) throughout the duration of project development.

5.0 REFERENCES CITED

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APPENDIX A

SAMPLE LETTER SENT TO POTENTIAL CONSULTING PARTIES

Pacific Basin — Oʻahu
146 Hekili Street, Suite 205
Kailua, HI 96734

Phone: 808.263.4800
Fax: 808.263.4300
www.pacificlegacy.com

DATE

RECIPIENT FIRST LAST
RECIPIENT EMAIL ADDRESS

Subject: Cultural Impact Assessment for the Proposed 15.6-Acre Expansion Area at the Makakilo Quarry, Kapolei, Honouliuli Ahupuaʻa, ʻEwa Moku, Island of Oʻahu

Aloha TITLE LASTNAME,

Pacific Legacy is updating a cultural impact assessment (CIA) for the Makakilo Quarry to include a proposed expansion area, which is planned for an area of approximately 15.6 acres. The project area is located in Honouliuli Ahupuaʻa, ʻEwa Moku, Oʻahu [TMK: (1) 9-2-003:018 (por.)] (Attachment 1, Figure 1).

The proposed project expands the current area approved for mining by roughly 15.6 acres on the west side of the current Makakilo Quarry footprint. The proposed expansion will provide Grace Pacific, LLC access to a seam of high-quality rock to be used in concrete and asphalt paving. In addition to the proposed expansion, Grace Pacific, LLC intends to apply for modifications to their current quarry permit that would extend the permit 15 years beyond its current expiry (from December 21, 2032 to December 21, 2047) and modify their existing operating hours (6 am to 6 pm) to permit hot mix asphalt production and sales in the pit of the quarry 24 hours per day, 7 days a week. Mining would continue to be restricted to daytime use only.

The purpose of the CIA is to evaluate potential impacts to traditional cultural practices as a result of the proposed project, in accordance with the guidelines for assessing cultural impacts, which were adopted by the State of Hawaiʻi Environmental Council on Nov. 19, 1997. For the CIA, the *ahupuaʻa* of Honouliuli is considered the overall study area, while the project area is defined as the 15.6-acre proposed expansion area shown in Figure 1.

A CIA was completed for a previous expansion to the Makakilo Quarry in 2008. Pacific Legacy has been contracted to provide an update to the existing CIA. This work involves contacting those who previously consulted on the 2008 CIA for updates, as well as reaching out to additional parties to expand the scope of our previous consultation efforts.

We are reaching out to you for this assessment because you have been identified as a source of knowledge in Honouliuli. We are seeking your *kōkua* regarding any updated information related to the following components of our study:

- Cultural associations of Honouliuli Ahupuaʻa such as *moʻolelo* or connections to legendary accounts.
- Knowledge of past and present land use within and near the project area.
- Knowledge of past and present traditional gathering practices in Honouliuli.
- Knowledge of cultural resources which may be impacted by the proposed project, including traditional plant and animal gathering sites, traditional access trails, archaeological sites, historic sites, and burials.

Business Office
4919 Windplay Dr., Ste. 4
El Dorado Hills, CA 95762
916.358.5156 Ph.
916.358.5161 Fax

Bay Area
900 Modoc St.
Berkeley, CA 94707
510.524.3991 Ph.
510.524.4419 Fax

Sierra/Central Valley
4919 Windplay Dr., Ste. 4
El Dorado Hills, CA 95762
916.358.5156 Ph.
916.358.5161 Fax

- Any other cultural concerns that community members may have in relation to traditional Hawaiian or other cultural practices within or near the proposed project area.

- Referrals to other knowledgeable individuals who may be willing to share their cultural knowledge of the proposed project area and wider Honouliuli Ahupuaʻa.

I have attached a figure which shows the location of the proposed project in relation to the wider landscape. The full text of the 2008 CIA can also be made available upon request.

Please contact me via telephone at 808-263-4800 or via email at swift@pacificlegacy.com if you have any questions. If you would like to share your *ʻike* and *manaʻo* to assist with this assessment, please call the above number or respond via email to swift@pacificlegacy.com indicating that you would like to participate. If you have suggestions for other knowledgeable individuals or organizations, we would appreciate you sharing contact information with us. We look forward to hearing from you soon.

Mahalo piha,

Jillian A. Swift, Ph.D.
Project Manager, Archaeologist

Enclosure

Page 2 of 3

Attachment 1

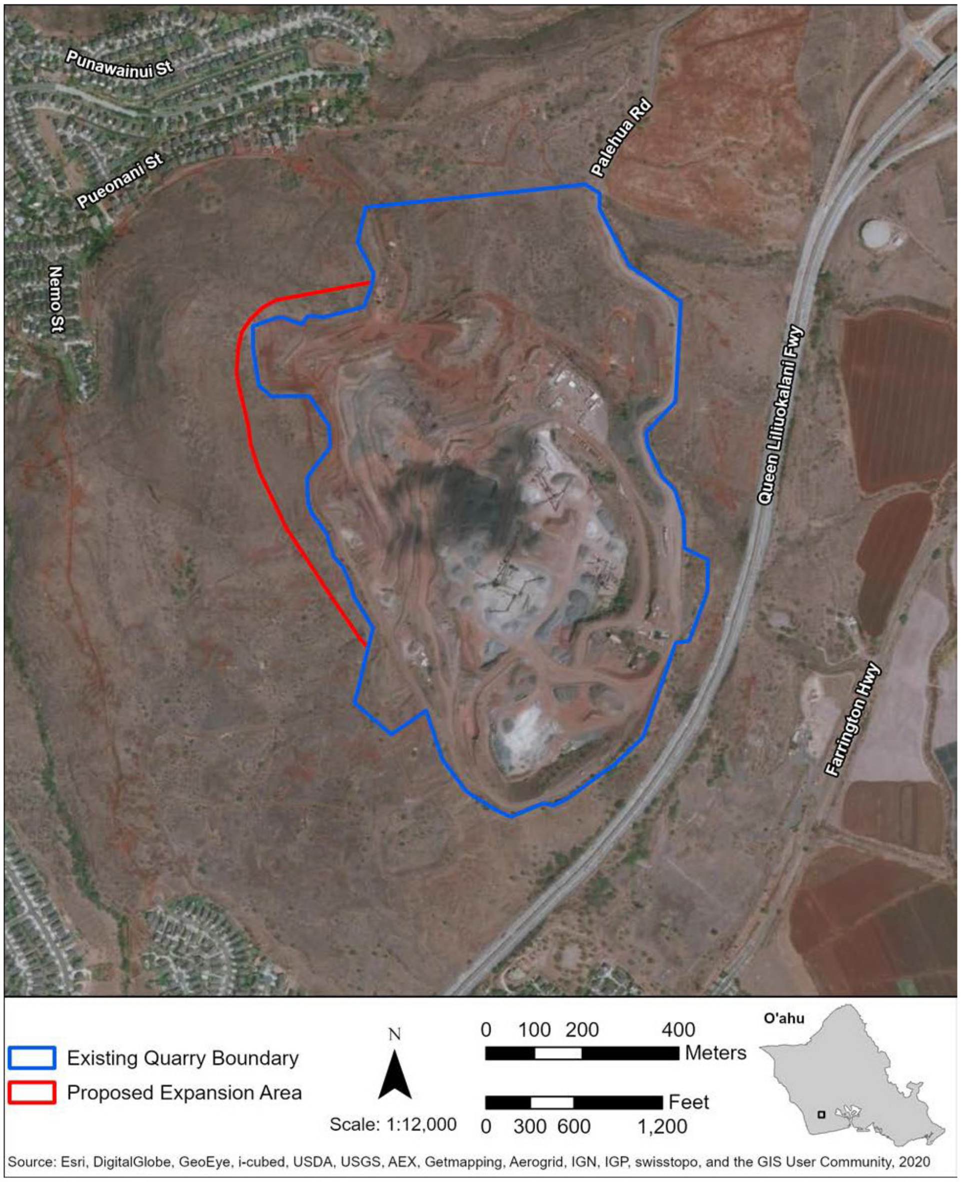

Figure 1. Location of the proposed 15.6-acre expansion to the Makakilo Quarry footprint and the project area for the Cultural Impact Assessment.

Page 3 of 3

Pacific Legacy

Historic Preservation

LITERATURE REVIEW AND FIELD INSPECTION FOR THE PROPOSED 15.6-ACRE EXPANSION AREA AT THE MAKAKILO QUARRY KAPOLEI, HONOULIULI AHUPUA‘A, ‘EWA MOKU, O‘AHU ISLAND

[TMK: (1) 9-2-003:074 (POR.)]

CULTURAL RESOURCES CONSULTANTS

Hawai‘i Office:
Kailua, O‘ahu

California Offices:
Bay Area
Sierra/Central Valley

Exhibit “T”

Pacific Legacy: Exploring the past, informing the present, enriching the future.

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LITERATURE REVIEW AND FIELD INSPECTION FOR THE PROPOSED 15.6-ACRE EXPANSION AREA AT THE MAKAKILO QUARRY KAPOLEI, HONOULIULI AHUPUA‘A, ‘EWA MOKU, O‘AHU ISLAND

[TMK: (1) 9-2-003:074 (POR.)]

Prepared by:
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Kapolei, HI 96707

October 2022

ABSTRACT

At the request of Grace Pacific, LLC, Pacific Legacy, Inc. conducted a Literature Review and Field Inspection (LRFI) for a proposed expansion area of the Makakilo Quarry in Honouliuli Ahupuaʻa, ʻEwa Moku, island of Oʻahu [TMK: (1) 9-2-003:074 (por.)]. The purpose of the LRFI was to investigate previous land use of the project area and to determine whether any undocumented historic properties exist in the project area.

The investigation was two-fold, consisting of historical background research and a site inspection:

1. Background research built upon the previous archaeological assessment prepared by Pacific Legacy (Mooney and Cleghorn 2008a) and also included review of more recent archaeological reports produced in the vicinity of the project area.
2. A one-day field inspection was carried out by two Pacific Legacy archaeologists with the purpose of determining whether undocumented historic properties exist within the project area.

The literature review found that there had already been significant disturbance within the project area from industrial agricultural and quarrying activities, as well as the modern development of a golf course in the 1990s. Most historic properties in the immediate vicinity of the project area relate to post-Contact industrial agriculture and quarrying, though some traditional Hawaiian features have been recorded in the greater Makakilo area. The field inspection identified five potential historic properties: a concrete ditch (T-01), two modified outcrops (T-03, T-04), and two terrace/wall segments (T-02, T-05), all with likely post-Contact associations.

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Cover Image: *The edge of the Makakilo Quarry access road along the southern portion of the project area (view to south).*

1.0 INTRODUCTION

At the request of Grace Pacific, LLC, Pacific Legacy, Inc. conducted a Literature Review and Field Inspection (LRFI) for a proposed expansion area of the Makakilo Quarry in Honouliuli Ahupuaʻa, ʻEwa Moku, island of Oʻahu [TMK: (1) 9-2-003:074 (por.)] (Figure 1).

The purpose of this LRFI was to investigate previous land use of the project area and to determine whether any undocumented historic properties exist in the project area. The work was also designed to facilitate historic preservation review by the State Historic Preservation Division (SHPD) under Hawaiʻi Revised Statutes (HRS) Chapter 6E.

1.1 METHODS & SCOPE

The background research conducted for this LRFI built on the previous archaeological assessment (AA) prepared by Pacific Legacy (Mooney and Cleghorn 2008a) and included a review of more recent literature produced for projects in the vicinity of the current expansion area.

In addition to updated background research, Pacific Legacy, Inc. conducted a field inspection on 7 June 2022. The inspection was conducted by Pacific Legacy archaeologists Jillian Swift, Ph.D. and Caleb Fechner, B.A., under the overall supervision of Mara Mulrooney, Ph.D. (Principal Investigator). The field inspection consisted of a reconnaissance pedestrian survey and limited recording of historic properties, including GPS point mapping, photography, brief descriptions, and site flagging. An addendum update to the Cultural Impact Assessment (CIA) prepared by Pacific Legacy (Mooney and Cleghorn 2008b) was also developed as a separate document (Swift and Mulrooney 2022). The addendum to the CIA was prepared to capture insights from regional stakeholders (current and former residents of Honouliuli Ahupuaʻa) who are knowledgeable about cultural practices that may have taken place in the project area.

1.2 PROJECT BACKGROUND

Grace Pacific, LLC is proposing an expansion area of approximately 15.6 acres on the northwest side of the current Makakilo Quarry footprint (Figure 1). The proposed expansion will provide Grace Pacific, LLC with access to a seam of high-quality rock for use in concrete and asphalt paving. In addition to the proposed expansion, Grace Pacific, LLC intends to apply for modification to their current quarry permit that would extend the permit 15 years beyond its current expiry (from 21 December 2023 to 21 December 2047) and expand hours of hot mix asphalt/concrete production and sales 24 hours per day, 7 days per week. Mining would continue to be restricted to daytime use only. They will also relocate the Hot Mix Asphalt Plant into the quarry pit (Figure 2).

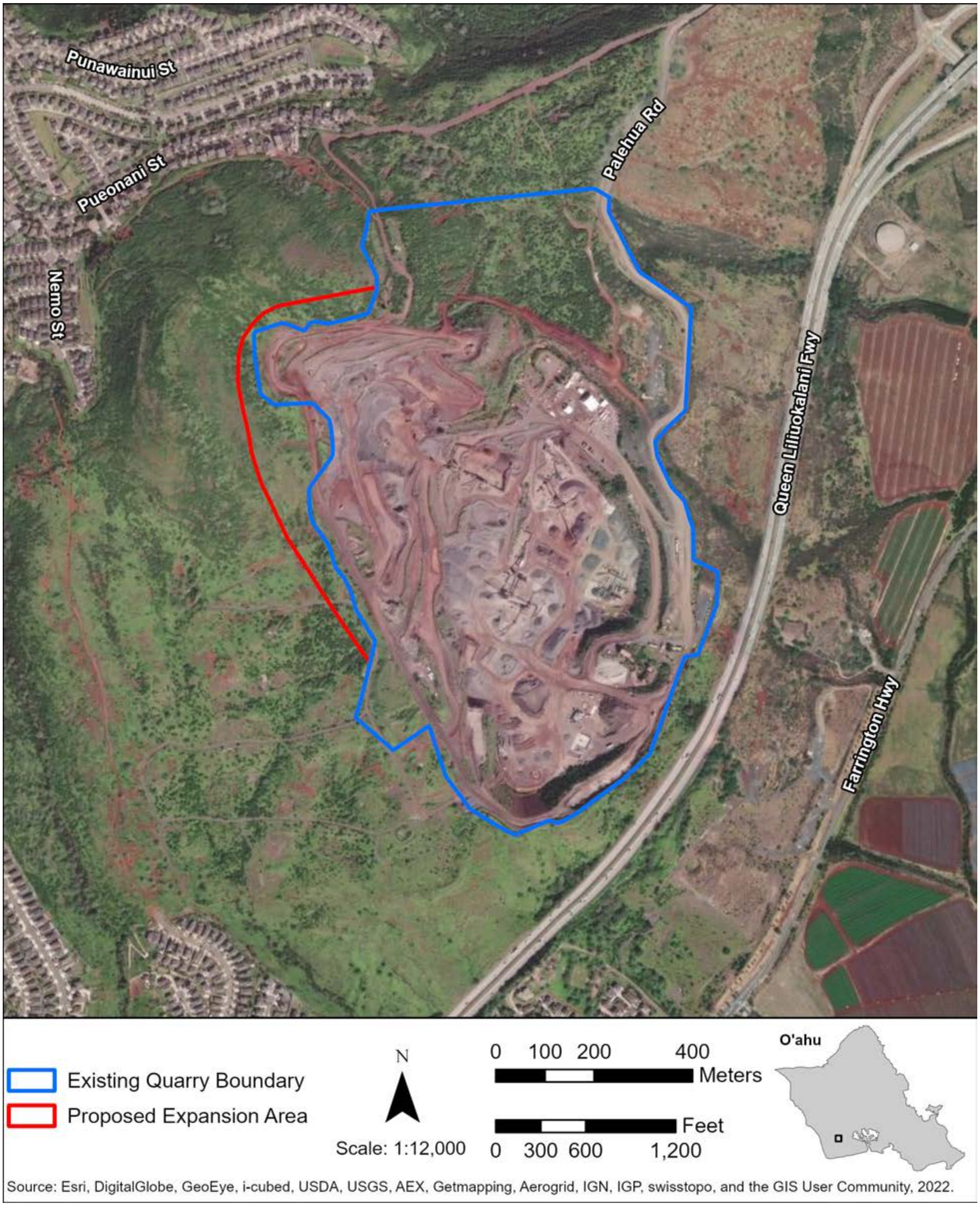
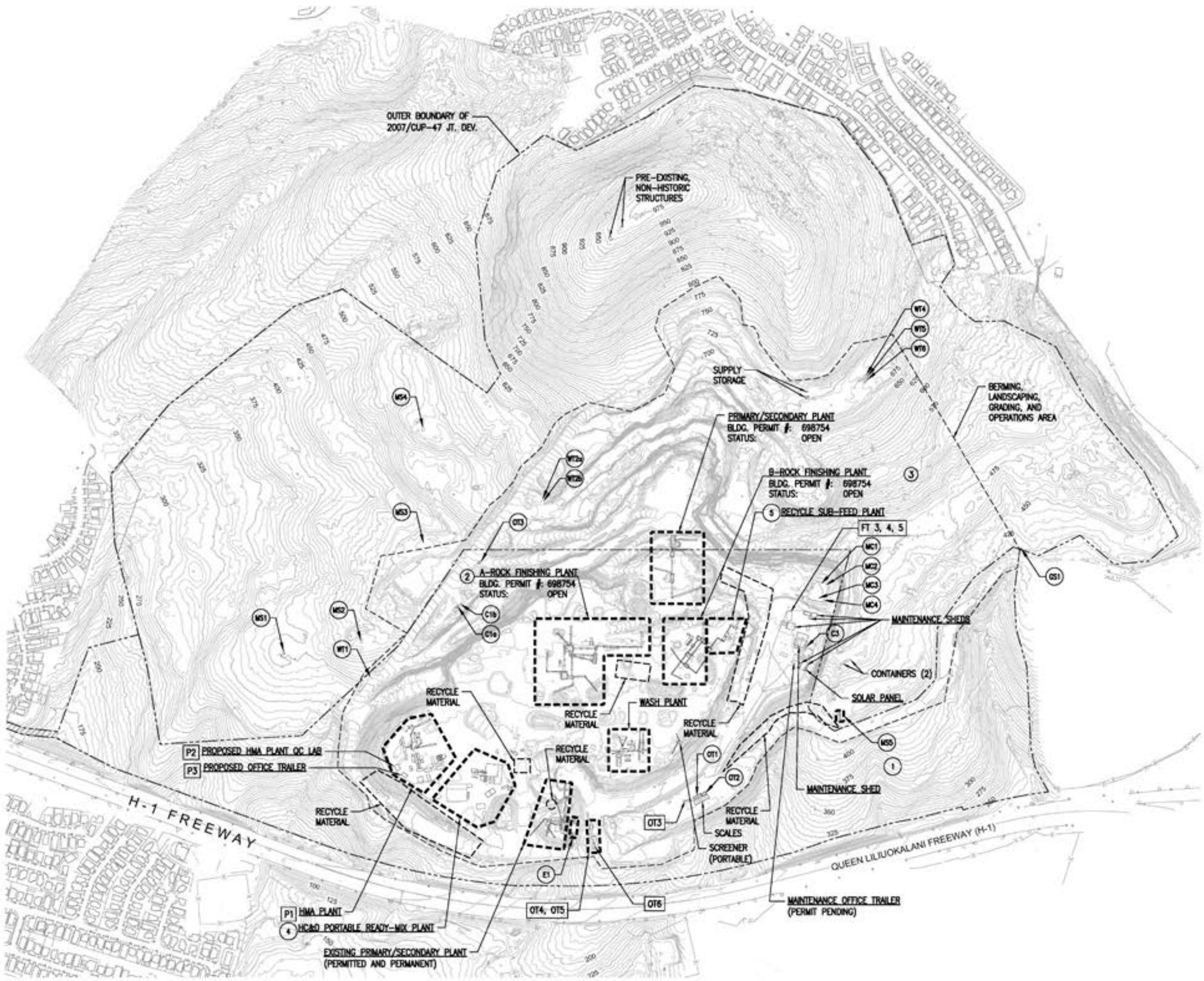


Figure 1. Location of the existing Makakilo Quarry boundary (blue) with outline of proposed expansion project area (red), and nearby roadways (base map: Esri World Imagery 2022).



	STATUS	DESCRIPTION	FLOOR AREA (FT^2)	LOT COVERAGE (FT^2)
MS1	EXISTING	MONITORING STATION	0	159
MS2	EXISTING	MONITORING STATION	0	268
MS3	EXISTING	MONITORING STATION	0	268
MS4	EXISTING	MONITORING STATION	0	258
MS5	EXISTING	MONITORING STATION	0	177
OT1	EXISTING	OFFICE TRAILER	540	540
OT2	EXISTING	OFFICE TRAILER	672	672
C1a	EXISTING	CONTAINER	194	194
C1b	EXISTING	CONTAINER	223	223
C2	EXISTING	CONTAINER	558	558
C3	EXISTING	CONTAINER	317	317
WT1	EXISTING	WATER TANK	0	348
WT2a	EXISTING	WATER TANK	0	152
WT2b	EXISTING	WATER TANK	0	152
WT4	EXISTING	WATER TANK	0	335
WT5	EXISTING	WATER TANK	0	262
WT6	EXISTING	WATER TANK	0	227
FT1	EXISTING	FUEL TANK	0	125
MC1	EXISTING	MAGAZINE CONTAINER	192	192
MC2	EXISTING	MAGAZINE CONTAINER	178	178
MC3	EXISTING	MAGAZINE CONTAINER	127	127
MC4	EXISTING	MAGAZINE CONTAINER	94	94
E1	EXISTING	EQUIPMENT	0	0
1	EXISTING	MAINTENANCE SHED	4,790	5,600
2	EXISTING	A-ROCK FINISHING PLANT	0	42773
3	EXISTING	B-ROCK FINISHING PLANT AND RECYCLE PLANT	0	16411
4	EXISTING	HC&D PORTABLE PLANT	–	32,000
5	EXISTING	RECYCLE SUB-FEED PLANT	–	4,800
GS1	EXISTING	GUARD STATION	36	36
OT3	EXISTING	OFFICE TRAILER	240	240
OT4	EXISTING	OFFICE TRAILER	835	835
OT5	EXISTING	OFFICE TRAILER	341	341
OT6	EXISTING	AGGREGATE QUALITY CONTROL	–	–
FT 3, 4, 5	EXISTING	FUEL TANKS	–	–
	EXISTING	RECYCLE MATERIAL		
P1	PROPOSED	HMA PLANT	–	13,000
P2	PROPOSED	PROPOSED HMA PLANT QC LAB	–	–
P3	PROPOSED	PROPOSED OFFICE TRAILER	–	–

PROJECTED QUARRY SITE PLAN

Exhibit "M"

Figure 2. Site plans for the Makakilo Quarry Proposed Expansion Project Area (courtesy of Grace Pacific, LLC, 2023).

1.3 PROJECT LOCATION AND ENVIRONMENT

The project area is located in Honouliuli Ahupuaʻa, ʻEwa Moku, island of Oʻahu, within a portion of TMK: (1) 9-2-003:074 (Figure 3, Figure 4). The proposed expansion area extends to the northwest of the current Makakilo Quarry footprint and comprises roughly 15.6 acres in total (Figure 1). The quarry lies on the southwest flank of Puʻu Makakilo, just outside the city of Kapolei and *mauka* (inland) of the H-1 Freeway. It is surrounded by Makakilo and Makalapa Gulches to the west, Kaloʻi Gulch to the north, and Hunehune Gulch to the east, all of which are seasonal drainages (Figure 5).

Puʻu Makakilo has a steep, kidney-shaped peak that rises to c. 950 feet above mean sea level (AMSL) and is the most prominent of several cinder cones that lie at the southern foot of the Waiʻanae Mountain Range. The summit of Puʻu Makakilo (c. 800–972 ft AMSL) has a 70%–90% slope, while the base (c. 200–800 ft AMSL) has only a 12%–20% slope and is relatively broad.

According to the U.S. Department of Agriculture (USDA) Soil Survey for Oʻahu and the State of Hawaiʻi's Natural Resources Conservation Service (NRCS), the soils that comprise the surface and substrate of Puʻu Makakilo are quite varied due to the contrast of lower depositional areas versus upper eroded elevations (Foote et al. 1972). The project area itself contains four types of soils: Helemano silty clay, 30 to 90 percent slopes (HLMG), Mahana-Badland complex (MBL), Mahana silty clay loam, 12 to 20 percent slopes, eroded (McD2), and Stony steep land (rSY) (Figure 6).

Makakilo has an average rainfall of approximately 60 cm, with as little as 1 cm in the dry months of June and July and as much as 10 cm in the wet months of December and January (Giambelluca et al. 1986:138–150).

Vegetation observed in the Makakilo area includes *kiawe* (*Prosopis pallida*), *haole koa* (*Leucaena glauca*), klu (*Acacia fanesiana*), lantana (*Lantana camara*), and a wide variety of other non-native grasses and weeds. Little remains of native plant species in the Makakilo area due to the intended and inadvertent introduction of exotics, and post-Contact land alterations for agriculture.

The Makakilo landscape has been changed by a variety of agricultural and construction activities since the post-Contact period. The most significant change in the area was the development of the Makakilo Golf Course, which was built in the late 1980s to early 1990s. Creation of the golf course grounds required significant bulldozing and reshaping of the landscape to create fairways, berms, and ponds. Golf course construction was terminated in the middle phase of its development, and the area has largely lain fallow ever since (a little over 30 years). As a result, invasive non-native flora has crept back into the landscape. At above c. 800 ft AMSL, the *puʻu* has remained relatively undisturbed by man-made features, aside from a historic wall segment recorded by Sinoto (1988), and a historic bunker with associated small concrete structures located at the pinnacle of Puʻu Makakilo (Mooney and Cleghorn 2008a).

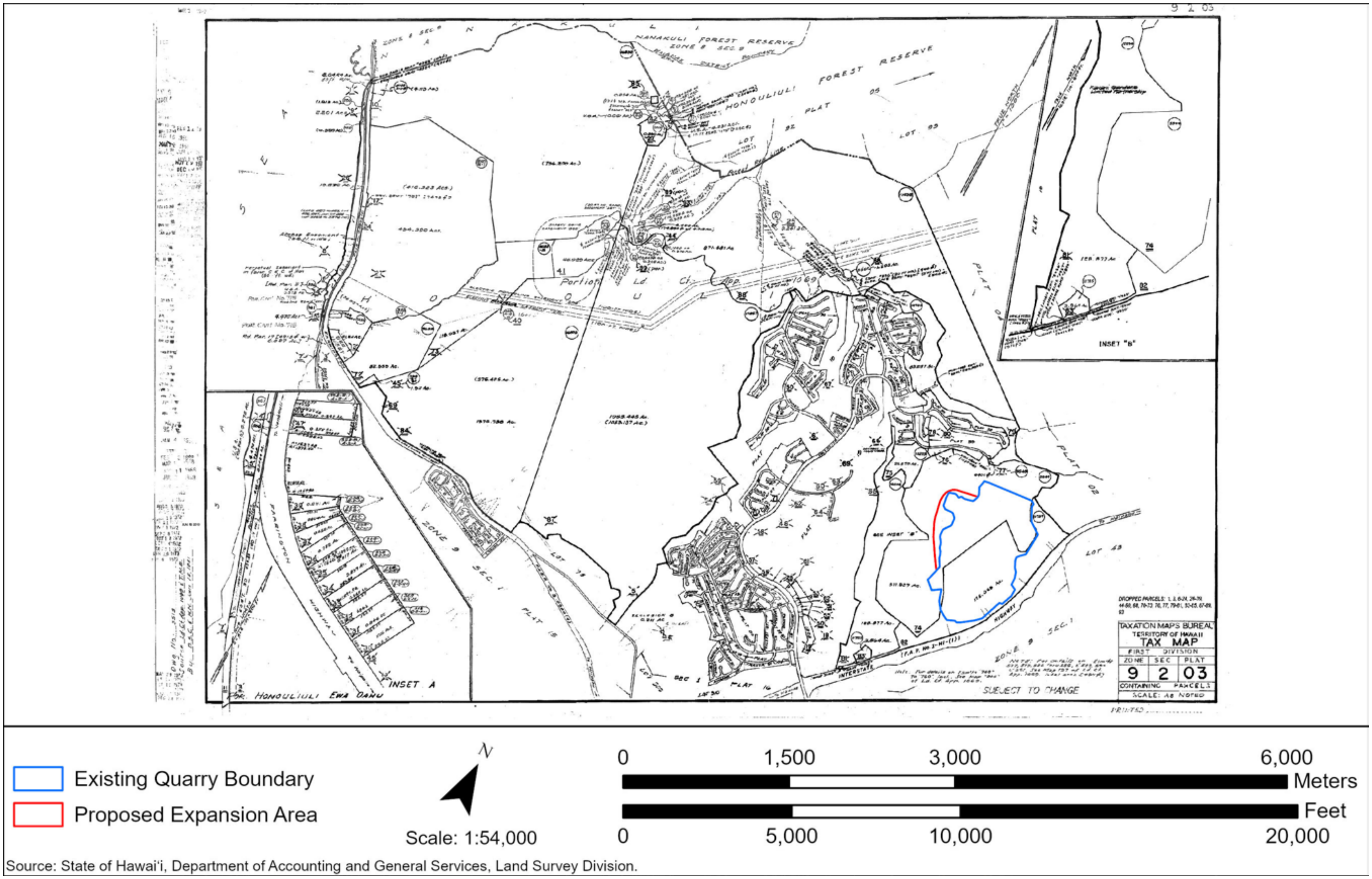


Figure 3. Tax map plat for TMK: (1) 9-2-003, with current Makakilo Quarry footprint and proposed expansion area outlined (source: State of Hawai'i, Department of Accounting and General Services, Land Survey Division, TMK: [1] 9-2-003:074 por.).

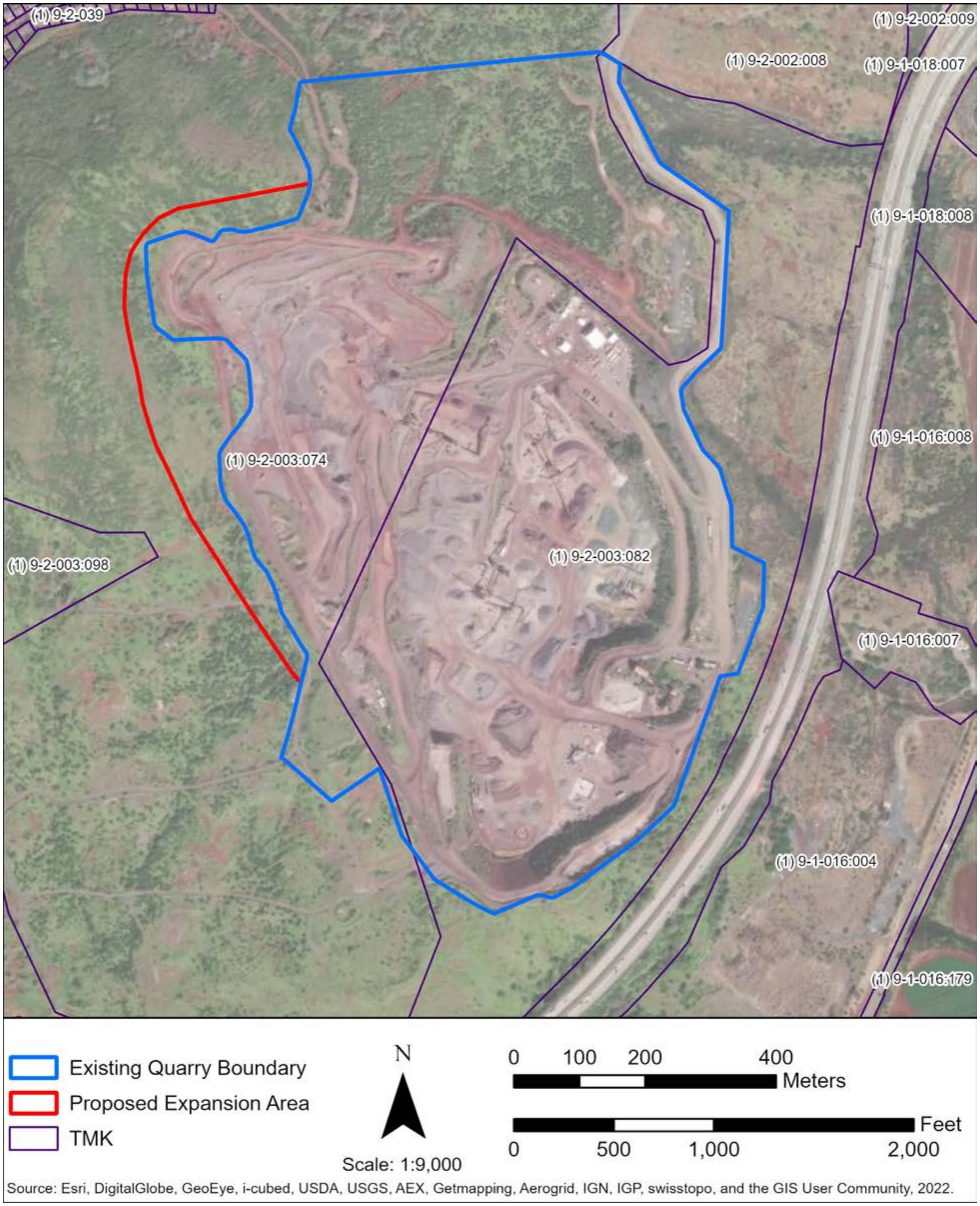


Figure 4. Location of TMK: (1) 9-2-003:074 and the Makakilo Quarry Proposed Expansion Project Area (source: State of Hawai'i, Department of Accounting and General Services, Land Survey Division; base map: Esri World Imagery 2022).

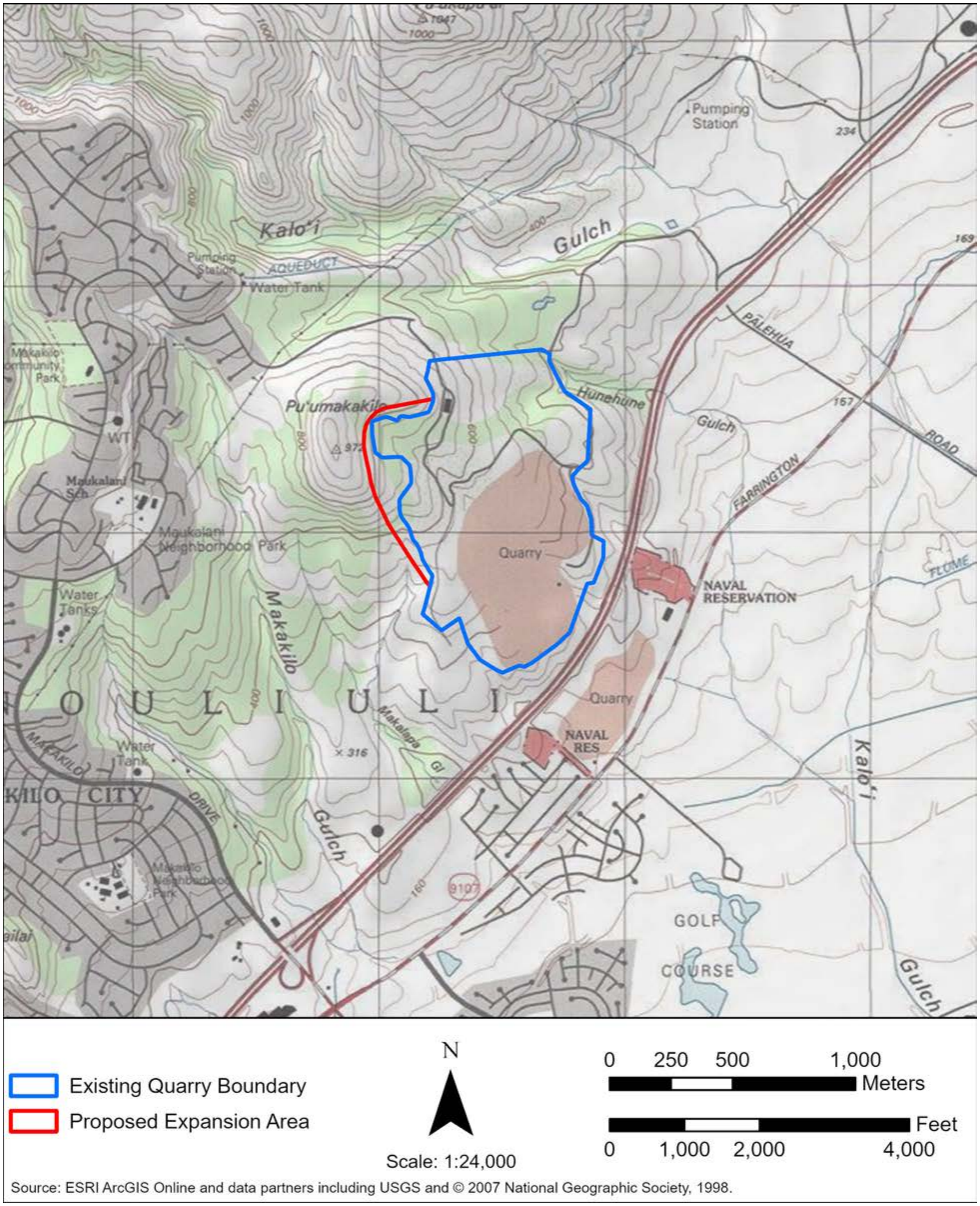


Figure 5. Location of the Makakilo Quarry Proposed Expansion Project Area, adjacent to the existing Makakilo Quarry footprint, Kapolei, Honouliuli Ahupuaʻa (base map: USGS Ewa Quadrangle 1998).

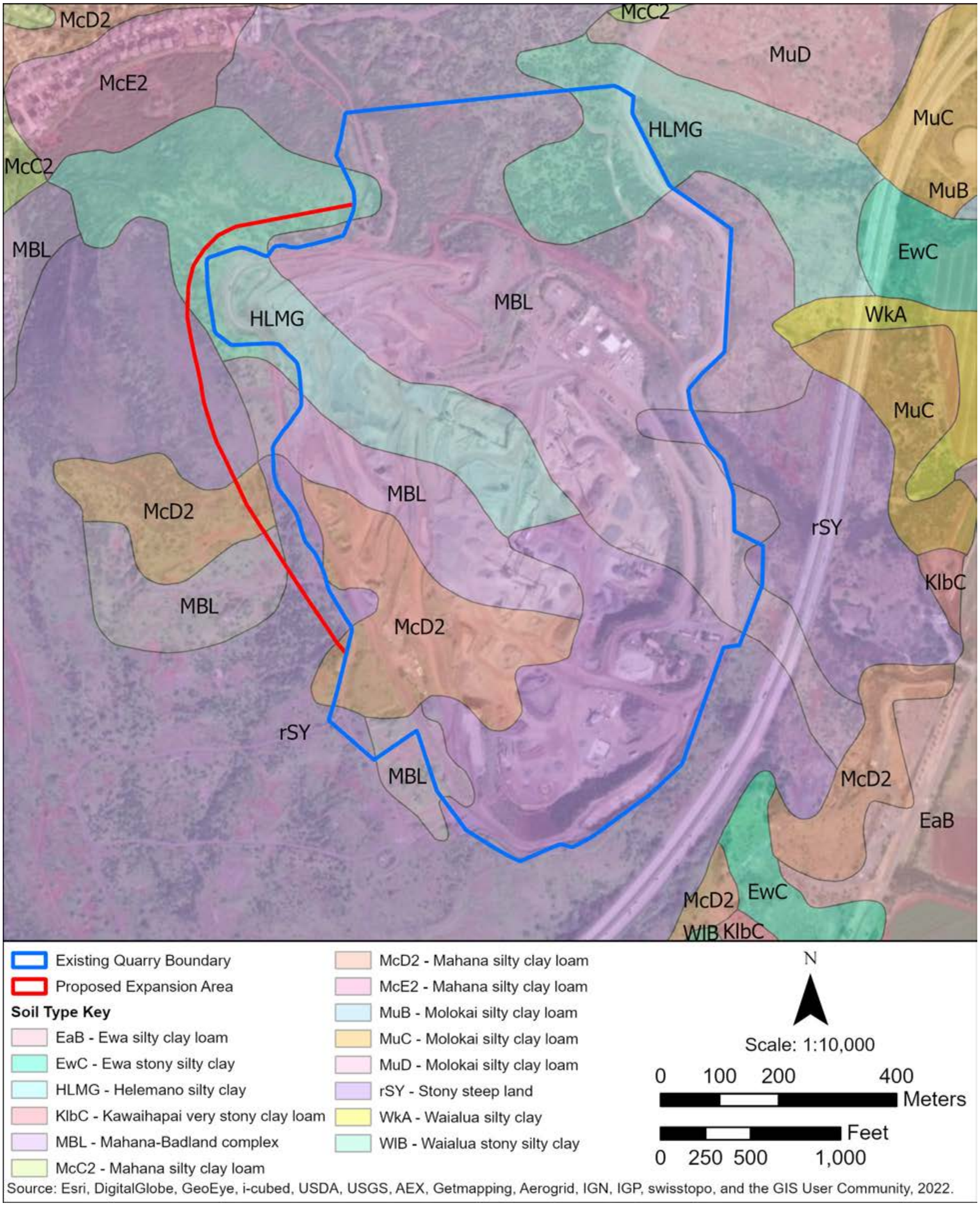


Figure 6. Map of soil types within the vicinity of the Makakilo Quarry Proposed Expansion Project Area (data from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture 2022).

2.0 BACKGROUND RESEARCH

Puʻu Makakilo literally translates as "observing eyes hill," and is located in the center of Honouliuli Ahupuaʻa within the *moku* or district of ʻEwa (Pukui et al. 1974:201). A manuscript housed in the T. Kelsey Collection at Bishop Museum (Kelsey, *Hawaiian Ethnological Notes Vol. 1*, unpublished ms, p. 820) notes that the area referred to as Makakilo or Makakilo City was once called Hanalei, and was described as "a small flat land with a little gulch on either side on the right of Puuloa mauka of Puu-o-Kapolei" (as cited in Sterling & Summers 1978:34). Most known oral historical accounts of Honouliuli focus on the eastern periphery of the ʻEwa Plain, in the area surrounding West Loch, as this was generally known to be the political and cultural center of Honouliuli Ahupuaʻa. However, a small number of accounts also pertain to central inland Honouliuli.

The first European historical account of the area was written on the arrival of Vancouver to ʻEwa in 1793. Vancouver observed that the land did not seem to be particularly populous or fertile. Regarding the area between Waiʻanae and the Koʻolau Mountains, he commented:

> This tract of land was of some extent but did not seem to be populous, nor to possess any great degree of natural fertility; although we were told that a little distance from the sea, the soil is rich, and all necessaries of life are abundantly produced. (Vancouver 1798, as cited in Sterling and Summers 1978:31)

Vancouver later commented on what he found to be the relatively dismal condition of west Honouliuli coast:

> From these shores we were visited by some of the natives, in the most wretched canoes I had ever yet seen amongst the South-sea islanders; they corresponded however with the appearance of the country, which from the commencement of the high land to the westward of Opooroah (Puuloa), was composed of one barren rocky waste, nearly destitute of verdure, cultivation or inhabitants, with little variation all the way to the west point of the island. (Vancouver 1798, as cited in Lewis 1970:6)

As with other areas of Hawaiʻi, European-introduced plants and animals generally had adverse impacts on the local ecosystems. The sandalwood trade, and the introduction of grazing animals such as goats, sheep and cattle, dramatically transformed the landscape. Introduced plants such as lantana (*Lantana camara*), *kiawe* (*Prosopis pallida*), *haole koa* (*Leucaena leucocephala*), and invasive grasses like *Cynodon dactylon* and *Eleusine indica* replaced the forested areas once populated by sandalwood trees and other native plants. Many of these introduced plants still dominate the vegetation in and around the project area.

After traversing much of the island of Oʻahu in the early 1800s, Edwin Hall, Hawaiian Minister of Finance, described west ʻEwa as a "barren, desolate plain" (Hall 1839 as cited in Lewis 1970:8). The first missionary to build a church in ʻEwa noted that the people were generally of ill health and overtaxed by Oʻahu's chiefs (Lewis 1970). In the mid-1800s, introduced European diseases devastated the island and led to a steep decline in the Native Hawaiian population (Kamakau 1961).

The entirety of Honouliuli Ahupuaʻa was awarded to the high chiefess, M.W. Kekauʻōnohi in the Māhele (Land Commission Award 11216, Royal Patent 6971). Upon her death in 1851, the lands were transferred to her husband, Levi Haʻalelea. Upon Haʻalelea's death, 42,000 acres of

Western Honouliuli was sold to J.H. Coney, who in turn sold the land to James Campbell in 1877 for $95,000. Campbell repurposed the land for cattle ranching under the name Honouliuli Ranch. A few years later, Campbell leased his lands, from Pearl Harbor to Waimānalo, to the Oahu Railway and Land Company (OR&L) for 50 years (Lewis 1970). There are no Land Commission Awards (LCAs) in the immediate vicinity of the project area.

Water, and often its scarcity, is a constant theme in the history of the Makakilo area. In the 1800s, it was said that Kaloʻi ("the taro patch"), the gulch located directly north of Makakilo, was one of the few places in the area that showed any potential for procuring fresh water. William R. Castle named a spring he tapped in the gulch "Wai o Kakela," though *kamaʻāina* (local residents) continued to refer to it as Kaloʻi (von Holt 1953 as cited in Sterling and Summers 1978:35). Tulchin and Hammatt (2005) identified what appears to be the remains of the spring during an archaeological inventory survey (AIS) of the Pālehua East B Project Area. The 11,000-acre ʻEwa Plantation Company, started in 1890, initially started with 775 acres of sugarcane planted at Honouliuli and irrigated with underground water (Campbell 1994). During this period, cattle were still ranched in the margins of the cane fields, and the *mauka* lands in western Honouliuli that were ill-suited to sugar production. A descendant of the ranch manager claimed that fishermen squatters lived in shanties by the beach and traded fish for taro at ʻEwa. That same individual reported that there was also a shrimp pond in the Barber's Point area (Lewis 1970).

In 1913, the Waiāhole Water Company (subsidiary of the Oʻahu Sugar Company) installed a water system known as the Waiāhole Ditch, which collected water from Kahana Valley in the north and transported it by tunnel through the Koʻolau Range to Waiawa, then westward to Honouliuli by ditch. The entire system was completed in 1916 and covered roughly 22 miles (Condé and Best 1973:37). Much of the system remains in use to this day, and portions of the Waiāhole Ditch system, State Inventory of Historic Places (SIHP) #50-80-09-02268, were identified in previous AISs by Dega et al. (1998), Tulchin and Hammatt (2004), and Hunkin and Hammatt (2009).

World War II-era military development also brought significant change to the Honouliuli landscape, as military installations were constructed in numerous areas of the coast and the uplands. This included the Honouliuli Internment Camp, now the Honouliuli National Historic Site (SIHP 50-80-08-09068, National Register of Historic Places #90000855, and National Monument under Proclamation 9234), as well as Barber's Point Military Reservation at Barber's Point Beach, Camp Malakole Military Reservation, Gilbert Military Reservation, Barber's Point Naval Air Station, Fort Barrette, and a number of other installations related to military surveillance and defense. On top of Puʻu Makakilo, Fire Control Station A was installed (and Fire Control Station B atop Puʻu Pālailai), and the Puʻu Makakilo Training Area was used for military training from 1942 to 1945 (Environment Hawaiʻi 1992, as cited in Hunkin and Hammatt 2009).

Until the residential boom of the early 1960s, the land in Makakilo remained agricultural. Over time, subdivisions have gradually replaced many of the areas previously used for ranching, sugar cultivation, or military activities. In the late 1980s/early 1990s, parts of the project area were subject to significant disturbance from the development of the Makakilo Golf Course; however, the project ran out of money before the course could be completed.

3.0 PREVIOUS ARCHAEOLOGY

A number of archaeological investigations have occurred in the vicinity of the Makakilo Quarry Proposed Expansion Area, most resulting in modest finds. Most of these studies are associated with the continued development of Makakilo within the greater Kapolei region (Figure 7, Figure 8).

The earliest archaeological investigation in the vicinity of the project area was conducted in the 1930s by Bishop Museum archaeologist J. Gilbert McAllister (1933). McAllister recorded several sites around the peripheries of Puʻu Makakilo; however, the site recording methods available to him in the early 20th century were rudimentary by today's standards. McAllister noted that on the side of Puʻu Kapolei, a mile south of Puʻu Makakilo, was a large rock shelter rumored to be the dwelling of Kamapuaʻa and his grandmother, Kamaunuahihio. He also documented the Puʻu Kapolei Heiau (Site 138) in the same vicinity (McAllister 1933:108). McAllister also described the Puʻu Kuina Heiau (Site 134), located in a gulch at the foot of Mauna Kapu, 2.5 miles north of Makakilo, but which had been destroyed and reduced to "a suggestion of a terrace" (as cited in Sterling & Summers 1978:32). In the same area, McAllister recorded a four- to six-foot square basalt and coral platform (Site 136) which was purportedly a sacred Hawaiian altar (McAllister 1933:107), though apparently the site was destroyed by the late 1950s (Sterling and Summers 1978:32).

In 1977, Archaeological Research Center Hawaiʻi, Inc. (ARCH) performed an archaeological reconnaissance survey for the Kaloʻi Gulch Landfill, just north of Puʻu Makakilo. Bordner (1997) identified three walls of stacked *pāhoehoe* slabs with possible pre-Contact associations (SIHP 50-80-12-02600 through -02602), but considered them to be of marginal significance and did not recommend further work (Bordner 1977).

In 1986, Paul H. Rosendahl, Inc. (PHRI) conducted a preliminary archaeological reconnaissance survey for the ʻEwa Town Center / Secondary Urban Center, a project area of roughly 1,400 acres (Haun 1986). Haun identified an irrigation ditch that followed the 200 ft contour of Puʻu Pālalai, and noted the existence of a WWII-era structure. He recommended no further archaeological work in the project area.

In March of 1988, a letter report was written by Aki Sinoto of Bishop Museum about the pedestrian surface survey performed by Williams and Duckworth for the Makakilo Golf Course. According to this report, the survey was conducted in an area which extends beyond the proposed Makakilo Quarry expansion area. Sinoto commented on the topography of the southeastern flank of Puʻu Makakilo by stating:

> As anticipated, large portions of the project area have been and still undergo severe erosion. Barren areas of exposed substrate is interspersed with areas dominated by dry grasses and small kiawe. Steep erosional gullies with vertical walled heads, bare areas of sheet wash, and pedestaled rocks attest to the severe and continuing erosion. (Sinoto 1988:1)

While no significant archaeological sites were located in the Makakilo Golf Course surface survey, Sinoto did discover a deteriorated wall segment inside of Puʻu Makakilo (Bishop Museum Site No. 50-OA-B6-276 and SIHP 50-80-12-01975). The site was located just outside (northwest) of the golf course project area's *mauka* extension. Sinoto (1988) described the 10.5 × 1.4 × 1.4-m wall as "double-faced" and "core-filled" with a north/south orientation. Sinoto speculated that the wall may have served as erosion control in historic times. However, due to its deteriorated state and the fact that the wall was not associated with any other features or structures, Sinoto determined that it did not meet the National Register criteria of significance and no further work was recommended (Sinoto 1988:1).

An AIS was conducted in 1993 on the parcels located southwest of the current project area (TMK: [1] 9-2-003:074, [1] 9-2-003:075, and [1] 9-2-003:081) by Aki Sinoto Consulting (Nakamura et al. 1993). This survey recorded a single historic site (SIHP 50-80-12-04664), described as a segment of an irrigation system constructed by the ʻEwa Plantation Company in 1941. Nakamura et al. (1993) documented the site in detail and deduced that "the significance can be considered to have been realized and no further work is necessary" (1993:32). The remaining area within the survey was also determined by Nakamura et al. to have a very low probability of subsurface remains.

In 1996, Scientific Consultant Services, Inc. (SCS) conducted an archaeological reconnaissance survey of an area extending from the H1 freeway to the north side of Renton Road. No historic properties were identified (Spear 1996).

In 1997, Cultural Surveys Hawaiʻi (CSH) (Hammatt and Chiogioji 1997) carried out an archaeological reconnaissance survey of a 4.5-kilometer land corridor. No historic properties were identified.

In 1998, SCS (Dega et al. 1998) conducted an AIS of the University of Hawaiʻi, West Oʻahu Campus project area. They identified a complex of irrigation features associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). Site -05593 was assessed as significant under Criteria a and d and no further work was recommended for either site (Dega et al. 1998).

In 1999, International Archaeological Research Institute, Inc. (IARII) carried out an archaeological reconnaissance survey for the Farrington Highway Expansion Project (Magnuson 1999). Magnuson identified six concrete bridges, a railroad track, and a set of unidentified concrete features. However, all features were determined to be not significant. No SIHP numbers were assigned and Magnuson recommended no further work beyond the recordation from the reconnaissance survey.

In 2004, CSH (Tulchin and Hammatt 2004) carried out an AIS for the Pālehua Community Association (PCA) common areas at Makakilo, a group of discrete parcels of agricultural land, which combine to cover a total area of roughly 86 acres (TMK: [1] 9-2-003:078 [por.] and [1] 9-2-003:079). Although historic accounts point to a substantial Hawaiian population within the vicinity of the project area, Tulchin and Hammatt recorded only four new sites and 10 features. The sites included a complex of concrete and iron structures associated with industrial rock quarrying (SIHP 50-80-12-06880), three boulder mounds they associated with land clearing or ditch construction by the Oʻahu Sugar Co. (SIHP 50-80-12-06881), a water diversion terrace associated with the historic period (SIHP 50-80-12-06682), and a remnant portion of the Waiāhole Ditch (SIHP 50-80-09-02268). They suggest that the limited number of findings might be due to extensive land modification from ranching, commercial sugar plantations, and industrial rock quarrying, or that extensive erosion of topsoil into the project area may have concealed surface archaeological features. Sites -06680, -06681, and -06682 were evaluated as significant under Criterion d. Site -02268 was evaluated as significant under Criteria a and d. No further work was recommended for any of these sites beyond documentation that was completed for the AIS (Tulchin and Hammatt 2004).

In 2005, CSH (Tulchin and Hammatt 2005) carried out an AIS for the Pālehua East B residential development project at Makakilo, an approximately 71-acre parcel bordered by the Royal Ridge Subdivision on the west, Pu‘u Makakilo on the south, and Kalo‘i Gulch on the north and east (TMK: [1] 9-2-003:076 and [1] 9-2-003:078). They found that the area had already undergone significant erosion of topsoil, as well as substantial land modifications from development (e.g., machine grading, bulldozer clearing, excavation ditches, and landscape irrigation). They recorded three newly identified historic properties and a total of six component features, which they ascribed to agricultural or water diversion functions. These included a boulder alignment and mound (SIHP 50-80-12-06666), a basalt wall and ditch feature (SIHP 50-80-12-06667), and a boulder alignment (SIHP 50-80-12-06668). Sites -06666 and -06668 were evaluated as significant under Criterion d, and Site -06667 was evaluated as significant under Criteria c and d. They recommended no further work beyond the testing completed during the AIS (Tulchin and Hammatt 2005).

In 2006, CSH (O’Hare et al. 2006) conducted an AIS for the East Kapolei or Ho‘opili Project. They identified several previously identified historic properties, including plantation infrastructure (SIHP 50-80-12-04344), a railroad berm (SIHP 50-80-12-04345), the northern pumping station (SIHP 50-80-12-04346), central pumping station (SIHP 50-80-12-04347), and southern pumping station (SIHP 50-80-12-04348). They recorded four additional features associated with the plantation infrastructure of SIHP -04344: two linear walls, a stone-faced berm, and a concrete ditch and masonry catchment basement (Features D through G). They noted that during a 1990 survey of the West Loch Bluffs project area (Hammatt and Shideler 1990), all of these sites were evaluated as significant under Criteria c and d. However, since that time, many of the original features of Site -04344 had deteriorated, and O’Hare et al. (2006) revised their determination for SIHP -04344 to significance under Criterion d only. No further work was recommended for SIHP -04344, and SIHP -04345 through -04348 were all recommended for preservation.

In 2006, IARII (Rasmussen 2006) carried out a three-part archaeological assessment in Makakilo and Makalapa Gulches for a D.R. Horton – Schuler Division development located approximately 2 km to the west and southwest of the project area (TMK: [1] 9-2-003:081, [1] 9-2-019:003, [1] 9-2-003:072, [1] 9-2-003:081, [1] 9-2-003:084, [1] 9-2-003:085). For the project, Rasmussen (2006) conducted three separate investigations which involved two pedestrian surface surveys and one test excavation unit. The 2004 survey yielded no archaeological sites, and Rasmussen concluded that there was little chance of finding sites due to heavy disturbance from off-roading trails, bulldozing, and natural erosion. In the 2006 survey, Rasmussen recorded one new historic property (SIHP 50-80-12-04664) with eight associated features related to sugarcane cultivation, including a flume, double drain culvert, walled drainage, rock-lined ditch, plow scars, crushed coral roadbed, crushed basalt cobble foundation or paving, and a curved rock alignment. SIHP -04664, inclusive of all component features, was evaluated as significant under Criterion d, and no further work was recommended.

In 2006, IARII (Rasmussen and Tomonari-Tuggle 2006) conducted archaeological monitoring work along the Waiau Fuel Pipeline Corridor. No historic properties were identified during monitoring.

In 2007, CSH (Tulchin and Hammatt 2007) carried out an Archaeological Literature Review and Field Inspection (LRFI) for a parcel measuring approximately 790 acres within Pālehua (TMK: [1] 9-2-003:002 por., [1] 9-2-003:005 por.), located just north of Makakilo City and encompassing portions of Makaīwa Gulch, Awanui Gulch, and Kaloʻi Gulch. They found that much of the pre-Contact cultural landscape remained intact because most of the land within this project area was used almost exclusively for ranching purposes up to the present. This included pre-Contact archaeological features such as habitation, agricultural, and ceremonial features, as well as post-Contact features associated with historic ranching and quarrying activities. They recommended an AIS with 100% coverage pedestrian inspection to identify and document all historic properties and evaluate their significance should plans arise to further develop the area.

In 2007, CSH (Tulchin et al. 2007) carried out an Archaeological Field Inspection, Literature Review, and Cultural Impact Evaluation for the proposed Kapolei 215 Reservoir No. 2 Project (TMK: [1] 9-2-003:083). No historic properties were identified.

In 2009, CSH (Hunkin and Hammatt 2009) carried out an AIS for the Makakilo Drive Extension Project (TMK: [1] 9-2-002:006 and [1] 9-2-002:079), bound on the south by Quarry Road, which connects Old Pālehua Road with the Grace Pacific Makakilo Quarry. The AIS recorded two newly identified historic properties and documented one previously identified historic property (the portion of Waiāhole Ditch, SIHP 50-80-09-02268). The two newly identified historic properties were both irrigation ditches, likely associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-09-06950 and 50-80-09-06951). Sites -06950 and -06951 were evaluated as significant under Criterion d, and no further work was recommended for these sites. Site -02268 was evaluated as significant under Criteria a, c, and d and avoidance and mitigation of inadvertent adverse impact was recommended.

In 2010, CSH conducted archaeological monitoring for Phase 1B of the North-South Road Project (TMK: [1] 9-1-017:004, 095, 096, 097, 098) and identified no historic properties (Runyon et al. 2010).

In 2011, CSH (Runyon et al. 2011) completed archaeological monitoring for Phase 1C of the North-South Road Project (TMK: [1] 9-1-018:001, 003, 004, 005; 9-2-002:001, 006). They identified one historic property previously identified by Nakamura et al. (1993), a historic water diversion structure (SIHP 50-80-12-04884), and documented one newly identified historic property, a burnt trash fill layer found under Pālehua Road, on the west edge of Ramp A (SIHP 50-80-12-07128). Both sites were evaluated as significant under Criterion d, and no further work was recommended.

In 2014, IARII (Pacheco and Rieth 2014) carried out an AIS for the East Kapolei Solar Farm (TMK: [1] 9-2-002:006 por.). They recorded one newly identified historic property, an unpaved early 20th-century road, likely associated with either industrial ranching or sugarcane cultivation activities (SIHP 50-80-12-07433). The site was evaluated as significant under Criterion d. No further work was recommended beyond the recordation involved in the AIS.

In 2014, IARII (Rieth et al. 2014) carried out an AIS of an area including SIHP 50-80-12-07664, a site comprised of two basalt boulders carrying five petroglyph figures, and approximately 0.16 acres of the surrounding area (TMK: [1] 9-2-048:092 por.). Aside from thorough documentation of the petroglyph site, no additional historic properties were identified. The site was evaluated as significant under Criteria d and e, and relocation and passive preservation was recommended.

In 2018, CSH (Zapor et al. 2018 as cited by Welser et al. 2020) conducted a supplemental archaeological inventory survey (SAIS) for the Makakilo Drive Extension Project. They identified two historic properties: portions of the previously documented Waiāhole Ditch (SIHP 50-80-09-02268), and an irrigation ditch with associated components (SIHP 50-80-09-06951). They documented an additional component feature of the Waiāhole Ditch (SIHP -02268, Feature D) consisting of an earthen mound and stacked stone wall which are likely the remnants of a reservoir. They assessed SIHP -02268 as significant under Criteria a, c, and d (Zapor et al. 2018 as cited by Welser et al. 2020). Significance assessment for SIHP -06951 and mitigation recommendations for both sites have not been made available.

In 2020, CSH (Welser et al. 2020) conducted an AIS for the AES West Oʻahu Solar Project, TMK: (1) 9-2-002:007 (por.). They identified two previously documented historic properties: a complex of irrigation features previously identified by Dega et al. (1998) and associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). SIHP -05593 was evaluated as significant under Criteria a and d, and -02268 was evaluated as significant under Criteria a, c, and d. Mitigation commitments included avoidance of adverse impact to component features within the project area, data recovery in the form of archaeological monitoring, Historic American Engineering Record (HAER) documentation of SIHP -05593, Feature 2 (mill building and Pump House 12 complex), and incorporation of the portions of -02268 within the project area to an existing Addendum to the Waiāhole Ditch Historic Context Study (Mason Architects, Inc. 2018).

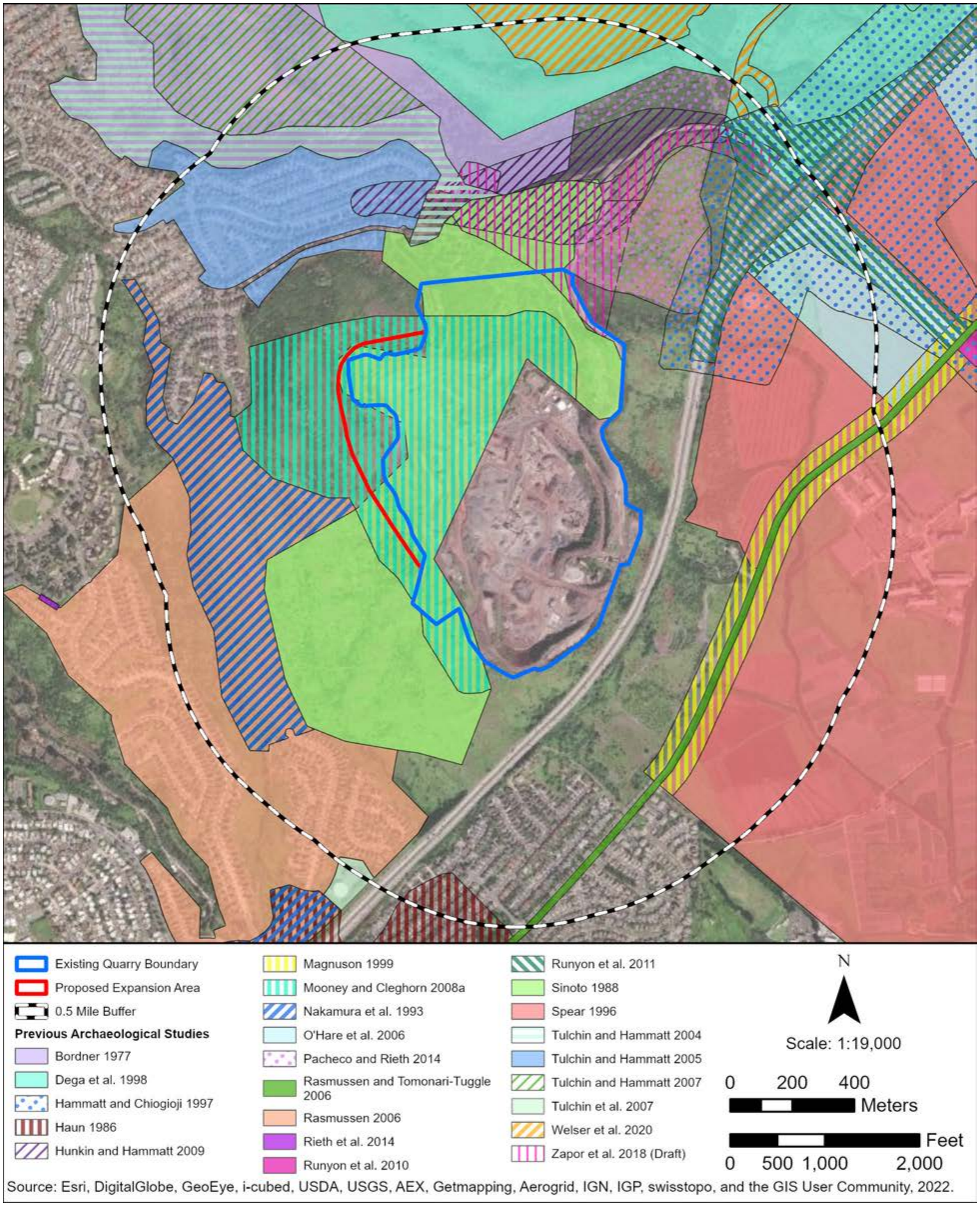


Figure 7. Locations of previous archaeological investigations in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2022).

Table 1. Previous Archaeological Studies in the Vicinity of the Makakilo Quarry Proposed Expansion Project Area

Reference	Type of Study	Location	Findings
Bordner 1977	Archaeological Reconnaissance Survey	Kaloʻi Gulch [TMK (1) 9-2-003]	Recorded abandoned quarry, pathway, retaining wall, and three walls of stacked pahoehoe slabs (SIHP 50-80-12-02600 through 02602).
Haun 1986	Archaeological Reconnaissance Survey	ʻEwa Town Center [TMK (1) 9-1-015: 004, 005, 017 pors.; (1) 9-1-016:001, 004, 006, 009, 016, 018, 024, 030 pors.; (1) 9-2-019: 001 por.]	Documented a single irrigation ditch, and noted the presence of a WWII-era structure.
Sinoto 1988	Surface Survey	Makakilo Golf Course [TMK (1) 9-2-003:018]	Documented a deteriorated, double-faced, core-filled wall segment, recommended no further work (SIHP 50-80-12-01975, Bishop Museum number 50-Oa-B6-276).
Nakamura et al. 1993	Archaeological Inventory Survey	Development Parcels D and D-1, Makakilo [TMK (1) 9-2-003:018 por., 075 por., 081 por.]	Documented a segment of an irrigation system constructed by the ʻEwa Plantation Company (SIHP 50-80-12-04664).
Spear 1996	Archaeological Reconnaissance Survey	From the H1 Freeway to the north side of Renton Road	No historic properties.
Hammatt and Chiogioji 1997	Archaeological Reconnaissance Survey	H1 corridor east of the project area	No historic properties.
Dega et al. 1998	Archaeological Inventory Survey	UH West O'ahu [TMK (1) 9-2-002:001]	Historic irrigation complex associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-08-05593) and remnant portions of the Waiāhole Ditch system (SIHP 50-80-09-02268).
Magnuson 1999	Archaeological Reconnaissance Survey	Farrington Highway	Recorded a railroad track, concrete bridges, and other concrete bridges, that were determined to be not significant. No SIHP numbers were assigned and no further work was recommended.

Reference	Type of Study	Location	Findings
Tulchin and Hammatt 2004	Archaeological Inventory Survey	Pālehua Community Association, Makakilo [TMK: (1) 9-2-003:078 por. and 079]	Recorded four archaeological sites and ten individual features associated with rock quarrying, water diversion, and agricultural activities (SIHP 50-80-12-02268, -06680 through -06682).
Tulchin and Hammatt 2005	Archaeological Inventory Survey	Pālehua East B Development, Makakilo [TMK (1) 9-2-003:076 and 078]	Recorded three new archaeological sites and six component features associated with agriculture and water diversion (SIHP 50-80-12-6666 through -06668).
O'Hare et al. 2006	Archaeological Inventory Survey	Hoʻopili, East Kapolei	Identified several previously identified historic properties, including plantation infrastructure (SIHP 50-80-12-04344), a railroad berm (50-80-12-04345), and northern, central, and southern pumping stations (50-80-12-04346 through -04348). Recorded four additional features associated with site -04344: two linear walls, a stone-faced berm, and a concrete ditch and masonry catchment basement (Features D through G).
Rasmussen 2006	Archaeological Inventory Survey	Makakilo and Makalapa Gulches [TMK (1) 9-2-003:081, 9-2-019:003, 072, 081, 084, 085]	Recorded site with 7 component features related to sugarcane cultivation (SIHP 50-80-12-04664). Components include drainage and irrigation features, a transport road, and crushed basalt paving.
Rasmussen and Tomonari-Tuggle 2006	Archaeological Monitoring	Waiau Fuel Pipeline Corridor, southeast of H1 corridor	No historic properties.
Tulchin and Hammatt 2007	Archaeological Literature Review and Field Inspection	790-acre parcel in Pālehua [TMK (1) 9-2-003:002 por. and 005 por.]	Numerous sites related to pre-contact Hawaiian habitation and activities and post-Contact ranching and quarrying.
Tulchin et al. 2007	Archaeological Field Inspection, Literature Review, and Cultural Impact Evaluation	Kapolei 215 Reservoir [TMK (1) 9-2-003:083]	No historic properties.
Hunkin and Hammatt 2009	Archaeological Inventory Survey	Makakilo Drive [TMK (1) 9-2-002:006 and 079]	Recorded two new archaeological sites associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-12-06950 and -06951) and documentation of previously identified Waiāhole Ditch site (SIHP 50-80-09-02268).

Reference	Type of Study	Location	Findings
Runyon et al. 2010	Archaeological Monitoring	North-South Road [TMK (1) 9-2-002:006; (1) 9-2-003:075]	No historic properties.
Runyon et al. 2011	Archaeological Monitoring	North-South Road [TMK (1) 9-1-018:001, 003, 004, 005; (1) 9-2-002:001, 006]	Identified one previously recorded site (historic water diversion structure, SIHP 50-80-12-4664) and recorded one new site (burnt trash fill layer, SIHP 50-80-12-07128).
Pacheco and Rieth 2014	Archaeological Inventory Survey	East Kapolei Solar Farm [TMK (1) 9-2-002:006 por.]	Recorded one new archaeological site, an unpaved rode likely associated with early 20th-century industrial ranching or sugarcane agriculture (SIHP 50-80-12-07433).
Rieth et al. 2014	Archaeological Inventory Survey	Site SIHP 50-80-12-07664 and surrounding area.	Thorough documentation of site SIHP 50-80-12-07664 and associated petroglyphs.
Zapor et al. 2018	Archaeological Inventory Survey	Makakilo Drive Extension Project [TMK: (1) 9-2-002: 007, 009; (1) 9-2-003:074, 092; (1) 9-2-039:110, 114; and (1) 9-2-045:001]	Identified two previously recorded sites (Waiāhole Ditch, SIHP 50-80-12-02268 and an irrigation ditch -06951), and recorded one new component feature (SIHP -02268 Feature D, an earthen mound and stacked stone wall).
Welser et al. 2020	Archaeological Inventory Survey	Southeastern foothills of the Waiʻanae Range [TMK: (1) 9-2-002:007 por.]	Identified two previously recorded sites (Waiāhole Ditch, SIHP 50-80-12-2268, and irrigation complex associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-08-05593).

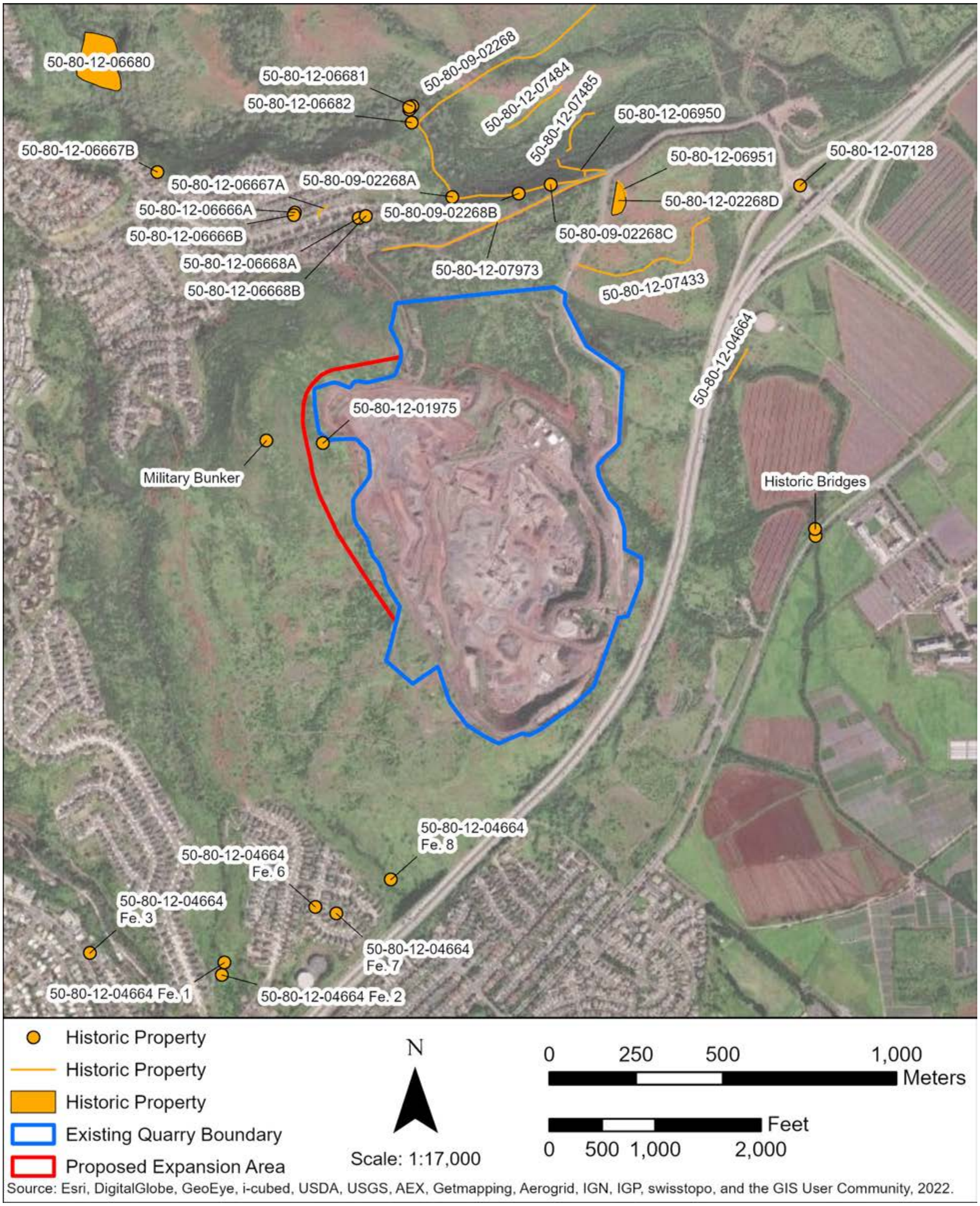


Figure 8. Map of previously identified sites in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2022).

4.0 RESULTS OF FIELD INSPECTION

A field inspection of the project area was conducted on 7 June 2022 by Jillian Swift, Ph.D. and Caleb Fechner, B.A. The work consisted of a reconnaissance pedestrian survey and limited recording of potential historic properties, which included GPS point mapping, photography, brief descriptions, and site flagging. A portion of the central project area east of the current access road was not surveyed, as this area was already in active use by the quarry, and the boundary to the unsurveyed area ended abruptly in a steep cliff (Figure 9).

Five potential historic properties were identified and assigned temporary site numbers (T-01 through T-05; Table 2, Figure 10). The potential historic properties that were identified included a concrete ditch (T-01), two stone alignments likely representing segments of post-Contact wall or terrace retaining features (T-02 and T-05), and two modified outcrops of indeterminate function (T-03 and T-04).

Table 2. Summary of Potential Historic Properties Identified during the Field Inspection

Temp Site No.	Site Type	Possible Function	Probable Age
T-01	Ditch	Water diversion	Post-Contact
T-02	Terrace/retaining wall	Soil retention/drainage	Post-Contact
T-03	Modified outcrop	Indeterminate	Post-Contact
T-04	Modified outcrop	Indeterminate	Post-Contact
T-05	Retaining wall	Soil retention/drainage	Post-Contact

Based on its location and morphology, T-05, a concrete retaining wall, may represent a previously recorded historic property, SIHP 50-80-12-01795, which was documented as a "double-faced" and "core-filled" wall with a north/south orientation that was likely used for erosion control during the post-Contact era (Sinoto 1988).

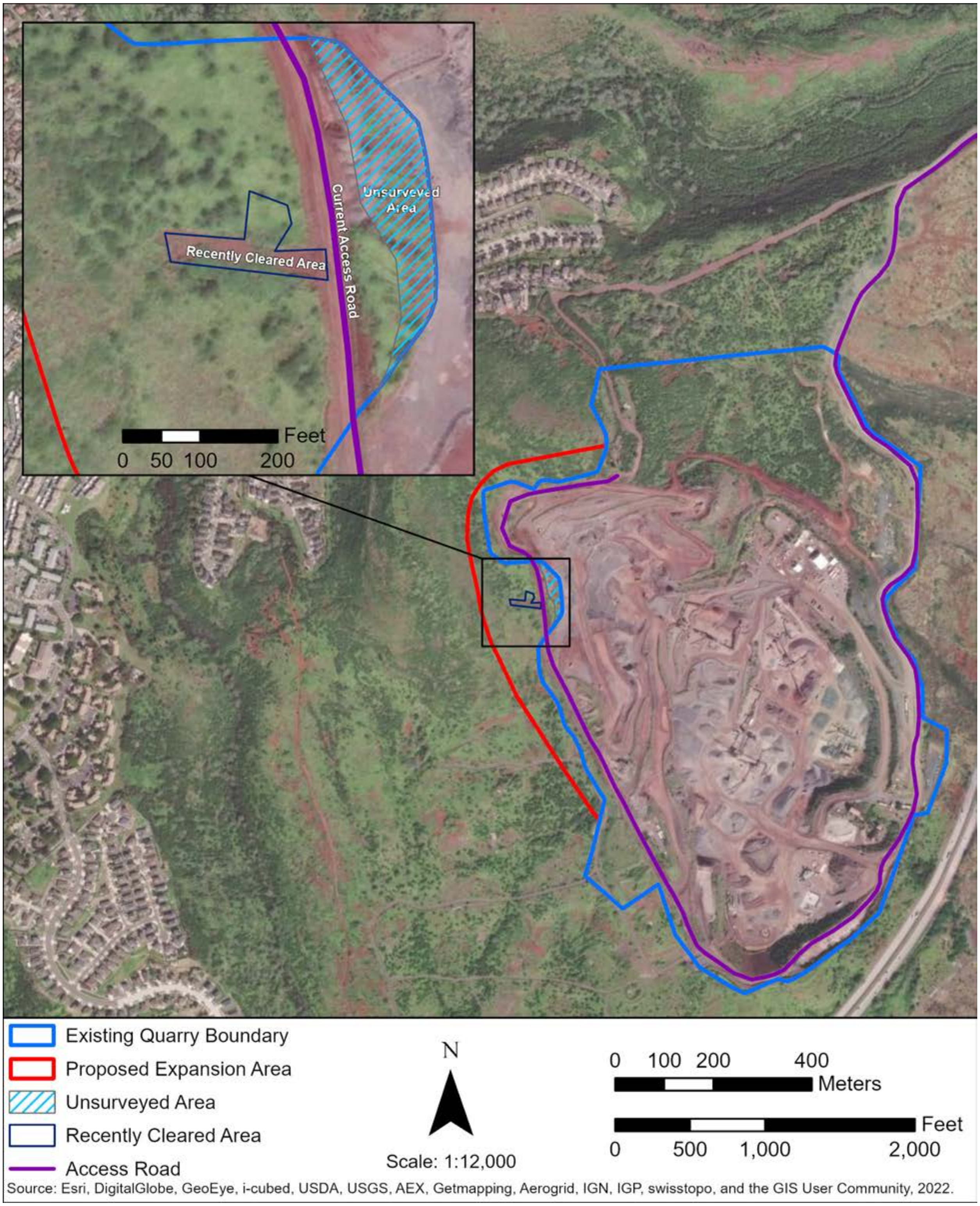


Figure 9. Map of the project area with inset showing the unsurveyed area in active use by the quarry, as well as a recently cleared area abutting the west side of the current access road (base map: Esri World Imagery 2022).

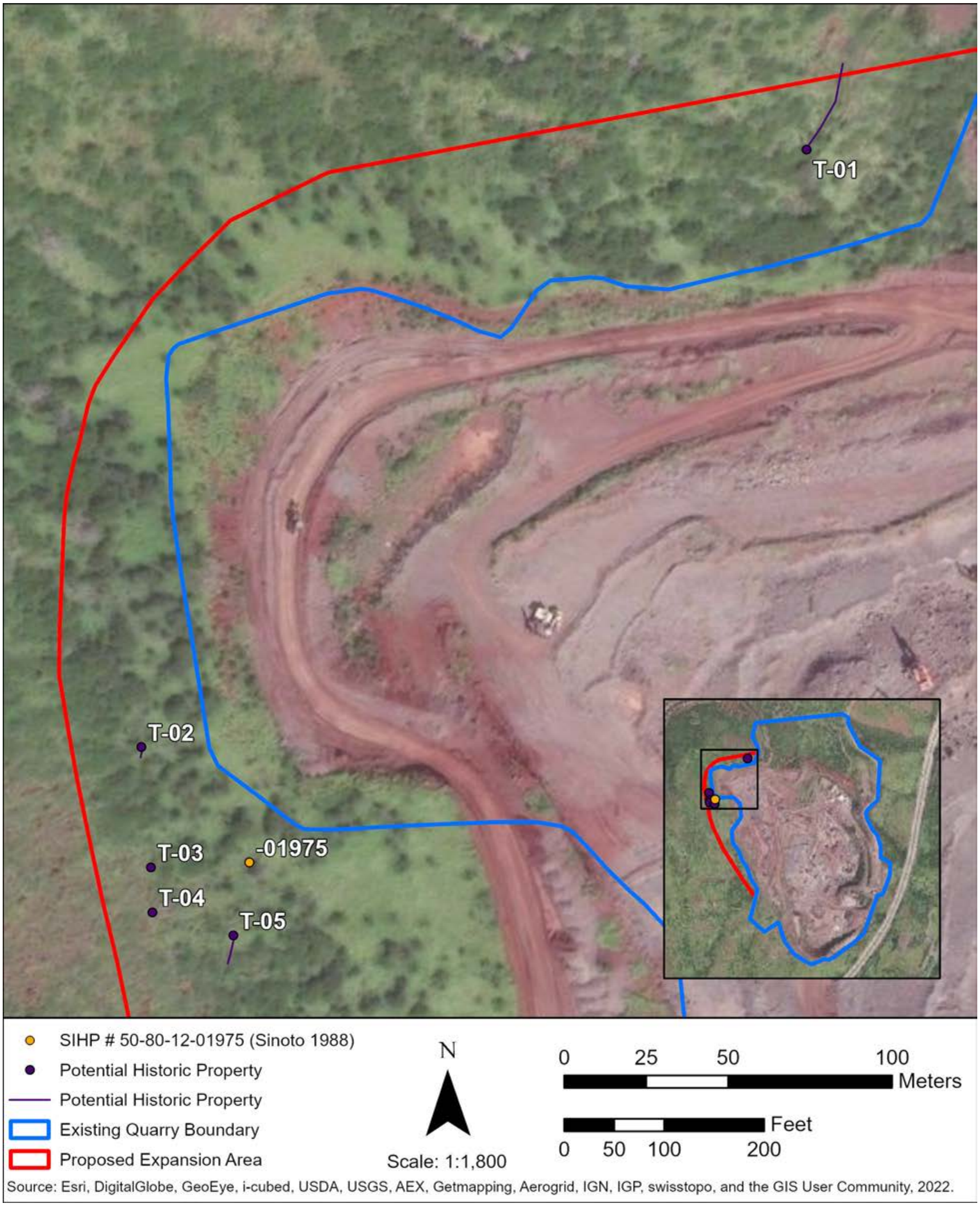


Figure 10. Map of potential historic properties identified during the field inspection, as well as SIHP 50-80-12-01975 (Sinoto 1988; base map: Esri World Imagery 2022).

Temporary Site Number: T-01
Site Type: Concrete ditch
Number of Features: 1
Overall Dimensions: 1.7 m W × 29 m L × 0.2 m D
Condition: Good
Possible Age: Post-Contact
Possible Function: Water diversion

Temporary Site T-01 is a concrete ditch running northeast to southwest, situated within a cleared area at the northwest corner of the project area (Figure 11). It likely functioned as a water diversion/drainage ditch.

Figure 11. Site T-01, concrete ditch (view to northeast).

Temporary Site Number: T-02
Site Type: Terrace/retaining wall
Number of Features: 1
Overall Dimensions: 4.8 m L × 0.4 m W × 0.65 m H
Condition: Good
Possible Age: Post-Contact
Possible Function: Soil retention, water diversion/drainage

Temporary Site T-02 is an alignment of stones running roughly north to south and measuring approximately 4.8 m long, with a small additional segment to the south. The ground is fairly level for approximately 2 m to the *mauka* (upslope) or west side of the feature, creating the appearance of a small terrace (Figure 12). The alignment may represent one segment of a former ditch that ran north-south across the slope.

Figure 12. Site T-02, stone terrace/retaining wall (view to northwest).

Temporary Site Number: T-03
Site Type: Modified outcrop
Number of Features: 1
Overall Dimensions: 1.6 m L × 0.8 m W × 0.25 m H
Condition: Fair
Possible Age: Post-Contact
Possible Function: Indeterminate

Temporary Site T-03 is a modified outcrop consisting of a few small boulders placed on top of natural basalt outcrop (Figure 13). Its probable function is indeterminate, though the site may have associations with other soil retention and water diversion features or clearing activities.

Figure 13. Site T-03, modified outcrop (view to west).

Temporary Site Number: T-04
Site Type: Modified outcrop
Number of Features: 1
Overall Dimensions: 0.9 m L × 0.7 m W × 0.25 m H
Condition: Fair
Possible Age: Post-Contact
Possible Function: Indeterminate

Temporary Site T-04 is a modified outcrop consisting of a few small boulders placed on top of natural basalt outcrop (Figure 14). Its probable function is indeterminate, though the site may have associations with other soil retention and water diversion features or clearing activities.

Figure 14. Site T-04, modified outcrop (view to north).

Temporary Site Number: T-05
Site Type: Wall
Number of Features: 1
Overall Dimensions: 11 m L × 1.2 m W × 1.1 m H
Condition: Good
Possible Age: Post-Contact
Possible Function: Soil retention, water diversion/drainage

Site T-05 is a substantial wall segment running roughly north-south. The wall is partially edged with stones on both east and west sides, and is filled with soil (Figure 15, Figure 16). The ground is fairly level for approximately 2 m to the *mauka* (upslope) or west side of the feature, and may represent a former ditch running north-south across the slope. The site may also be associated with the wall segment recorded by Sinoto for the Makakilo Golf Course Surface Survey in 1988 (SIHP 50-80-12-01975, and Bishop Museum Site No. 50-OA-B6-276). Sinoto describes Site -01975 as a:

> deteriorated wall segment … located inside of Puʻu Makakilo, probably outside of the project area. The wall is double-faced and core-filled and measures 10.5 meters in length, 1.14 meters in width, and .74–1 meter [sic] in height. It is oriented North/South across the slope and may have served as an historic erosional control feature. (Sinoto 1988)

While the locations of SIHP -01975 and T-05 do not perfectly line up, it is important to note that SIHP -01975 was mapped by marking an approximate location on the Makakilo Golf Course Project Area map, as opposed to the more precise GPS methods used in the current study, which could account for the discrepancy in recorded locations (Figure 17).

Figure 15. Plan view of Temporary Site T-05, retaining wall (view to south).

Figure 16. Oblique view of Temporary Site T-05 showing the *makai* (seaward) wall face (view to northwest).

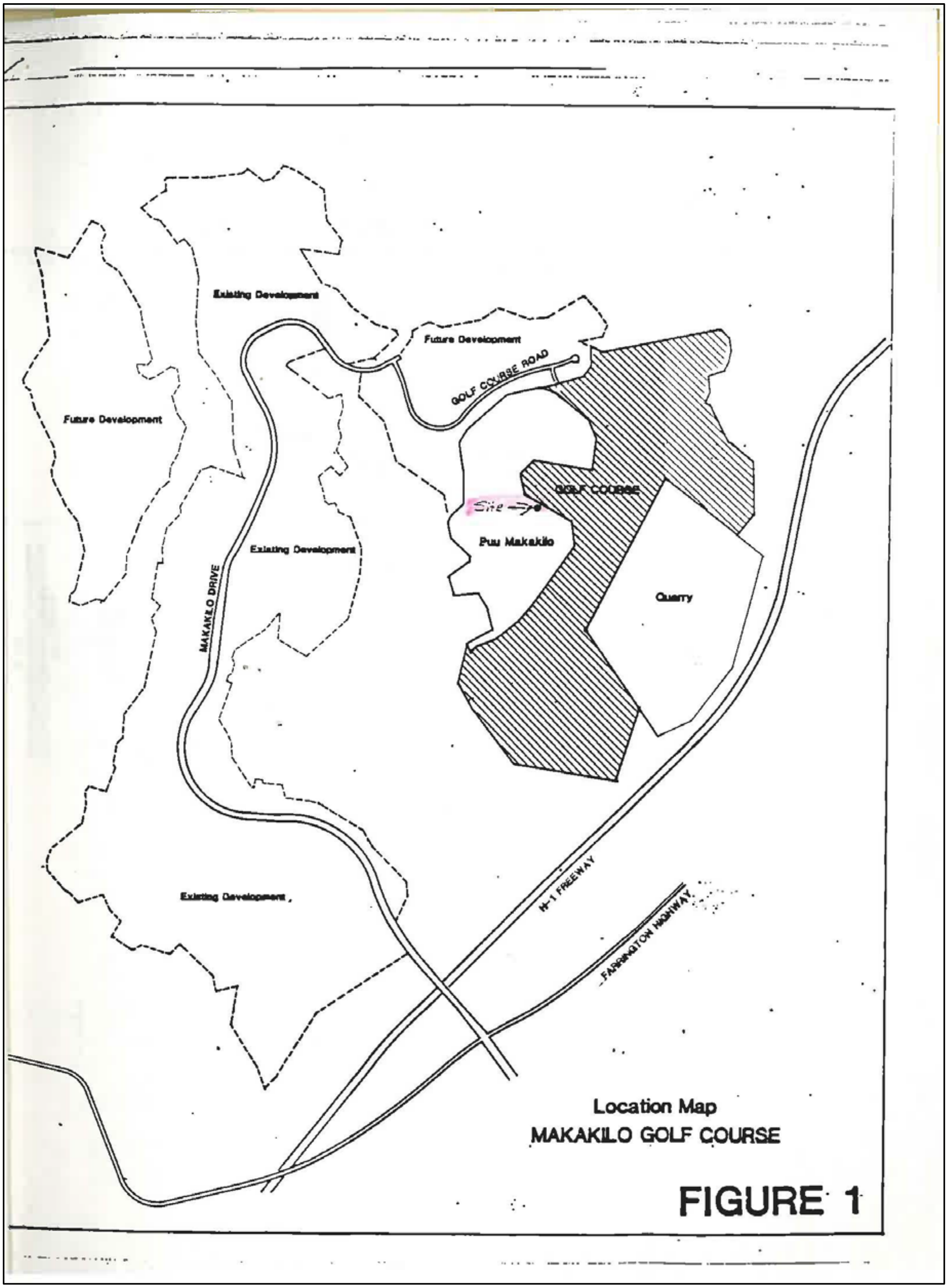


Figure 17. Location of SIHP 50-80-12-01975 as mapped by Sinoto (1988).

5.0 SUMMARY AND RECOMMENDATIONS

A literature review and field inspection were conducted for the proposed expansion area at the Makakilo Quarry, Kapolei, Honouliuli Ahupuaʻa, ʻEwa District, Oʻahu [TMK: (1) 9-2-003:074 (por.)]. The literature review consisted of conducting additional background research building on the AA prepared by Pacific Legacy in 2008 (Mooney and Cleghorn 2008a). A one-day archaeological field inspection was conducted on 7 June 2022.

This work was initiated to facilitate historic preservation review by SHPD, as mandated by HRS Chapter 6E, for a proposed 15.6-acre expansion to quarrying activities on the northwest side of the existing Makakilo Quarry footprint. The expansion would provide Grace Pacific, LLC with access to a seam of high-quality rock to be used in concrete and asphalt paving.

The field inspection identified five potential historic properties (temporary site numbers T-01 through T-05). All appear to be post-Contact features generally relating to soil retention and water drainage along the lower slope of Puʻu Makakilo. The sites are concentrated in the northern half of the project area, and may be associated with past industrial agriculture or ranching activities known to have occurred in Makakilo and the broader Honouliuli Ahupuaʻa. The southern portion of the project area appears to have already been severely impacted by previous development activities, particularly golf course construction in the 1990s. It is unlikely that any historic properties remain in the southern half of the proposed expansion area.

One historic property, SIHP 50-80-12-01975, a core-filled, double-faced wall segment, was previously identified within the project area (Sinoto 1988). Based on the recorded location of this historic property, as well as its general morphology, Temporary Site T-05, which was recorded during the current field inspection, may represent this site. Following the AIS completed in 1988 for the Makakilo Golf Course, Sinoto recommended this historic property for no further work due to its deteriorated condition. Based on our preliminary observations, this historic property should be fully recorded, along with the other four potential historic properties within the proposed expansion area at the Makakilo Quarry.

Given that expanded quarrying activities would remove any remaining historic properties within the project area, an Archaeological Inventory Survey is recommended to thoroughly identify and document all historic properties, and to provide significance assessments and mitigation recommendations in accordance with HRS Chapter 6E for all historic properties within the project area.

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CENSEO
AV+Acoustics

Noise Impact Report

Makakilo Quarry

Kapolei, Oahu

(R1) June 16, 2023

Prepared For:

Grace Pacific, LLC

Prepared By:

CENSEO AV+ACOUSTICS

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Exhibit "U"

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1 Executive Summary

CENSEO AV+Acoustics completed a noise impact study at the Makakilo Quarry. The noise impact study included an assessment of existing noise levels at the quarry and in the surrounding residential areas to the north and northwest. A noise model was developed to predict noise levels due to the proposed changes to the quarry's Conditional Use Permit. Noise impacts to the surrounding areas are not expected.

2 Introduction

Grace Pacific LLC intends to apply for modifications to the existing SUP/CUP. Modifications include:

- Extend the expiration date of the quarrying permit for 15 years beyond the current expiry, from December 31, 2032 to December 31, 2047.
- Modify the existing operating hours to permit 24-7 hot mix asphalt and concrete plant production and sales in the pit of the quarry. Mining hours of operation will not change.
- Reshape the area approved for mining, exchanging 15.5 acres of the existing footprint.

2.1 Purpose

The purpose of this noise impact study is as follows:

- Identify existing and proposed quarry operation noise sources.
- Quantify existing noise levels within the quarry and at various noise receptor location near the property line of the quarry.
- Predict sound levels at noise sensitive neighborhood locations due to the proposed quarry operations.
- Predict future sound levels at noise sensitive neighborhood locations due to the future mining operations based on the future topography of the quarry.

2.2 Project Location Description

Makakilo Quarry is located in Kapolei on the island of Oahu. A map of the project site and the surrounding area is shown in Figure 1.

2.3 Noise Sensitive Receptors

The properties surrounding Makakilo Quarry are primarily residential to the north, south and west. The H-1 Freeway is at the south-eastern boundary of the quarry with residential, university, and agricultural uses beyond. As there are over 50 residences that are along the north and west boundary lines of the quarry, the nearest noise sensitive receptor locations have been grouped into neighborhoods. For reference, the closest distances between the residential neighborhoods and the Primary/Secondary Plant and the H-1 Freeway are provided in Table 1 below. Refer to Figure 1 for noise sensitive receptor locations.

Table 1: List of Noise Sensitive Receivers Locations

Receptor ID	Neighborhood	Receiver Type	Closest Distance (ft.) from Neighborhood to Plant and Freeway Noise Sources	
			Prim/Sec Plant	H-1
R1	Kulihi Street/Ohio Street	Single Family Residences	3,500	200
R2	Nemo Street	Single Family Residences	2,500	4,500
R3	Pueonani Street	Single Family Residences	2,500	3,200
R4	Kapolei Knolls	Single Family Residences	3,400	300
R5	UH West Oahu	University/Commercial	3,500	1,600

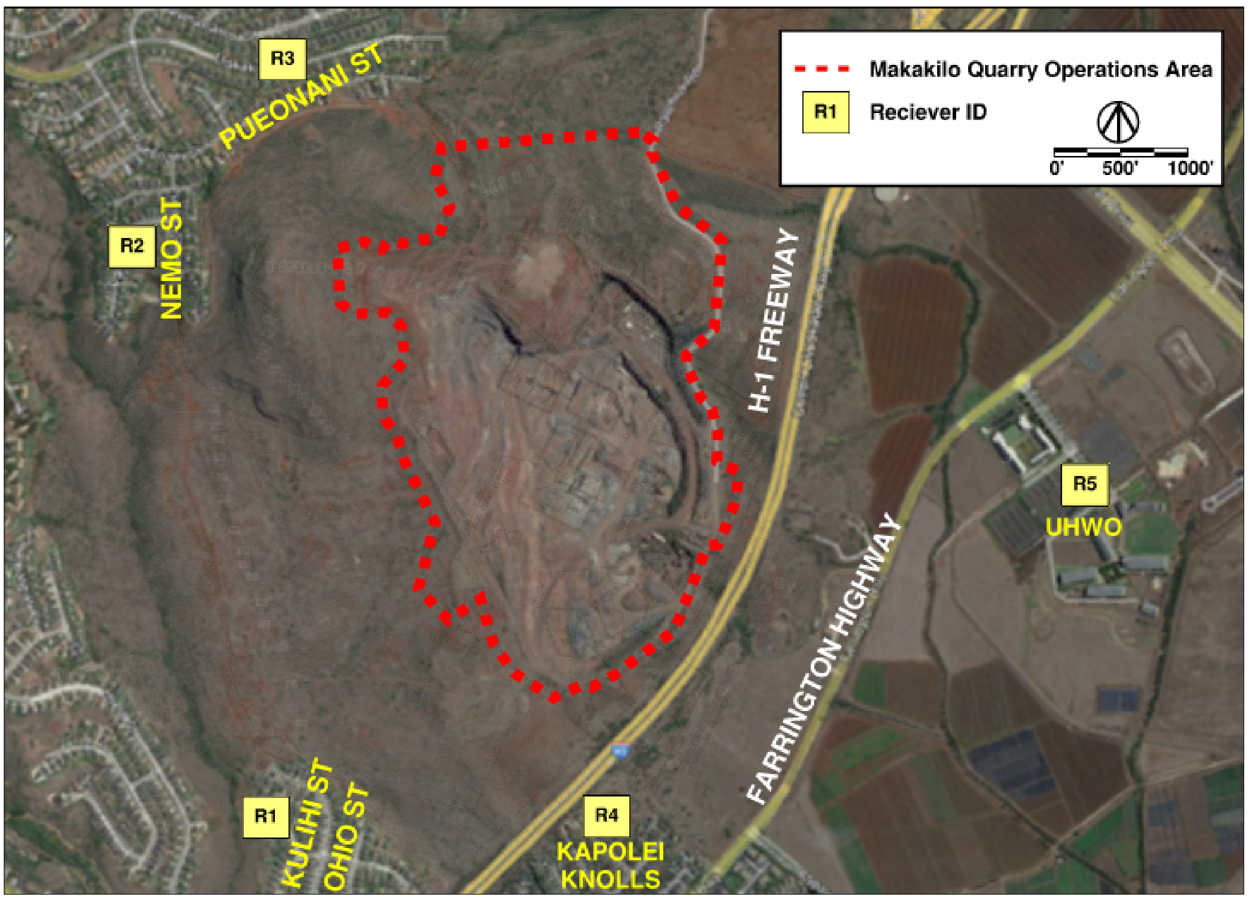

Figure 1: Map of Project Site and Surrounding Area

3 Environmental Noise Regulations and Guidelines

3.1 HDOH Community Noise Control – Stationary & Agriculture Equipment

Hawaii Administrative Rules, Title 11 – Department of Health, Chapter 46 – Community Noise Control regulates environmental noise limits within the state of Hawaii. Table 2 summarizes the maximum permissible noise levels for each zoning district. These sound level limits apply to *“stationary noise sources, and equipment related to agriculture, construction, and industrial activities”*. The noise regulation further defines stationary sources as *“any mechanical source of noise fixed in or on a station, course, or mode within any premises, including but not limited to mechanical air conditioning units, exhaust systems, generators, compressors, pumps, or other similar equipment”*. Therefore, sounds generated by vehicles, hand tools, etc. are not required to satisfy the noise limits shown in Table 2 since these sources do not qualify as a stationary noise source, as defined by the noise regulation.

Table 2 : HDOH Property Line Maximum Permissible Noise Levels

Land Use	Day Noise Limit 7 am 10 pm	Night Noise Limit 10 pm 7 am
Class A – Residential, conservation, preservation, public space, open space, or similar	55 dBA	45 dBA
Class B – Multi-family dwellings, apartment, business, commercial, hotel, resort, or similar	60 dBA	50 dBA
Class C – Agriculture, country, industrial, or similar	70 dBA	70 dBA

In mixed zoning areas, the primary land use designation is used for determining the zoning district. The maximum permissible sound levels shall not be exceeded (at or beyond the property line) by more than 10% of the time for any 20-minute period. The maximum permissible sound levels for impulsive sounds can be up to 10 dB above the maximum sound levels in the table above.

For this noise assessment, the project property is considered Class C and adjacent residential properties are considered Class A. Due to the noise sensitive land use of the adjacent residential areas, the applicable maximum noise levels are 55 dBA at project site property lines during daytime hours and 45 dBA at project site property lines during nighttime hours.

Note that for the purposes of this noise impact assessment, the HDOH terminology “stationary noise source” refers to the site as a whole. This represents the composite effect of all of the individual sound sources, even if the sources are not stationary and move around the site (e.g., on-site trucks).

3.2 Various Agencies - Community Noise Response

The ability of the average person to perceive increases in noise has been documented by various government agencies, including the Federal Highway Administration (FHWA) and the International Standards Organization (ISO). The ISO has developed a scale, as shown in Table 3, for estimating community response to increases in noise levels. This scale relates changes in noise levels to the subjective response of the community. The scale also allows for a direct estimation of the community's probable response to a predicted change in noise level.

Table 3: Community Response to Changes in Noise Levels

Noise Level Change (dB)	Category	Subjective Description
0	None	No observed reaction
5	Little	Sporadic complaints
10	Medium	Widespread complaints
15	Strong	Threats of community action
20	Very Strong	Vigorous community action

4 Existing Ambient Sound Environment

Ambient noise level measurements were conducted to assess the existing acoustical environment within the quarry and establish background noise levels at three of the nearby noise sensitive receptor locations. Short term measurements were also conducted to quantify quarry equipment sound pressure levels. The long-term measurements were conducted continuously from April 20 through April 29, 2022 and the short-term measurements were conducted on the morning of April 20, 2022 and August 4, 2022.

4.1 Sound Measurement Equipment and Procedure

At each long-term sound measurement location, the microphone and preamplifier were mounted on a tripod (approximately 5 feet above grade) and connected to the sound level meter with a microphone extension cable. The sound level meter was contained in a weather-resistant equipment case and an open-cell polyurethane foam wind screen covered the microphone. At each short-term sound measurement location, the sound level meter was handheld (approximately 5 feet above grade). The microphone was directly connected to the sound level meter and an open-cell polyurethane foam wind screen covered the microphone. All measurements were obtained in free-field conditions. The measurement equipment used for conducting sound level measurements is described in Table 4 below.

Table 4: Summary of Noise Measurement Equipment

Equipment Type	Manufacturer	Model No.	Equipment Quantity
Sound Level Meter	Larson Davis	831C	6
Pre-amp	PCB	PRM831	6
Microphone	PCB	377B02	6
Calibrator	Larson Davis	CAL200	2

On the day that the long-term equipment was set up, weather conditions were dry and sunny, temperatures were 80-85 °F, and wind speeds were in the range of 6-12 mph and less than 5 ft/sec. During the measurement period, the weather remained more or less the same, with no precipitation and wind speeds less than 15 mph. Wind gusts up to 25 mph were typical during the daytime hours and typically occurred during the 9:00 am to 6:00 pm timeframe.

Sound levels were measured as decibels (dB) in 1/3 octave bands as well as overall equivalent sound levels. The measurement data was post-processed to provide various sound level metrics, as described below:

- The $L_{eq(1\text{-}HR)}$ is the time-equivalent sound level over a specified time period (t), 1-hour, and is a measure of sound energy.
- The $L_{eq(max)}$ is the maximum sound level which is the highest sound level measured during a single noise event and is commonly used to evaluate a single noise event.
- The L_{90} is the sound level that is less than 90% of the measured sound levels over an hour and is considered to represent the background noise level.
- The L_{dn} describes a receptor's cumulative noise exposure from all events over 24 hours. A 10-dB penalty is applied to nighttime hours (between 10:00 pm and 7:00 am). This metric corresponds well to human annoyance levels and is commonly used for site planning.

4.2 Sound Measurement Locations

A total of five (5) long-term noise measurement locations were selected and are shown in Figure 2. The three outer boundary locations (L1 - L3) were selected as they are representative of background noise levels in the residential neighborhoods surrounding the quarry site. These neighborhoods were also selected because that are not exposed to high traffic noise levels from the H-1 Freeway. The inner boundary locations (L4 - L5) were selected as they are representative of existing noise levels at the site and the proposed location of the hot mix asphalt plant. Appendix A contains photographs of all long-term measurement locations.

The sound level measurement locations and descriptions of the ambient environments are summarized in Table 5. Dominant noises affecting measurement locations L1 – L3 include residential noise sources such as local traffic, landscaping equipment, pedestrians, etc. Secondary noises include natural sources such as wind, birds, etc., and distance traffic noise from the H-1 Freeway. Quarry noises were not audible at t hese locations. Within the quarry pit at locations L4 – L5, the dominant noise sources include operational equipment utilized within the Quarry pit.

Table 5: Measurement Location Summary

ID	Location	Sound Sources
L1	South-Western outer boundary line (behind residence at 92-1968 Kulihi Street)	Primary: Residential Secondary: Natural
L2	North-Western outer boundary line (behind residence at 92-6009 Nemo Street)	Primary: Residential sources Secondary: Natural
L3	Northern outer boundary line (behind residence at 92-1133 Pueonani Street)	Primary: Residential sources Secondary: Natural
L4	Quarry pit, approx. 500 ft to southern boundary line at proposed HMA Plant location (21 deg 21'12.2" N – 158 deg 4'7.1" W)	Primary: Quarry Equipment
L5	Above quarry pit, approx. 200 ft to -western boundary line (21 deg 21'19.2" N - 158 deg 4'15.1" W)	Primary: Quarry Equipment

Figure 2: Long-Term Measurement Site Map

4.3 Sound Measurement Results

4.3.1 Long-Term Measurement Results

Table 6 presents a summary of the measured sound levels at locations L1 – L5. The data is presented in terms of the 1-hour equivalent sound level ($L_{eq(1\text{-}HR)}$), the 90% exceedance level (L_{90}), the day-night level (L_{dn}), and the minimum and maximum L_{eq} sound levels during the measurement period. Graphical representations of the long-term sound level measurements at each location are provided in Appendix B.

Table 6: Long-Term Measurement Results Summary

ID	Period	Measured Sound Pressure Level (dBA)				
		$L_{eq(1\ hr)}$	L_{90}	Min. L_{eq}	Max L_{eq}	L_{dn}
L1	Daytime (7:00 am – 10:00 pm)	51.5	46.6	35.5	78.2	53.4
	Nighttime (10:00 pm – 7:00 am)	45.5	40.8	27.7	75.6	
L2	Daytime (7:00 am – 10:00 pm)	53.6	39.4	25.3	83.0	53.3
	Nighttime (10:00 pm – 7:00 am)	42.7	37.5	25.0	65.5	
L3	Daytime (7:00 am – 10:00 pm)	51.5	46.0	39.0	86.2	54.3
	Nighttime (10:00 pm – 7:00 am)	46.9	42.8	28.9	77.8	
L4	Daytime (7:00 am – 10:00 pm)	68.1	53.4	37.7	98.3	66.4
	Nighttime (10:00 pm – 7:00 am)	49.6	44.1	30.4	86.6	
L5	Daytime (7:00 am – 10:00 pm)	64.7	60.4	42.0	83.5	65.5
	Nighttime (10:00 pm – 7:00 am)	56.7	50.7	33.7	77.6	

It should be noted that blasting and drilling activities, typically the loudest noise sources on-site, occurred during the long term measurement period. Drilling generally occurred between 6:45 am and 2:15 pm on the following dates: 4/20/22, 4/23/22, 4/27/22, and 4/28/22. Blasting events occurred on the following dates and times: 4/21/22 at 10:43 am, 4/25/22 at 11:51 am, 4/26/22 at 10:56 am, and 4/29/22 at 11:29 am. The measurement data at all five measurement locations do not indicate any sound level peaks on these dates and times when the drilling and blasting occurred. However, this could be attributed to the 5-minute time-weighted average where the short-duration impulsive events were simply averaged out.

4.3.2 Short-Term Measurement Results

Short-term measurements were performed within the quarry boundary to obtain source noise emissions associated with each type of equipment. The hot mix asphalt plant was measured at its current location at the Grace Pacific Kalaeloa site at Hanua Street. Because the quarry equipment includes various components that generate noise, noise levels were measured in the near-field at varying distances from the equipment. The intent of the short-term measurements was to obtain source noise levels of quarry equipment to input into the sound prediction model (described in Section 0 below). Note that some equi pment was not operational during the time of the site visit and could not be measured (e.g., Primary/Secondary Plant and Concrete Plant).

The short-term measurement data was used to calculate the respective octave band sound power levels of each type of equipment. A summary of the equipment sound power levels, used as input into the sound prediction model, can be found in Appendix C.

5 Quarry Operations

Existing and future site plans and a description of typical quarry operations were provided by Grace Pacific. The following section summarizes the quarry activities, hours of operation, and the equipment used in the quarry.

5.1 Hours of Operation

The existing and proposed hours of operation are summarized in Table 7. Typical quarry operations are from 6:00 am to 6:00 pm, Monday to Saturday. The unloading of recycle materials currently takes place outside of the normal operating hours.

Table 7: Makakilo Quarry Operation Hours

Time of Day (Existing)	Use/Activity	Time of Day (Proposed)
6:00 am to 6:00 pm Monday - Saturday	Mining/Quarrying Rock Processing Rock Recycling	6:00 am to 6:00 pm Monday - Saturday
6:00 am to 6:00 pm Monday - Saturday	Sales at Pit (transportation)	24 hours a day, 7 days a week
3:00 pm to 6:00 pm Monday - Saturday	Maintenance	24 hours a day, 7 days a week
6:00 pm to 10:00 pm Sunday - Friday	Unloading of recycle materials	24 hours a day, 7 days a week
---	Concrete Plant Asphalt Plant	24 hours a day, 7 days a week

5.2 Quarry Operations

Quarry operations are dynamic in nature and are described in more detail below.

- Mining/quarrying rock
- Processing of aggregate (crushing, sorting, stockpiling, washing)
- Recycle Plant (processing, asphalt, concrete, separate out steel)
- Sales (transportation of materials)

Aggregate is extracted at the working face using drilling and blasting techniques. Figure 3 shows the boundaries of the working face for the existing and future proposed expansion area conditions.. Generally, drill rigs are used to bore 30-50 blast holes into a 1000 ft^2 area. Explosives are inserted into each blast hole. The blast occurs once per day to fragment rock from the quarry face.

The extracted material is transported to the Primary/Secondary Plant using up to four (4) front end loaders and two (2) excavators at the working face. Material is transported by up to four (4) haul trucks directly into the primary/secondary plant which is in a fixed location near the working face. Processed material is stored in the vicinity of the processing area.

Processed aggregate material is then moved from the primary/secondary plant to the finishing plants (A-Rock and B-Rock) via conveyor. After processing, the material is stockpiled or delivered to the wash plant with up to one (1) front end loader and up to three (3) haul trucks. The fully processed materials are loaded into highway haul trucks using front end loaders for shipment to market. The highway haul trucks are loaded from stockpiles of aggregate at the A-Rock and B-Rock finishing plant and the wash plant locations.

The recycling plant receives deliveries of recyclable materials which have been stockpiled in various locations on site. The material is hauled to the recycle plant with up to one (1) front end loader and up to two (2) haul trucks.

The concrete plant receives materials from the wash plant from up to one (1) front end loader and up to two (2) haul trucks. Aggregate would then be delivered to the bunkers and blended, and finally loaded into customer drum trucks.

The hot mix asphalt (HMA) plant receives materials from the wash plant from up to one (1) front end loader and up to two (2) haul trucks. The processed materials would then be loaded into highway haul trucks for shipment to market.

Customer traffic volumes for processed materials from the quarry, concrete plant, and HMA plant were provided by Grace Pacific. The data, provided in terms of projected tonnage and yearly customer truck volumes, was processed into hourly traffic volumes using the quarry hours of operation from Table 7. Based on the information provided, it is assumed that approximately twenty (20) truckloads of quarry materials, four (4) truckloads of concrete materials, and six (6) truckloads of asphalt materials are shipped per hour.

5.3 Quarry Equipment

The existing extraction, processing and transport equipment includes:

- Drill Rig
- Explosives
- Primary/Secondary Plant
- Rock Finishing Plants A & B
- Wash Plant
- Recycling Plant
- Front End Loaders
- Haul Trucks

- Excavator
- Highway Trucks

The relocated equipment includes:
- HC&D Portable Ready-Mix (Concrete) Plant
- Hot Mix Asphalt Plant

The Makakilo Quarry site plan and quarry equipment noise sources are shown in Figure 3 below. The equipment identified in the figure below are expected to remain in the same location until the closure of the quarry. Only the drilling and blasting locations are expected to be repositioned in to the proposed new expansion area as the working face is expanded.

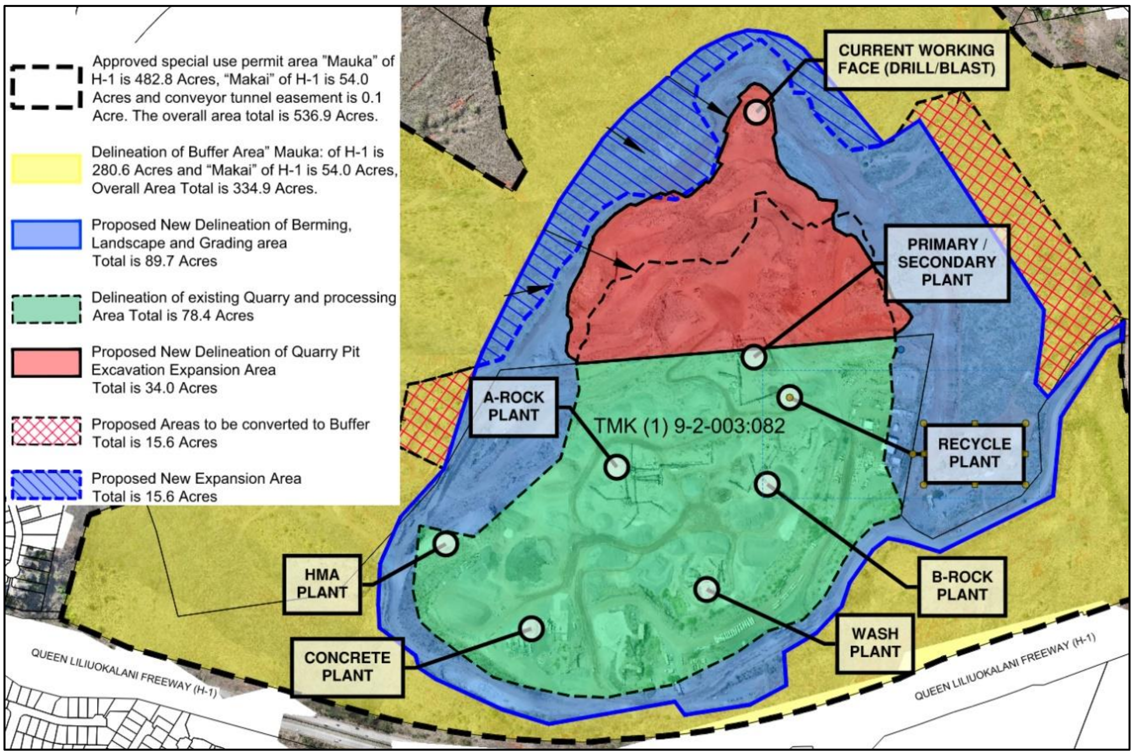

Figure 3: Makakilo Quarry Future Site Plan

6 Noise Evaluation

6.1 Noise Model Methodology

The Makakilo Quarry existing and proposed future operations, described in Section 5, were modeled using CadnaA, a noise prediction software by Datakustik Gmbh. The computerized model was based on noise prediction methods outlined in the standard ISO 9613-2 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method and calculation*". The sound propagation model was developed using the existing topography of the Makakilo Quarry site, which was provided by Grace Pacific. To be conservative, downwind conditions and hard reflective ground surfaces were assumed (i.e., vegetation was not included in the noise model).

Noise levels of existing and proposed operations under existing site conditions were calculated based on the predictable "worst-case" noise impact to the noise receptor locations due to the quarry operations. Specifically, the worst-case condition is when the quarry is running at full capacity and with all of the on-site equipment operating simultaneously (aside from the blasting activity). It is expected that the quarry equipment will operate intermittently and not concurrently, as represented in the noise model. However, for a conservative "worst-case" estimate, continuous and concurrent operations were assumed for all equipment and transportation noise sources within the quarry.

Future site conditions were modeled to represent drilling and blasting activities relocated within the boundary expansion area. In addition, transportation activities (movement of the extracted material from the working face to the stationary processing plants) were also relocated within the noise model to be closer to be the future working face. All other quarry equipment will remain in its present location. Future topographical contours for the quarry closure condition (year 2047) were inserted into the noise model. Again, these future 2047 noise levels were calculated based on the predictable "worst-case" noise impacts due to the drilling and blasting operations located within the expansion boundaries nearest to the mauka receptor locations (R2 and R3).

6.2 Quarry Noise Sources

Quarry equipment sound power levels and source heights are listed in Appendix C and are based on the short-term noise measurement results, as described in Section 4.3 of this report, and CENSEO's internal noise emission reference database. The objective of the noise model is to determine the impact of the noisiest operational activities. There are a number of noise sources related to processing, HC&D, HMA, and sales operations that are acoustically insignificant compared to the sources shown in Appendix C (e.g., standby generators, forklifts, employee vehicles, small fans, pumps, and motors, etc.). These acoustically insignificant noise sources were excluded from the analysis.

6.3 Predicted Sound Levels of Proposed Operations (Existing Site Condition)

The predicted operational noise levels resulting from the noise model considers the impacts from the four major quarry activities and the overall impact to the nearest noise sensitive receptors. Table 8 summarizes the impacts that are predicted to occur based on the proposed quarry operations at Makakilo Quarry, as described in Section 5 of this report. The sound levels are presented in terms of an equivalent sound level, $L_{eq,}$, and are considered "worst case". For reference, the corresponding HDOH daytime and nighttime maximum permissible property line noise limits (from Table 2) are also included in Table 8. Because quarry operations begin at 6:00 am, the predicted noise levels for the processing activities must also be compared to the nighttime maximum permissible noise limits.

Table 8: Summary of Predicted Overall Noise Levels due to Proposed Quarry Operations at Nearby Receptor Locations (dBA)

Receptor ID	Time Period	HDOH Noise Limit	Predicted Overall Noise Levels, L_{eq} (dBA)				
			Overall	Processing	Trucking (Sales)	HC&D (Concrete)	HMA (Asphalt)
R1	Day	50	33.7	33.1	19.3	19.8	20.7
	Night	45					
R2	Day	50	32.7	32.7	< 15	< 15	< 15
	Night	45					
R3	Day	50	34.4	33.1	28.2	< 15	< 15
	Night	45					
R4	Day	50	43.1	42.9	26.7	21.9	24.6
	Night	45					
R5	Day	60	44.5	44.1	31.2	24.9	29.1
	Night	50					

6.4 Predicted Sound Levels of Drilling and Blasting Operations (Existing and Future Site Conditions)

Table 9 summarizes the impacts that are predicted to occur based on the processing, drilling, and blasting activities that occur near the current boundary (using the existing site topography) and expected to occur near the future boundary (using the future closure topography) of Makakilo Quarry. Because blasting is considered an impulsive noise event, the sound levels are presented in terms of a maximum equivalent sound level, $L_{MAX,}$ and are considered "worst case". The blast occurs once per day, typically between 10:00 am to 12:00 pm. Drilling and processing activities are presented in terms of an equivalent sound level, $L_{eq,,}$ and are considered "worst case". With processing hours from 6:00 am to 6:00 pm and drilling typically occurring from 6:45 am to 2:15 pm, the predicted noise levels for these activities must be compared to the nighttime maximum permissible noise limits.

Table 9: Summary of Predicted Noise Levels due to Quarry Mining Operations in 'Existing' and 'Future Closure' Conditions at Nearby Receptor Locations (dBA)

Receptor ID	Time Period	HDOH Noise Limit	Processing Noise, L_{eq} (dBA)		Drill Noise, L_{eq} (dBA)		Blast Noise, L_{MAX} (dBA)	
			Existing	Future Closure	Existing	Future Closure	Existing	Future Closure
R1	Day	50	33.1	35.2	23.9	26.7	31.7	36.5
	Night	45						
R2	Day	50	32.7	33.2	29.9	35.4	31.5	35.5
	Night	45						
R3	Day	50	33.1	33.8	30.1	34.2	32.9	34.7
	Night	45						
R4	Day	50	42.9	41.7	32.3	36.7	38.1	36.6
	Night	45						
R5	Day	60	44.1	40.0	32.4	36.7	38.3	36.5
	Night	50						

7 Truck Traffic on Haul Route

The noise impact due to truck traffic on public roadways (such as the H-1 Freeway) is not addressed by the HDOH Community Noise Rule. However, noise impacts can be evaluated by comparing existing truck volumes to/from the quarry to the future predicted truck volumes. Future truck volumes were not available for this noise study and, therefore, truck traffic noise outside of the quarry was not evaluated.

8 Conclusions

Based on the results of the noise impact assessment, adverse noise impacts to the communities surrounding the Makakilo Quarry project site are not expected based on the existing quarry activities and the future proposed activities. The followings conclusions were made:

1. The predicted noise levels from the proposed Makakilo Quarry operations are expected to comply with the HDOH maximum permissible noise limits at the surrounding noise sensitive receptors.
2. The predicted noise levels from the future Makakilo Quarry drilling and blasting operations that occur near the future boundary are expected to comply with the HDOH maximum permissible noise limits at the surrounding noise sensitive receptors.
3. Overall operational activities are not expected to be audible at the residential neighborhoods to the north and northwest of the project site due to the topographical features that block the line-of-sight into the quarry from these north and northwest locations.
4. The residential and commercial areas to the south of the quarry project site are exposed to vehicular traffic noise from H-1 Freeway that will likely mask operational noises from the quarry.
5. The HC&D and HMA operations are not expected to significantly contribute to the overall quarry operations noise levels as received at the surrounding noise sensitive receptors.
6. The expanded sales hours that will result in 24/7 trucking activities are significantly less than the existing ambient noise environment and are not expected to be audible at the surrounding noise receptor locations.
7. The mining activities (e.g., drilling, blasting, and transportation of materials to the processing plant) will move closer to the residential neighborhoods to the north and northwest of the project site due to the proposed boundary amendment. Noise levels during these activities are expected to increase by up to 7.5 dB. While this change is not considered a non-significant amount, noises from these activities are not expected to be audible since they are still less than the existing ambient noise environment.

Appendix A: Long-Term Measurement Photographs

A1. Measurement Location L1

South-Western outer boundary line, behind residence at 92-1968 Kulihi Street
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

Figure A1: Long-Term Measurement Site L1

A2. Measurement Location L2

North-Western outer boundary line (behind residence at 92-6009 Nemo Street)
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

Figure A2: Long-Term Measurement Site L2

A3. Measurement Location L3

Northern outer boundary line, behind residence at 92-1133 Pueonani Street
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

Figure A3: Long-Term Measurement Site L3

A4. Measurement Location L4

Quarry Operations Area at Future HMA Plant location, approximately 500 ft from southern boundary line
Primary Sound Source: Quarry Operations (during hours of operation)
Secondary Sound Source: Natural noises (wind, birds, etc.)

Figure A4: Long-Term Measurement Site L4

A5. Measurement Location L5

Quarry Operations Area, 200 ft from south-western boundary line
Primary Sound Source: Quarry Operations (during hours of operation)
Secondary Sound Source: Natural noises (wind, birds, etc.)

Figure A5: Long-Term Measurement Site L5

Appendix B: Long-Term Measurement Results

B1. Measurement Location L2

South-Western outer boundary line, behind residence at 92-1968 Kulihi Street
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

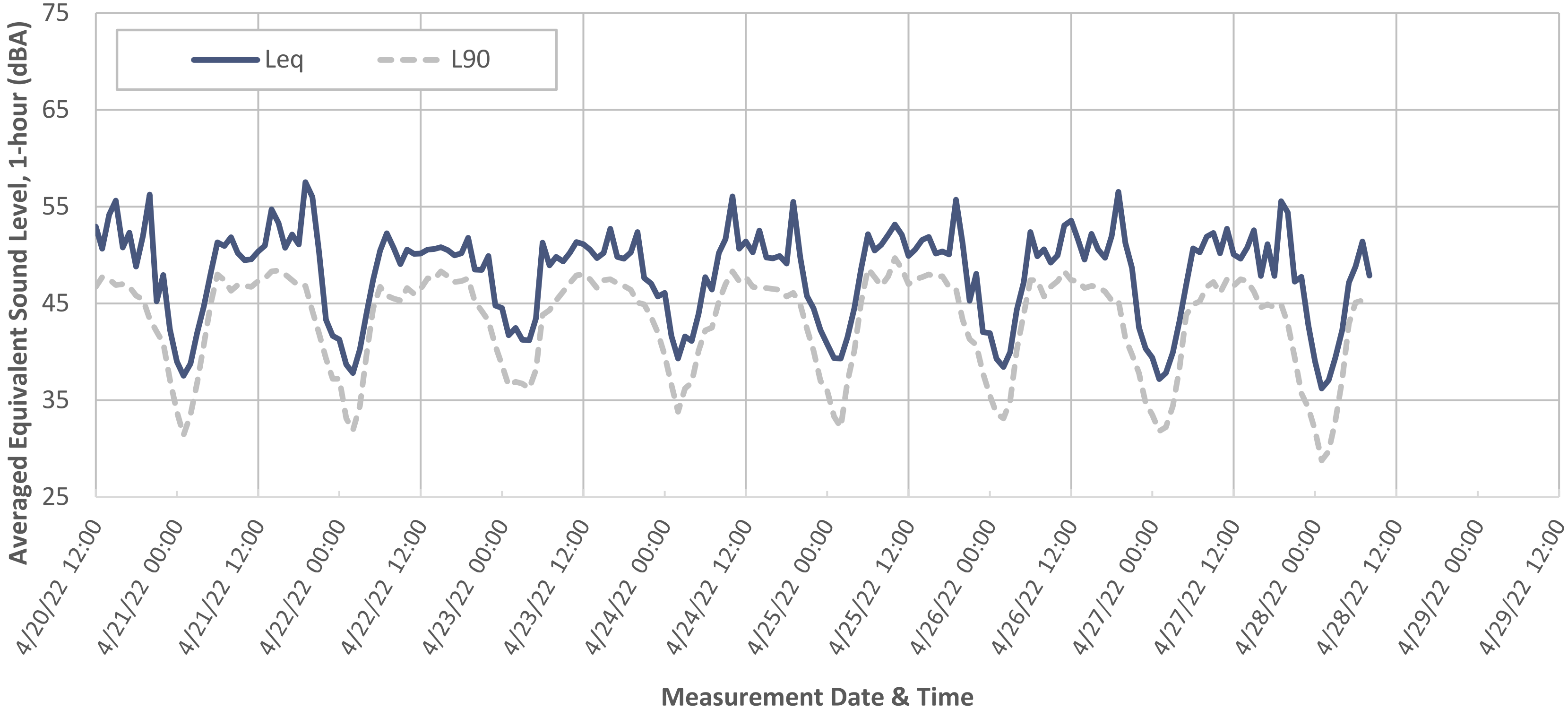

Figure B1: Long-Term Measurement Site L1 Sound Levels

B2. Measurement Location L2

North-Western outer boundary line, behind residence at 92-6009 Nemo Street
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

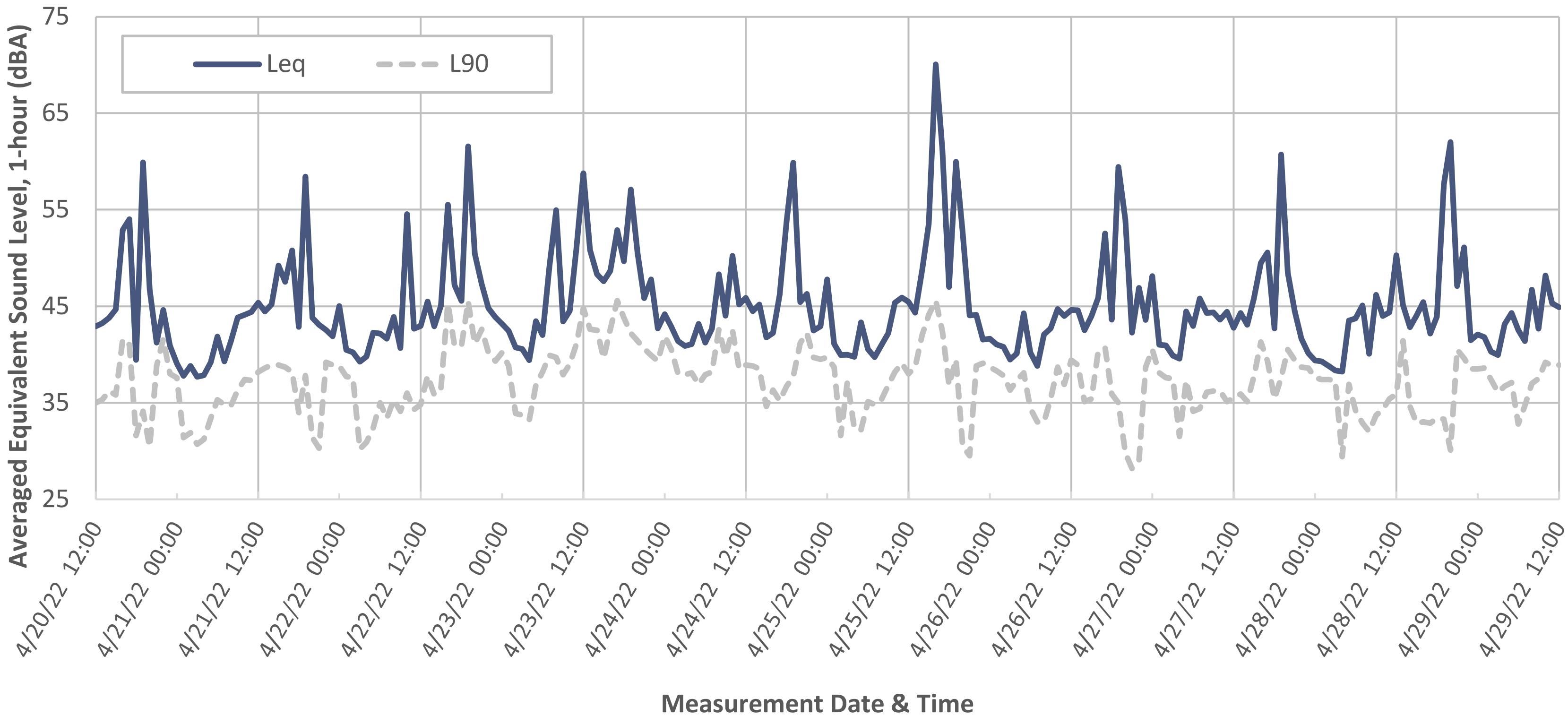

Figure B2: Long-Term Measurement Site L2 Sound Levels

B3. Measurement Location L3

Northern outer boundary line, behind residence at 92-1133 Pueonani Street
Primary Sound Source: Residential noises (local traffic, landscaping equipment, pedestrians, etc.)
Secondary Sound Source: Natural noises (wind, birds, etc.)

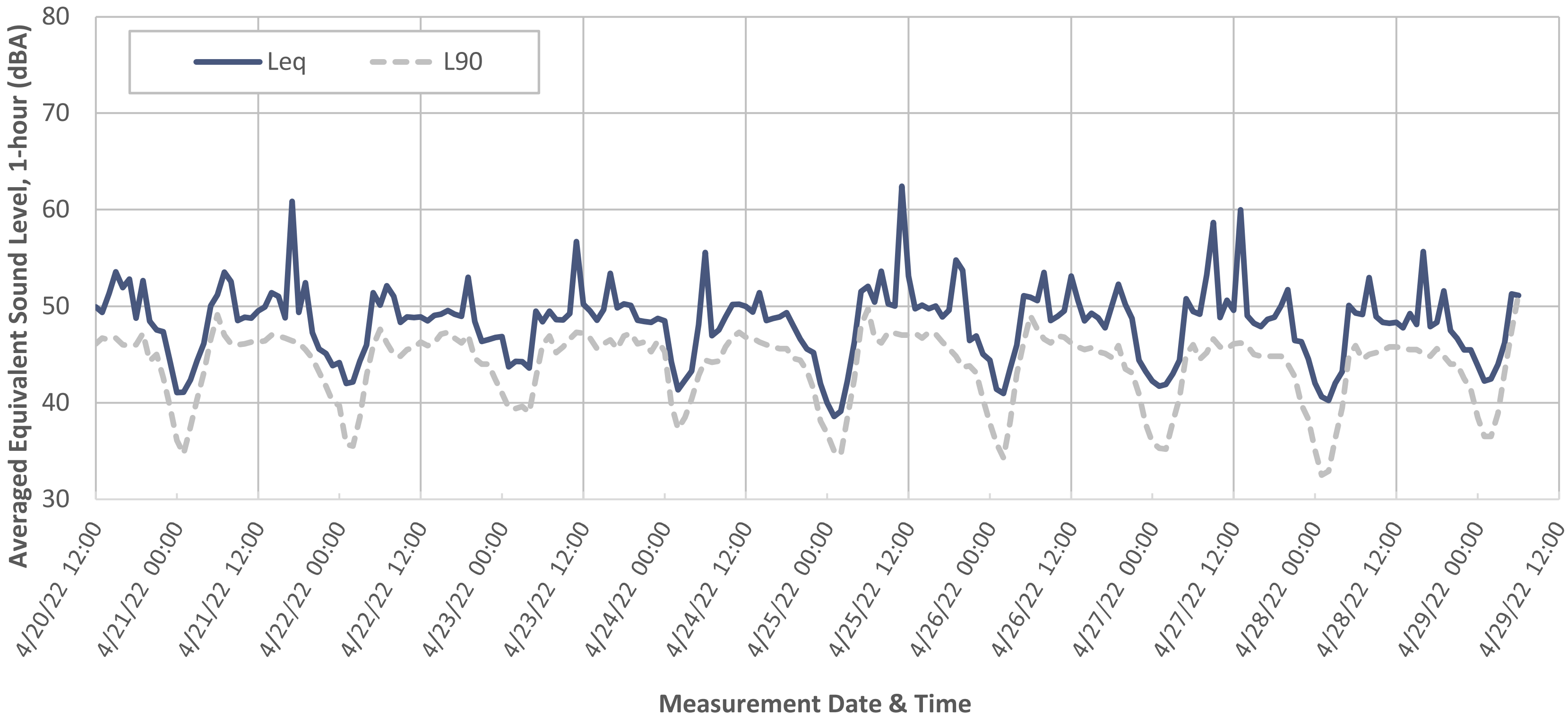

Figure B3: Long-Term Measurement Site L3 Sound Levels

B4. Measurement Location L4

Quarry Operations Area at Future HMA Plant location, approximately 500 ft from southern boundary line
Primary Sound Source: Quarry Operations (during hours of operation)
Secondary Sound Source: Natural noises (wind, birds, etc.)

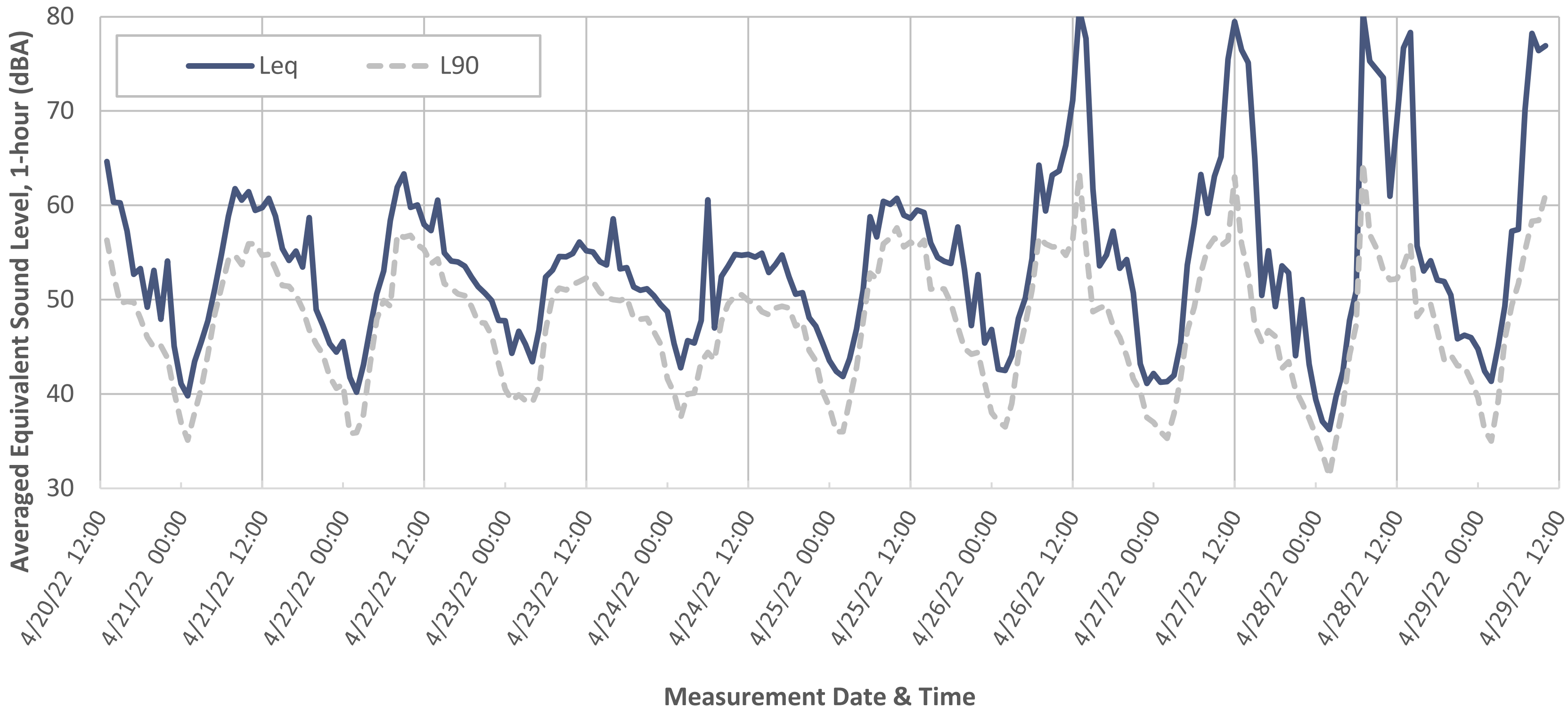

Figure B4: Long-Term Measurement Site L4 Sound Levels

B5. Measurement Location L5

Quarry Operations Area, 200 ft from south-western boundary line
Primary Sound Source: Quarry Operations (during hours of operation)
Secondary Sound Source: Natural noises (wind, birds, etc.)

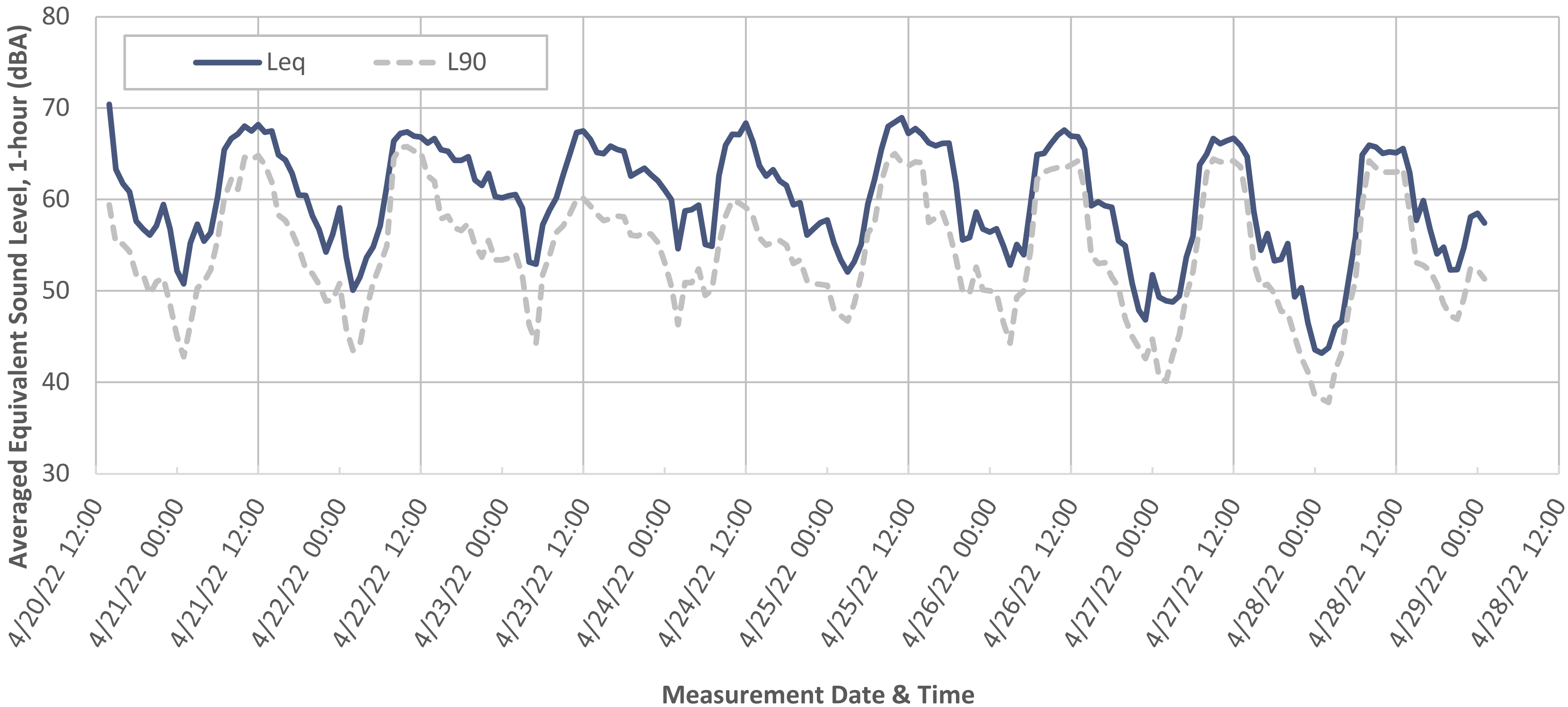

Figure B5: Long-Term Measurement Site L5 Sound Levels

Appendix C: Quarry Equipment Sound Emissions

Name	Height (ft)[1]	Correction Factor[2]	1/3 Octave Spectrum (dB)									Overall (dBA)	Source[3]
			31.5	63.0	125.0	250.0	500	1000	2000	4000	8000		
Prelim_Plant_CrushDeck	12	-6	113.0	119.1	115.5	110.5	115.8	116.0	116.0	110.7	104.4	**121.1**	CENSEO Measurements
Prim_Plant_InclineScreen	12	-6	123.9	125.9	124.1	126.2	127.0	129.6	131.0	127.3	120.4	**135.6**	CENSEO Measurements
Prim_Plant_Jaw	12	-6	0.0	112.0	109.0	111.0	113.0	113.0	111.0	108.0	103.0	**117.6**	Reference 1
A_Plant_HorizShaker	15	-6	126.7	124.7	116.4	116.0	116.1	114.5	114.6	112.7	106.0	**120.8**	CENSEO Measurements
A_Plant_CrushDeck	15	-6	117.4	116.4	115.4	113.8	116.3	113.6	111.9	108.7	103.0	**119.0**	CENSEO Measurements
A_Plant_InclineScreen	15	-6	123.9	125.9	124.1	126.2	127.0	129.6	131.0	127.3	120.4	**135.6**	CENSEO Measurements
B_Plant_CrushDeck	12	-4	113.0	119.1	115.5	110.5	115.8	116.0	116.0	110.7	104.4	**121.1**	CENSEO Measurements
B_Plant_HorizScreen	12	-5	113.8	114.5	114.3	113.9	115.3	117.0	117.6	113.3	103.4	**122.4**	CENSEO Measurements
B_Plant_InlineScreen	12	-6	114.0	115.7	115.2	114.7	116.5	114.3	114.3	112.3	104.0	**120.5**	CENSEO Measurements
Wash_Plant_InlineScreen	12	-8	130.8	121.3	117.1	108.2	112.9	105.9	108.7	100.0	93.3	**114.3**	CENSEO Measurements
Wash_Plant_HorizScreen	12	-8	129.8	125.5	121.6	109.6	112.3	105.1	103.3	101.5	96.1	**113.4**	CENSEO Measurements
HMA_Plant_N	12	0	114.4	106.4	104.3	107.7	101.7	98.1	97.1	94.6	90.6	**105.3**	CENSEO Measurements
HMA_Plant_S	12	0	114.0	112.5	107.9	110.6	110.3	104.5	99.8	96.5	89.1	**110.6**	CENSEO Measurements
Recycle_Plant_Jaw	12	-6	0.0	112.0	109.0	111.0	113.0	113.0	111.0	108.0	103.0	**117.6**	Reference 1
Recycle_Plant_HorizScreen	12	-6	113.8	114.5	114.3	113.9	115.3	117.0	117.6	113.3	103.4	**122.4**	CENSEO Measurements
Drill	0	0	115.0	124.0	123.0	115.0	116.0	120.0	124.0	123.0	119.0	**128.9**	CENSEO Measurements
Blast2	0	0	113.9	129.9	136.7	129	119.5	110	108.9	105.5	100.9	**124.7**	CENSEO Measurements
CAT773_HaulTruck	8	0	0.0	112.0	109.0	111.0	108.0	106.0	105.0	98.0	93.0	**111.5**	Reference 1
FrontEndLoader	8	0	0.0	118.0	110.0	109.0	103.0	102.0	100.0	97.0	88.0	**107.8**	Reference 1
HighwayTruck	8	0	0.0	115.0	104.0	100.0	102.0	104.0	101.0	93.0	85.0	**107.4**	Reference 1

Notes:

1. The height of the quarry equipment is an estimate based on site visit observations.
2. The short-term measurements were used to calibrate the model to within 3 dBA. A correction factor was applied to the sources noted in the table above in order to ensure modeling accuracy.
3. Reference 1, Lynwood Quarry Minor Modification Noise Impact Assessment, September 1, 2010, Umwelt (Australia) Pty Ltd.

Lighting Assessment Report
for the
Makakilo Quarry
Kapolei, Hawaii

July 2022

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Exhibit "V"

Table of Contents

Figures

Executive Summary

The current operations in Makakilo Quarry are restricted to day-time only. This lighting assessment is being done to identify the impacts of added illumination that will be necessary to support nighttime operations at the quarry. The results of this lighting assessment will be included in the entitlements for the quarry's application for expanded night time / 24-hour operations.

This assessment performed several illumination calculations and found that there will be no appreciable direct illumination or light being reflected off the exposed quarry walls. The calculations were based on the existing lighting and additional lighting being proposed at the Asphalt Batching Plant, Concrete Ready-Mix Plant, trailers, scales, and at the maintenance sheds.

The lighting from within the quarry will all be mounted below the perimeter berms which prevent any direct illumination from escaping the quarry. In addition, the distance from the light sources to the quarry walls, coupled with the dark color of the quarry walls, eliminate any appreciable light being reflected off the face of the quarry walls.

However, the following situations will have visual impacts to the surrounding areas due to nighttime operations.

1. **Light Reflecting Off Rain (Remote Visible Impact)**
   Due to the quarry's elevation over the Kapolei area, light reflecting off light misting to moderate rain fall will cause a noticeable illumination over the quarry. The City & County of Honolulu recently converted 55,000 street lights to full cutoff LED lights which lessened the uplighting caused by their street lights. Therefore, the night sky is considerably darker than before, thereby making any light reflected off rain more noticeable. However, Makakilo experiences very low rain fall and the asphalt batching plant will cease operations during heavy rains so the visual impact of light reflecting off falling rain is remote.

2. **Portable Generator Mounted Floodlights at the Asphalt Batching Plant (High Impact)**
   It was noted that the Asphalt Batching Plant had three portable generator lighting systems, of which one was being utilized during our site visit. There are four (4) unshielded white HID floodlights on each generator lighting system. Each light is aimable along the horizontal and vertical axis.

Based on the above mentioned findings, we provide the following recommends to minimize any impacts to the surrounding areas.

1. **3000K Light Sources (Recommendation – High)**
   The color of the light is very important in minimizing any perceived lighting impacts to the surrounding areas. Most people notice or object to very white lights at night when in

the context of light pollution. The color of white light and bluish white light is 5000 Kelvin (K) and above. The color of warmer yellower light is 3000 Kelvin and below. Since the major cause of any visible light emanating from the quarry will only be observed during a light misting to moderate rain fall, the contrast between the dark night sky and the light reflecting off the rain needs to be minimized. Although there will be no uplighting that will project light straight up into the night sky, the concrete batching plant has highly reflective concrete pavement that will reflect the area lighting upwards. The Asphalt Batching Plant may also have concrete pavement around that site when the ABP is relocated to the quarry from Kalaeloa. Hence, it is important to select light fixtures with color temperatures of 3000K to minimize the contrast of any light reflected upwards from the concrete pavements.

2. **Full Cutoff Light Fixtures (Recommendation – High)**
   As mentioned previously, it is important to minimize any light that may reflected off falling rain. To do this, all light fixtures should be of the full cutoff type which do not allow light to be distributed above the light fixture's horizontal plane. Hence, it is recommended that all existing light fixtures be replaced with full cutoff 3000K lights. It is especially important to replace any white colored floodlights.

3. **Portable Generator Lighting Systems (Recommendation – High)**
   To minimize stray light from being directed upwards, each floodlight should be provided with add-on shielding and should be directed at a slightly downward angle. The color of the HID lamps should also be changed from the current 5,000K to 3,000K. Lastly, the generators should be located on the southern side of each work area so the floodlights will only be pointed in the north, east, and west direction, away from Kapolei.

Section 1 Introduction

1.1 Background

a. Grace Pacific Corporation acquired Pacific Concrete and Rock in 1984 which included the Makakilo Quarry. Currently all work at the Makakilo Quarry is restricted to day-time hours only.

b. External visual sight lines of the quarry's operations are blocked through the careful placement of berms which increase the elevations of the quarry's perimeter. The berms prevent visual observations of the quarry and the structures within the quarry. Natural vegetation usually covers any newly constructed berms within a year, which allow the berms to blend in with the surrounding hillside.

c. Landscaping around office trailers also help to obscure the sight of some otherwise exposed trailers.

d. The existing operations cause very little dust so dust clouds during any future nighttime operations is not expected to reflect any light coming from within the quarry.

e. There are very limited existing lighting installations at the office trailers, maintenance sheds, and the concrete batching plant. All vehicles have headlights for driving between the illuminated areas and on roads without roadway illumination.

1.2 Purpose

a. The purpose of this lighting assessment is to verify if the relocation of the Asphalt Batching Plant and the addition of any lighting, that is provided to support nighttime operations, will have any detrimental visual impacts to the surrounding properties.

b. The results of this lighting assessment will be included in the entitlements submittal for the proposed nighttime operation request.

1.3 Scope of Work

a. Review available record drawings.

b. Conduct a non-intrusive field investigation to verify the types and locations of existing lighting installations.

c. Meet with facility personnel to gain additional information on the anticipate nighttime operations.

d. Perform an illumination calculation based on the existing lighting installations to create a baseline of how much light may be reflecting off the quarry walls and how much light may be escaping the quarry.

e. Perform an illumination calculation based on the relocation and installation of the existing Asphalt Batching Plant that is currently located in Kalaeloa; adding full cutoff 3000K floodlights onto the existing Concrete Ready-Mix Plant; and adding full cutoff 3000K floodlights at the existing maintenance sheds.

f. Provide a lighting assessment report with the findings of the calculations and recommendations to minimize any visual impacts of the added lighting.

Section 2 Existing Conditions

2.1 Quarry Observations

a. The current operations in Makakilo Quarry are restricted to day-time only. Therefore, there are only very limited existing lighting installations at the office trailers, maintenance sheds, scales, and trailers at the Concrete Ready-Mix Plant.

b. The existing lighting only provide localized illumination of key areas frequented by personnel during the early morning at the start of operations and the early evening at the end of operations.

c. The existing lights mainly consist of non-cutoff wall packs at the office trailers and storage unit, small floodlights at the maintenance sheds and on a pole at the office trailers, and a medium sized post mounted HID floodlight at the end of one of the office trailers that is pointed towards the quarry.

d. Lighting at the Concrete Ready-Mix Plant (CRMP) only consists of a single wall pack light fixture above the trailer office door. There are no floodlights that illuminate the area surrounding the CRMP. A storage container that is off on the Diamond Head side of the CRMP site also has a wall pack light fixture but the illumination from the light does not contribute to the lighting levels surrounding the CRMP.

e. The highest part of the Concrete Ready-Mix Plant is well below the southern berm of the quarry so no part of the CRMP installation is visible for east Kapolei.

f. The tallest structure/part of the Concrete Ready-Mix Plant includes a platform at the top which appears ideally suited for any new area lighting that may be required.

g. The quarry has three wooden utility poles that are stored at the maintenance sheds for possible use for future area lighting at the maintenance sheds. Lights can be mounted onto the wooden poles provided that the proper mounting brackets are provided with the light fixtures.

Figure 1 – Concrete Ready-Mix Plant. The tallest part of the sturture appears ideally suited for the mounting of any additional area lighting.

Figure 2 – Quarry - Various light fixtues types. Clockwise from upper left: Office Trailer with wall pack lights; Office Trailer with large floodlight; trailer at Concrete Ready-Mix Plant; Storage Container at Concrete Ready-Mix Plant; Mini floodlights at Maintenance Sheds; and Wall Packs at Maintenance Sheds.

2.2 Asphalt Batching Plant Observations

a. The Asphalt Batching Plant (ABP), which is currently located in Kalaeloa, is scheduled to be relocated to the Makakilo Quarry. The ABP has many exterior lights mounted on the various structures that provide localized illumination of specific areas. The existing illumination is not continuous within the ABP as there are many dark spots with very little or no illumination. The highest illumination level and greatest illumination coverage is provided by a portable generator lighting system which utilizes four (4) large HID floodlights. See figure 3.

b. The light fixture types at the ABP are varied and consist of small to large floodlights; incandescent, fluorescent, fluorescent induction, high intensity discharge (HID), and LED lamps; warm colored (2500K) to white colored (5000K); and bare bulb, enclosed, and wraparound light fixtures. See Figure 4.

c. There is a floodlight light on the tallest structure at the ABP which is at about the same height of the existing berm on the south side facing east Kapolei. Hence, this light may be visible from east Kapolei. The existing light is a non-shielded floodlight that is used to illuminate the upper work platform of the structure. See Figure 5.

Figure 3 – Asphalt Batching Plant - Portable generator lighting system (left); Area illuminated by the portable generator lighting system.

Figure 4 – Asphalt Batching Plant - Various light fixtures. Clockwise from upper left: Various floodlights on the operations building; bare bulb light fixtures; HID Floodlight (top) and fluroescent wraparound light fixtures at the QC lab; LED floodlights; LED floodlight; and fluorescent induction floodlights.

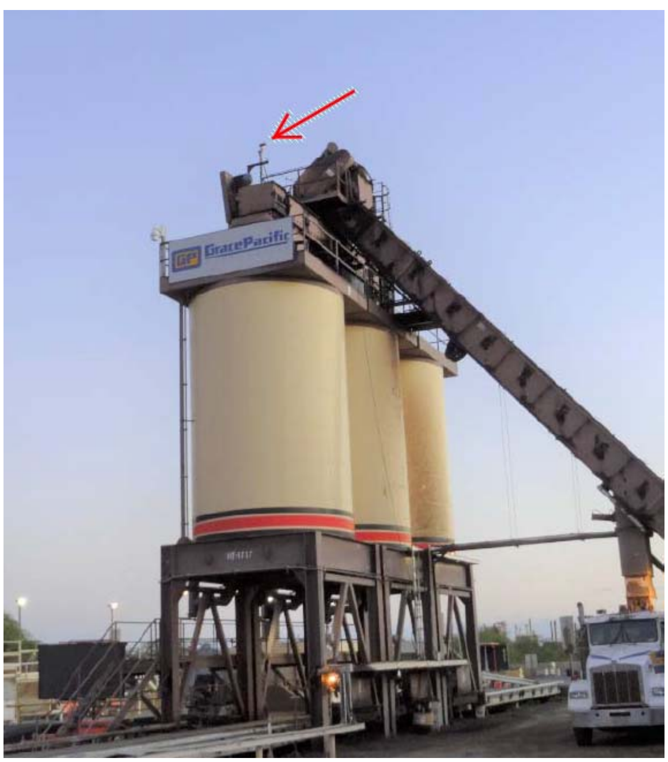

Figure 5 – Asphalt Batching Plant - Highest light on the highest structure may be visible from east Kapolei over the the quarry's southern berm.

Section 3 Analysis

3.1 Analysis

a. Lighting calculations were performed by creating a lighting model that was based on the topographic survey of the entire quarry. See Figure 6. The existing light fixtures that are currently located at the quarry and at the Asphalt Batching Plant (ABP) in Kalaeloa were added to the model. Because information (manufacturer, model number, lumen output, distribution patterns, etc.) of the existing light fixtures were not available, a night time site visit was conducted to measure the lighting levels in order to estimate the performance of existing light fixtures. The initial lighting calculation was adjusted to match the measured lighting levels and serves as the baseline. See Figure 7.

b. Once the lighting baseline was completed, the proposed additional lights were added to the calculation. See Figure 8. The additional lights included relocating the ABP to the quarry, adding four (4) full cutoff wide area lights at the Concrete Ready-Mix Plant (CRMP), and adding three (3) pole mounted full cutoff wide area lights at the maintenance sheds.

c. The lighting calculations indicate that the areas surrounding the quarry would not be able to see any observable light being reflected off the quarry face.

d. The layout of the ABP at the new quarry location does not include the QC lab building and the roof mounted floodlight or the ceiling mounted fluorescent wraparound light fixtures. The new ABP layout in the quarry does not include the QC lab so the QC lab was omitted.

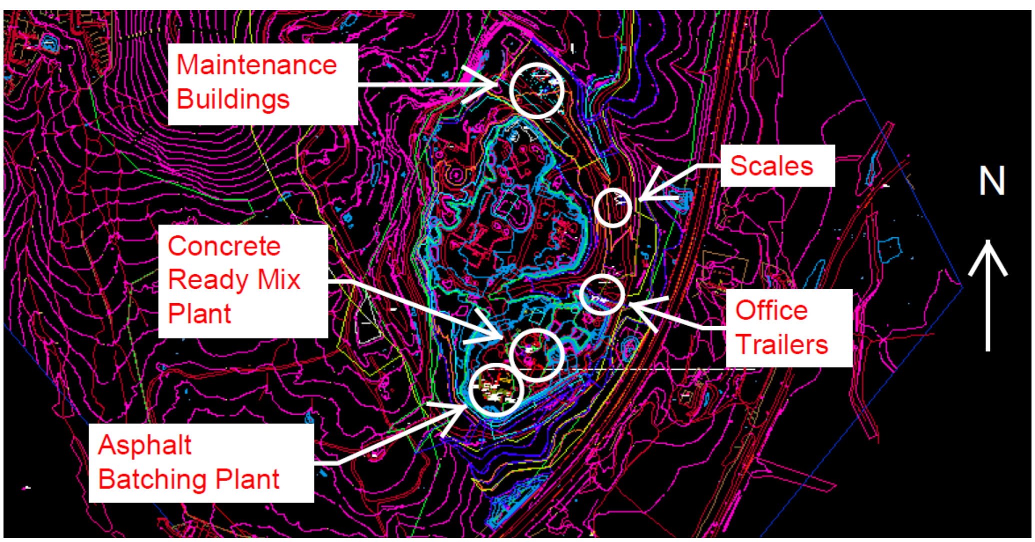

Figure 6 – Topographic survey used for the lighting calculations include the locations of the maintenance sheds; scales; office trailers; Concrete Ready-Mix Plant; and the Asphalt Batching Plant.

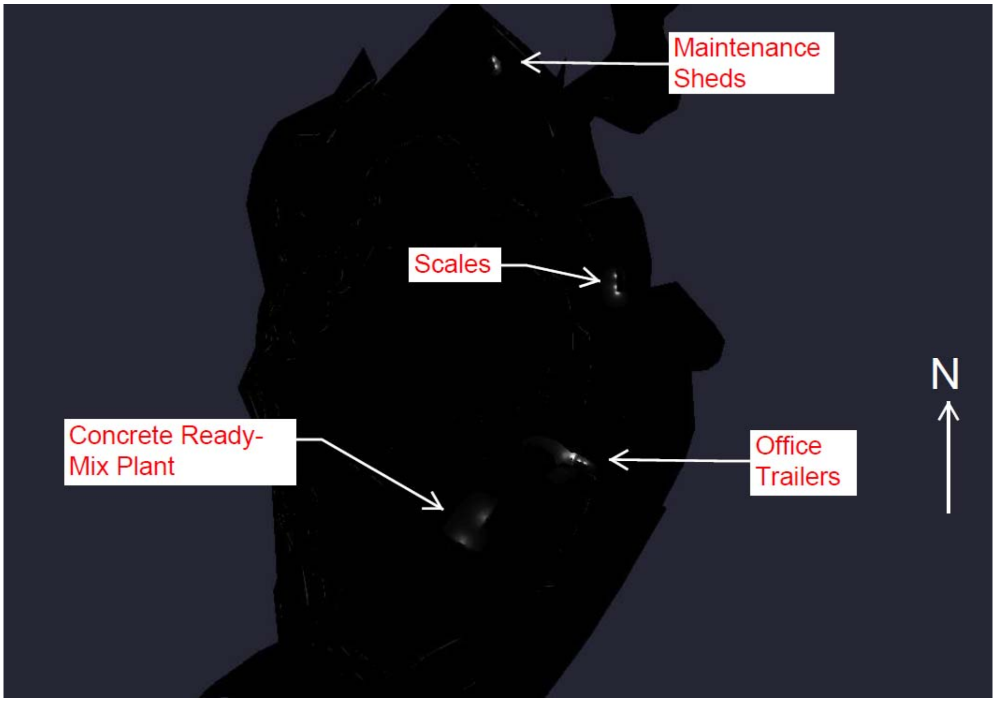

Figure 7 – Baseline Lighting Calculation (plan view) of the quarry. The illuminated areas include the maintenance sheds; scales; office trailers; and Concrete Ready-Mix Plant.

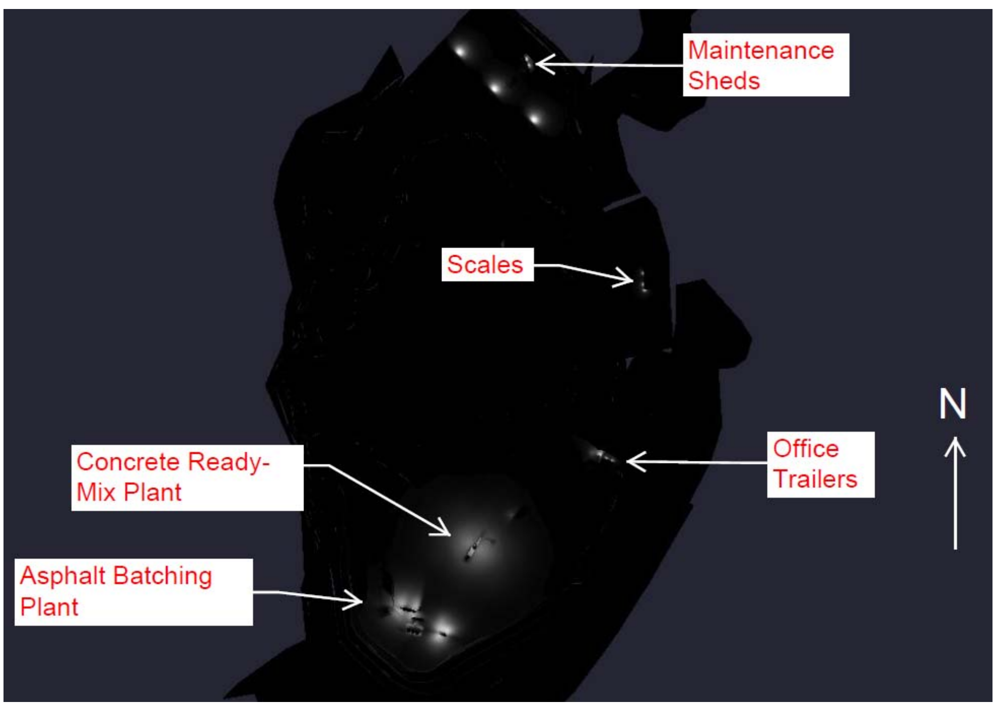

Figure 8 – Lighting calculation (plan view) of quarry with the additional lighting at the maintenance sheds; Concrete Ready-Mix Plant; and the relocated Asphalt Batching Plant.

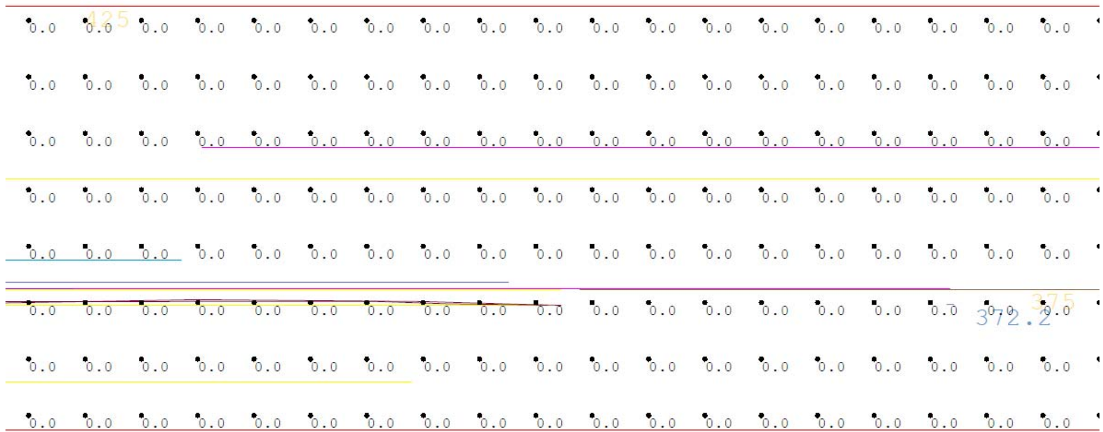

Figure 9 – Illumination calculation (Footcandles) of the north-western quarry face indicate there would be no observable light being reflected off the quarry face between an elevation of 350’ to 425’. Similar for higher elevations.

Section 4 Recommendations

4.1 Recommendations

The following recommendations are based on adding lights to illuminate key areas and to minimize visual impacts of the lighting system on the surrounding areas.

1. **General Recommendations**
   Where possible, lights should be individually or group controlled to allow selective illumination of specific areas and to darken areas where lighting is not needed. The lighting controls should be located on the ground level to provide easy access to the controls. The lights should also be controlled with either a photocell or time switch to ensure the lights are only utilized during the night and are automatically turned off during the day.

   Full cutoff LED type light fixtures should be provided for long life, energy efficiency, and instant “on” (whereas HID type light fixtures require several minutes to warm up). Full cutoff light fixtures do not allow light to be distributed above the light fixture’s horizontal plane, thereby minimizing light pollution.

   The color of the lights should be selected to be no higher than 3000K. 3000K is a warmer color of light which will minimize the refection off the exposed rock faces of the quarry’s north face and will allow any reflected light to blend in with the hill side.

3000K lights will also minimize the contracts with the dark night sky when the light reflects off of light misting to moderate rain.

2. **Concrete Ready-Mix Plant**
   The area surrounding the Concrete Ready-Mix Plant (CRMP) can be illuminated by adding four (4) full cutoff floodlights on the highest portion of the CRMP facility. Full cutoff light fixtures are defined as light fixtures that do not allow any direct illumination to be distributed above the horizontal plane (no up lighting).

   In addition, all existing trailer mounted wall pack light fixtures should be replaced with full cutoff 3000K wall mounted light fixtures.

3. **Asphalt Batching Plant**
   The ABP already has lighting in most of the required locations. However, portable generator lighting systems are used where additional lighting is required. The portable generator lighting systems utilize white floodlights which create a lot of light pollution. Therefore, it is recommended that new 3000K full cutoff light fixtures be provided on the ABP structures, where required, to allow the elimination of the portable generator lighting systems. If the portable generator lighting systems are to still be used, we recommend adding shields onto the existing light fixtures and replacing the existing 5000K HID lamps with 3000K HID lamps.

   In addition, all existing structure mounted light fixtures should be replaced with full cutoff 3000K light fixtures.

4. **Maintenance Sheds**
   Additional pole mounted full cutoff 3000K lighting can be added to cover selected high use areas and unloading areas.

   In addition, all existing trailer mounted wall pack and floodlight fixtures should be replaced with full cutoff 3000K wall mounted light fixtures.

5. **Office Trailers**
   The large pipe mounted floodlight and the two smaller flood lights, that are mounted on the utility pole, should be replaced with a full cutoff LED floodlights.

   In addition, all existing trailer mounted wall pack and floodlight fixtures should be replaced with full cutoff 3000K wall mounted light fixtures.

DUST EVALUATION
GRACE PACIFIC
MAKAKILO QUARRY

Submitted To:

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Submitted By:

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July 2022

Exhibit "W"

EXECUTIVE SUMMARY

Grace Pacific, LLC has retained Environmental Risk Analysis LLC (ERA) to evaluate potential fugitive dust concerns associated with operational activities at their Makakilo Quarry, located at 91-920 Farrington Highway in Kapolei, HI. The Grace Pacific Makakilo Quarry is located adjacent to the H1 Queen Liliuokalani Freeway in Kapolei, Oahu Hawaii. The nearest residential communities are located approximately ¼-mile to the northeast, east, and south.

This assessment was conducted to evaluate:

1. Current mining operations at the Makakilo Quarry (Section 2)
2. A future Hot-Mixed Asphalt (HMA) Plant (Section 3)
3. The recently completed Ready-Mix Concrete Plant (Section 4)[1]

Current operations at the Site were evaluated through use of applicable historic dust monitoring data collected from the boundaries of the quarry pit (2019). An HMA plant was previously located in the quarry pit between 2013 and 2018. Historic air monitoring data from this time period was deemed to be applicable for evaluation of dust from the future HMA Plant. Estimation of total dust generation from the recently completed concrete plant operation[1] was obtained from USEPA AP-42 (USEPA 1995b) by estimating dust levels generated from individual tasks (i.e. aggregate delivery, aggregate loading, wind erosion).

Emission rate estimates were input into SCREEN3 to model dust migration to offsite residential receptor locations. SCREEN3 is a single source Gaussian plume model that provides maximum ground-level concentrations for point, area, flare, and volume sources, as well as concentrations in the cavity zone, and concentrations due to inversion break-up and shoreline fumigation. SCREEN3 is a screening version of the ISC3 model. SCREEN3 determines 1-hour maximum chemical concentrations under worst-case wind conditions. SCREEN3 also does not account for site-specific terrain. As the dust generating activities are within a quarry pit, it is likely that the modeling performed overestimates the dust generated and transported to receptor locations.

The estimated 24-hour average concentration for the concrete plant was added to the estimates for quarry operations and the HMA plant to evaluate a cumulative estimate for the future operations at the Site. These cumulative estimates are provided in Table ES-1. Dust concentrations were compared to the applicable National Ambient Air Quality Standards (NAAQS) for particulate matter (PM10) of 150 $\mu g/m^3$ (EPA 1997).

[1] The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022.

The resulting estimated 24-hour average concentrations for all dust generating activities did not exceed the NAAQS of 150 μg/m^3. Based on the modeling performed, it is not anticipated that receptor locations approximately ¼-mile away from the Site would experience PM10 concentrations exceeding the NAAQS due to the current or future (HMA and concrete plant) operations at Makakilo Quarry.

TABLE ES-1
Future Concrete Plant, HMA Plant, and Quarry Operations
PM10 Respirable Dust Concentrations

	Estimated 24-hour Average Concentration at ¼-mile (μg/m^3)	National Ambient Air Quality Standard (PM10) – 24-hour Average (μg/m^3)
Current Quarry Operations	12.27	150
Current Quarry Operations + HMA Plant	49.6	150
Current Quarry Operations + Concrete Plant Operations [1]	36.31	150
Current Quarry Operations + HMA Plant + Concrete Plant Operation	73.64	150

Notes:
1 - The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022

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SECTION 1. INTRODUCTION

Grace Pacific, LLC has retained Environmental Risk Analysis LLC (ERA) to evaluate potential fugitive dust concerns associated with operational activities at their Makakilo Quarry, located at 91-920 Farrington Highway in Kapolei, HI. This assessment was conducted to evaluate current mining operations at the Makakilo Quarry, as well as two additional operations:

1. A Hot-Mixed Asphalt (HMA) Plant to be located within the quarry
2. A Ready-Mix Concrete Plant which has been recently completed and located within the quarry[1]

Estimated impacts from dust were modeled to the nearest residential locations approximately ¼-mile from the quarry boundary. Conservative health protective assumptions were made throughout the evaluation.

1.1. Site Location

The Grace Pacific Makakilo Quarry is located adjacent to the H1 Queen Liliuokalani Freeway in Kapolei, Oahu Hawaii (Figure 1). The approximate coordinates of the center of the quarry location are: Latitude/Longitude: 21°21'24.8"N / 158°04'06.4"W. The Site is bounded by the H1 Freeway to the south and east, and other vacant land to the north and west. The nearest residential communities are located approximately ¼-mile to the northeast, east, and south.

[1] The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022

Environmental Risk Analysis	PROJECT NAME: Dust Evaluation Grace Pacific Makakilo Quarry	FIGURE TITLE: Site Location Map
		FIGURE NUMBER: 1

1.2. General Study Approach

This study is split into three (3) sections, evaluation of current operations (Section 2), evaluation of the future Hot-Mixed Asphalt (HMA) plant operations (Section 3), and evaluation of the concrete plant operations (Section 4). This assessment will use data from ambient air monitoring stations set up at the perimeter of the quarry as well as standard factors for estimating emission rates for aggregate handling.

Current operations at the Site include:

- Mining/quarrying rock
- Processing rock (crushing, sorting, stockpiling, washing)
- Recycle Plant (processing asphalt, concrete, separate out steel)
- Trucking
- Maintenance Shop
- Offices
- Storage

Current operations at the Site were evaluated through use of applicable historic dust monitoring data collected from the boundaries of the quarry pit.

Future operations at the Site include the addition of an HMA Plant (Section 3). A concrete plant has also recently been added[1] and will be considered in the evaluation (Section 4).

An HMA plant was previously located in the quarry pit between 2013 and 2018. Historic air monitoring data from this time period was deemed to be applicable for evaluation of dust from the future HMA Plant.

Estimation of total dust generation from the concrete plant operation will be obtained from USEPA AP-42 (USEPA 1995b) by estimating dust levels generated from individual tasks (i.e. aggregate delivery, aggregate loading, wind erosion).

Emission rate estimates will then be used to estimate dust concentrations at nearby residential locations. Dust concentrations will be compared to the applicable National Ambient Air Quality Standards (NAAQS) for particulate matter (PM10) (EPA 1997).

[1] The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022

SECTION 2. CURRENT OPERATIONS

Air monitoring was previously conducted at locations surrounding the active quarry area. This section summarizes the air monitoring conducted for respirable dust and the methodology used to estimate fugitive dust concentrations at receptor locations ¼-mile away from the Site.

2.1. Air Monitoring Results

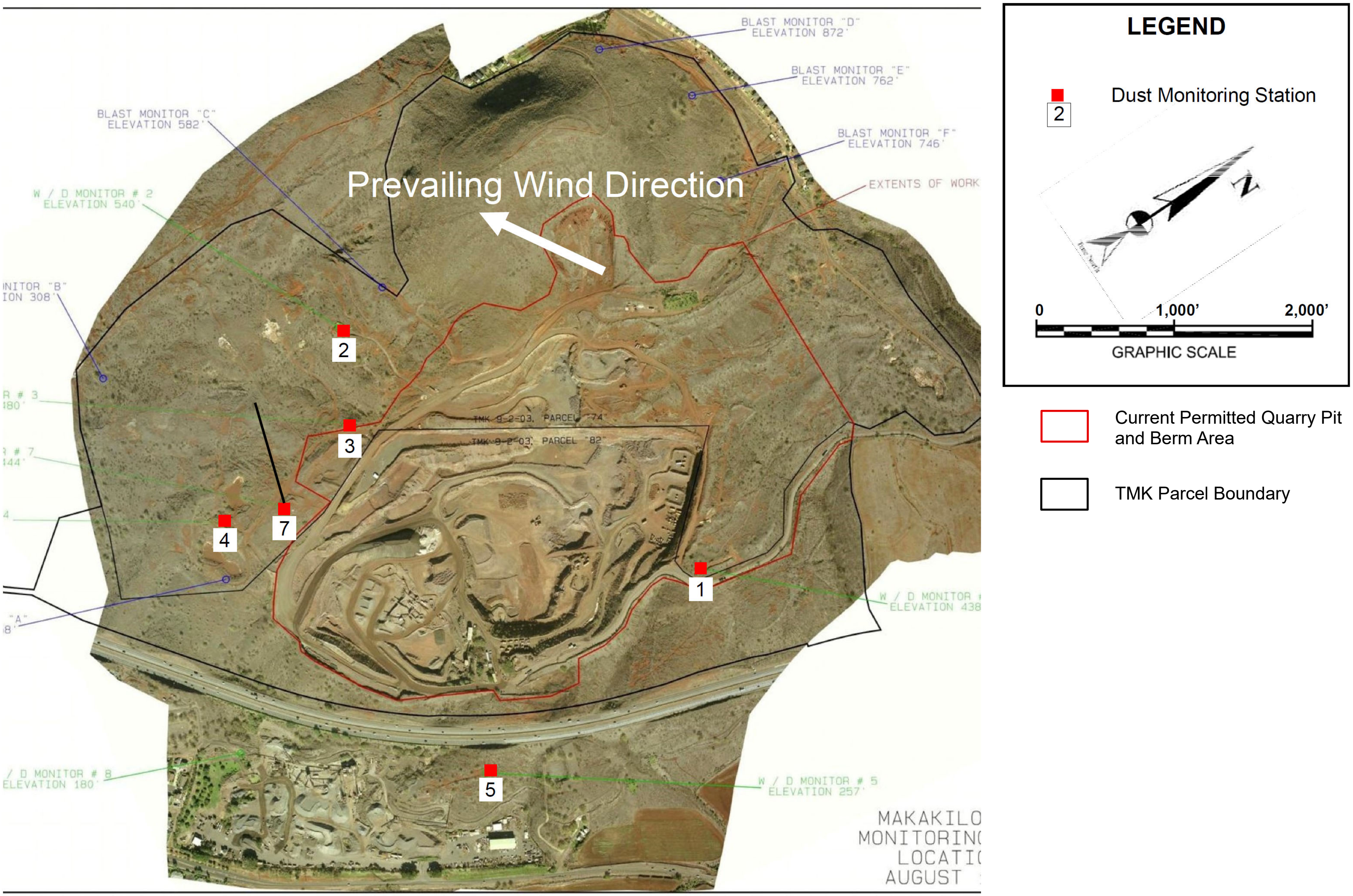
As previously mentioned, the active monitoring data provides respirable dust concentrations at various locations surrounding the quarry. To evaluate current operations, ERA used the most recent dataset available (2019). According to Grace Pacific, an HMA plant was present at the Site between 2013 and 2018 therefore data prior to 2019 were not considered representative of current site conditions. Three (3) monitoring stations were identified which contained data acquired since 2019. The locations of the air monitoring stations are presented in Figure 2. Other air monitoring stations have not collected data since 2019 due to equipment malfunction and the monitoring stations were returned to the manufacturer but deemed inoperable. In an effort to be health protective, this assessment has utilized the maximum observed 24-hour average dust concentrations in evaluating potential risk.

TABLE 2-1

Current Operations - Air Monitoring Results

Location	Maximum 24-hour Average Concentration (ug/m^3)	Average Annual Concentration (ug/m^3)	Mean Wind Speed (m/s)
Station 1	125	33	2.47
Station 3	85	34	6.70
Station 4	**125**	33	**7.07**

Notes:
Results in bold were the maximum detected concentration used to evaluate potential fugitive dust generation.



Environmental Risk Analysis

PROJECT NAME:

Dust Evaluation
Grace Pacific
Makakilo Quarry

FIGURE TITLE: Air Monitoring Locations

FIGURE NUMBER: 2

Air monitoring data was evaluated and the maximum 24-hour average concentration from any of the monitoring station's datasets was used in the air dispersion model, SCREEN3 to model dust migration to offsite receptors. SCREEN3 is a single source Gaussian plume model that provides maximum ground-level concentrations for point, area, flare, and volume sources, as well as concentrations in the cavity zone, and concentrations due to inversion break-up and shoreline fumigation. SCREEN3 is a screening version of the ISC3 model.

2.2. Estimation of Concentrations of Fugitive Dust

In order to estimate fugitive dust concentrations at offsite residential locations, SCREEN3 air dispersion model (Version 13043) (EPA 2013) was used to predict off-site ambient PM10 concentrations for based on observed monitoring results. The source areas of the quarry were modeled as ground-level sources of 45 x 45 square meters (0.5 acre). 0.5 acres is the EPA Region 9 default source size as well as the approximate area of work areas of dust generating activities within the quarry.

SCREEN3 calculations were based on the following assumptions:

Parameter	Value
Source type	area
Source release height	0.1 m
Length of larger side for area	45 m
Length of smaller side of area	45 m
Receptor height above ground	1.8 m
Urban or Rural Area	Rural
Meteorology	
Stability class	D – Neutral Condition
Anemometer height wind speed	7.07 m/s – monitoring data

As noted above, air monitoring is conducted around the perimeter of the quarry pit. Due to the distance from dust generating activities and the air monitoring locations, SCREEN3 was first used to estimate an emission rate from the dust generating activities. The maximum 24-hour average PM10 concentration from the air monitoring datasets was used to estimate an emission rate at the generating activities. It was assumed that the generating activities occur approximately 150 meters from the air monitoring station.

Based on the assumptions above, for a dust concentration of 125 ug/m^3 150 meters away from dust generating activities, an emission rate estimated at the generating activities was **1.68E-04 g/s-m^2.**

For estimate of fugitive dust concentration at receptor locations, the receptors were deployed using the SCREEN3 receptor distance array ranging from 0 meters to 8,047 out meters with a receptor height of 1.8 m. A discrete distance of 402 meters (1/4-mile) was used to estimate the maximum 1-hour concentration at the nearest receptor location. The maximum 1-hour concentration estimated was **30.67 ug/m^3**.

SCREEN3 determines 1-hour maximum chemical concentrations under worst-case wind conditions. It assumes that fugitive dust blows in the direction of the receptor continuously, 100% of the time. The model does not allow for an adjustment to be made to the percentage of time wind blows in the direction of the residents over a longer averaging time. To account for this, EPA states that 24-hour average PM10 concentrations should be calculated by multiplying the 1-hour maximum concentration by a factor of 0.4 (EPA 1992). The resulting estimated 24-hour average concentration of **12.27 μg/m^3** did not exceed the NAAQS of 150 μg/m^3. Based on the modeling performed, it is not anticipated that receptor locations approximately ¼-mile away from the Site would experience PM10 concentrations exceeding the NAAQS due to the current operations at Makakilo Quarry.

TABLE 2-2
Current Operations
PM10 Respirable Dust Concentrations

	Maximum 24-hour Average Measured Concentration at Monitoring Location (μg/m^3)	Estimated Maximum 1-Hour Concentration at ¼-mile (μg/m^3)	Estimated 24-hour Average Concentration at ¼-mile (μg/m^3)
Station 4	125	30.67	12.27

Notes:
Estimated 24-hour Average Concentration at ¼-mile is compared to the NAAQS of 150 μg/m^3

2.3. Maximum Concentrations of Fugitive Dust

To evaluate a worst case scenario for potential 24-hour operation of the facility, another modeling was conducted using the maximum 1-hour concentration from the 2019 dataset.

TABLE 2-1

Current Operations - Air Monitoring Results

Location	Maximum 1-hour Concentration (ug/m^3)	Mean Wind Speed (m/s)
Station 1	686	2.47
Station 3	713	6.70
Station 4	**1004**	**7.07**

Notes:
Results in bold were the maximum detected concentration used to evaluate potential fugitive dust generation.

Again, SCREEN3 calculations were based on the following assumptions:

Parameter	Value
Source type	area
Source release height	0.1 m
Length of larger side for area	45 m
Length of smaller side of area	45 m
Receptor height above ground	1.8 m
Urban or Rural Area	Rural
Meteorology	
Stability class	D – Neutral Condition
Anemometer height wind speed	7.07 m/s – monitoring data

The maximum 1-hour average PM10 concentration from the air monitoring dataset (2019) was used to estimate an emission rate at the generating activities. It was assumed that the generating activities occur approximately 150 meters from the air monitoring station.

Based on the assumptions above, for a dust concentration of 1,004 ug/m^3 150 meters away from dust generating activities, an emission rate estimated at the generating activities was **1.35E-03 g/s-m^2.**

For estimate of fugitive dust concentration at receptor locations, the receptors were deployed using the SCREEN3 receptor distance array ranging from 0 meters to 8,047 out meters with a receptor height of 1.8 m. A discrete distance of 402 meters (1/4-mile) was used to estimate the maximum 1-hour concentration at the nearest receptor location. The maximum 1-hour concentration estimated was **246.6 ug/m^3**.

Again, to account for extrapolation of a 24-hour average from the 1-hour maximum concentration, EPA states that 24-hour average PM10 concentrations should be calculated by multiplying the 1-hour maximum concentration by a factor of 0.4 (EPA 1992). The resulting estimated 24-hour average concentration of **98.64 µg/m^3** did not exceed the NAAQS of 150 µg/m^3.

Based on the modeling performed, even based on 1-hour maximum concentration observed during the monitoring year (2019), receptor locations approximately ¼-mile away from the Site would not experience PM10 concentrations exceeding the NAAQS due to the current operations at Makakilo Quarry. As this modeling was based on a 1-hour maximum any day in 2019, this also suggests that if the quarry operated 24-hours per day, it would not be anticipated to have a maximum concentration exceeding the NAAQS.

TABLE 2-3
Current Operations
Maximum PM10 Respirable Dust Concentrations

	Maximum 1-hour Average Measured Concentration at Monitoring Location (µg/m^3)	Estimated Maximum 1-Hour Concentration at ¼-mile (µg/m^3)	Estimated 24-hour Average Concentration at ¼-mile (µg/m^3)
Station 4	1,004	246.6	98.64

Notes:
Estimated 24-hour Average Concentration at ¼-mile is compared to the NAAQS of 150 µg/m^3

SECTION 3. FUTURE HOT MIXED ASPHALT PLANT OPERATIONS

As with the evaluation of current operations, previous air monitoring results were used to estimate potential contributions from a future HMA plant to be located within the quarry. According to Grace Pacific staff, a previous HMA plant was present within the quarry from 2013 to 2018.

3.1. Air Monitoring Results

As previously mentioned, the active monitoring data provides dust concentrations at various locations surrounding the quarry. ERA evaluated air monitoring results from air monitoring stations between 2013 and 2018. Six (6) monitoring stations were identified which contained data acquired between 2013 and 2018. The locations of the air monitoring stations were presented in Figure 2. In an effort to be health protective, this assessment has utilized the highest dust concentrations in evaluating potential fugitive dust concentrations. As the monitoring data would also include contributions from quarry operations which were taking place between 2013 and 2018, the dust concentration evaluated includes both quarry operation as well as operation of the HMA plant.

TABLE 3-1

Future HMA Plant - Air Monitoring Results

Location	Maximum 24-hour Average Concentration (μg/m^3)	2013 – 2018 Average Concentration (μg/m^3)	Mean Wind Speed (m/s)
Station 1	247	29	5.94
Station 2	110	16	7.31
Station 3	114	23	8.43
Station 4	359	39	8.87
Station 5	150	29	9.02
Station 7	**1013**	**36**	-

Notes:
Results in bold were the maximum detected concentration used to evaluate potential fugitive dust generation.
Station 7 did not have recorded wind speeds. The windspeed from the next closest monitoring station (Station 4) was used for modeling purposes.

As previously discussed for current operations, air monitoring data was evaluated and the maximum 24-hour average concentration from any of the monitoring station's datasets was used in the air dispersion model, SCREEN3 to model dust migration to offsite receptors.

3.2. Estimation of Concentrations of Fugitive Dust

In order to estimate fugitive dust concentrations at offsite residential locations, SCREEN3 air dispersion model (Version 13043) (EPA 2013) was used to predict off-site ambient PM10 concentrations for based on observed monitoring results. The source areas of the quarry were modeled as ground-level sources of 45 x 45 square meters (0.5 acre). 0.5 acres is the EPA Region 9 default source size as well as the approximate area of work areas of dust generating activities within the quarry.

SCREEN3 calculations were based on the following assumptions:

Parameter	Value
Source type	area
Source release height	0.1 m
Length of larger side for area	45 m
Length of smaller side of area	45 m
Receptor height above ground	1.8 m
Urban or Rural Area	Rural
Meteorology	
Stability class	D – Neutral Condition
Anemometer height wind speed	8.87 m/s – monitoring data

As noted above, air monitoring is conducted around the perimeter of the quarry pit. Due to the distance from dust generating activities and the air monitoring locations, SCREEN3 was first used to estimate an emission rate from the dust generating activities. The maximum 24-hour PM10 concentration from the air monitoring datasets was used to estimate an emission rate at the generating activities. It was assumed that the generating activities occur approximately 150 meters from the air monitoring station.

Based on the assumptions above, for a dust concentration of 1,013 ug/m^3 150 meters away from dust generating activities, an emission rate estimated at the generating activities was **1.70E-04 g/s-m^2**.

For estimate of fugitive dust concentration at receptor locations, the receptors were deployed using the SCREEN3 receptor distance array ranging from 0 meters to 8,047 out meters with a receptor height of 1.8 m. A discrete distance of 402 meters (1/4-mile) was used to estimate the maximum 1-hour concentration at the nearest receptor location. The maximum 1-hour concentration estimated was **248.6 µg/m^3**.

SCREEN3 determines 1-hour maximum chemical concentrations under worst-case wind conditions. It assumes that fugitive dust blows in the direction of the receptor continuously, 100% of the time. The model does not allow for an adjustment to be made to the percentage of time wind blows in the direction of the residents over a longer averaging time. To account for this, EPA states that 24-hour average PM10 concentrations should be calculated by multiplying the 1-hour maximum concentration by a factor of 0.4 (EPA 1992). The resulting estimated 24-hour average concentration of **49.6 µg/m^3** did not exceed the NAAQS of 150 µg/m^3. Based on the modeling performed, it is not anticipated that receptor locations approximately ¼-mile away from the Site would experience PM10 concentrations exceeding the NAAQS including an HMA plant at Makakilo Quarry.

TABLE 3-2
Future HMA Plant
PM10 Respirable Dust Concentrations

	Maximum 24-hour Average Measured Concentration at Monitoring Location (µg/m^3)	Estimated Maximum 1-Hour Concentration at ¼-mile (µg/m^3)	Estimated Annual Average Concentration at ¼-mile (µg/m^3)
Station 7	1,013	248.3	49.6

Notes:
Estimated Annual Average Concentration at ¼-mile is compared to the NAAQS of 150 µg/m^3

SECTION 4. CONCRETE PLANT OPERATIONS

A concrete plant has also been recently begun operations within the quarry pit[1]. No air monitoring data was available for current concrete plant operations. Estimation of total dust generation for the concrete plant operations was accomplished by estimating dust levels generated from individual tasks (i.e. aggregate delivery, aggregate loading, wind erosion) and summing them together. Conservative dust emission rates for concrete plant operations were obtained from USEPA AP-42 (USEPA 1995b).

4.1. Emission Rate for Future Concrete Plant Operations

The primary dust generating activity associated with the concrete plant will be aggregate handling and stockpiling. USEPA AP-42, Section 13.2.4 provides equations and standard factors for estimating emission rates for aggregate handling. The USEPA acknowledges and provides these standard equations because it is understood that fugitive dust may be generated by aggregate handling activities and that these piles are usually left uncovered because of the need for frequent material transfer into and out of storage. Dust emissions addressed by these equations include several points in the storage cycle such as material loading onto the pile, disturbances by strong wind currents, loadout from the pile and the movement of loading equipment in the storage pile area. Wind erosion of aggregate storage piles were addressed with standard USEPA AP-42 equations presented in Section 13.2.5, Industrial Wind Erosion. These two emission rates were summed to conservatively estimate the dust emission rate from the stockpiling and handling of processed materials.

4.1.1. Emission Rate for Aggregate Handling and Storage Pile

Emission rate for Aggregate Handling and Storage Pile is estimated by the following equation:

$$\mathbf{E = k(0.0016)\left((U/2.2)^{1.3} / (m/2)^{1.4}\right)}$$

Parameters		Value	Reference
E:	PM10 emission rate (kg/Mg)		calculated
U:	mean wind speed (m/s)	8.72	site-specific
M:	material moisture content (%)	0.7	AP-42 for crushed limestone
k:	particle size multiplier	0.35	for PM10

E = 0.0146 kg/Mg

[1] The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022.

Wind speed used in the above equation was based on the average recorded windspeed between 2013 and 2019 from the closest air monitoring station (Station 4).

It is assumed that the material handled would be approximately 10 metric tons/hr. The area of the storage pile, including the aggregate storage area, apron slab, and feed ramp was identified as 13,142 ft^2 or 1,220.92 m^2. The concrete plant layout is presented in Figure 3.

$$EmissionRate = \frac{\frac{10Mg}{hr} \times 0.0146kg/Mg}{1{,}220.92\,m^2} = 0.0001196kg/hr - m^2$$

The area emission rate for Aggregate Storage and Handling of 1.196E-04 kg/hr-m^2 is equivalent to **3.32E-05 g/s-m^2.**

4.1.2. Emission Rate for Industrial Wind Erosion

$$EF = k \sum_{i=1}^{N} P_i$$

$$P = 58(u * -u_t *)^2 + 25(u * -u_t *)$$

Parameters		Value	Reference
EF:	Emission Factor (g/m^2-yr)		calculated
u_t:	threshold friction velocity (m/s)	1.33	site-specific
u:	0.053 * fastest mile (m/s)	2.486	site-specific
P:	erosion potential (g/m^2)	104.6	site-specific
N:	disturbances	365	site-specific
k:	particle size multiplier	0.5	for PM10

EF = 6.16E-04 g/s-m^2

Wind speed used in the above equation was based on the average highest windspeed between 2013 and 2019 from the closest air monitoring station (Station 4) of 105 mph or 46.9 m/s. The Emission Rates for Aggregate Storage and Handling and for Industrial Wind Erosion were summed to have to total Emission Rate for the handling of aggregate material at the concrete plant of **6.49E-04 g/s-m^2**.

Site Plan Makakilo Ready-Mix Facility

Land Area: 43560 ft2

Impervious Area: 22960 ft2

Environmental Risk Analysis	PROJECT NAME: Dust Evaluation Grace Pacific Makakilo Quarry	FIGURE TITLE: Concrete Plant Site Layout FIGURE NUMBER: 3

4.2. Estimation of Concentrations of Fugitive Dust

In order to estimate fugitive dust concentrations at offsite residential locations, SCREEN3 air dispersion model (Version 13043) (EPA 2013) was used to predict off-site ambient PM10 concentrations for based on the assumed concrete aggregate handling and wind erosion as calculated in Section 4.1. The source areas of the concrete plant were modeled using the size of the aggregate storage area of approximately 35 m by 35 m (3,142 ft^2 or 1,220.92 m^2).

SCREEN3 calculations were based on the following assumptions:

Parameter	Value
Source type	area
Source release height	0.1 m
Length of larger side for area	35 m
Length of smaller side of area	35 m
Receptor height above ground	1.8 m
Urban or Rural Area	Rural
Meteorology	
Stability class	D – Neutral Condition
Anemometer height wind speed	8.72 m/s – monitoring data

For estimate of fugitive dust concentration at receptor locations, the receptors were deployed using the SCREEN3 receptor distance array ranging from 0 meters to 8,047 out meters with a receptor height of 1.8 m. A discrete distance of 402 meters (1/4-mile) was used to estimate the maximum 1-hour concentration at the nearest receptor location. The maximum 1-hour concentration estimated was 60.11 ug/m^3.

SCREEN3 determines 1-hour maximum chemical concentrations under worst-case wind conditions. It assumes that fugitive dust blows in the direction of the receptor continuously, 100% of the time. The model does not allow for an adjustment to be made to the percentage of time wind blows in the direction of the residents over a longer averaging time. To account for this, EPA states that annual average PM10 concentrations should be calculated by multiplying the 1-hour maximum concentration by a factor of 0.4 (EPA 1992). The resulting estimated 24-hour average concentration of **24.04 μg/m^3** did not exceed the NAAQS of 150 μg/m^3. Based on the modeling performed, it is not anticipated that receptor locations approximately ¼-mile away from the Site would experience PM10 concentrations exceeding the NAAQS from operation of the concrete plant at Makakilo Quarry.

TABLE 4-1
Concrete Plant
PM10 Respirable Dust Concentrations

	Estimated Emission Rate ($g/s\text{-}m^2$)	Estimated Maximum 1-Hour Concentration at ¼-mile ($\mu g/m^3$)	Estimated 24-hour Average Concentration at ¼-mile ($\mu g/m^3$)
Concrete Plant Operations	6.49E-04	60.11	24.04

Notes:
Estimated 24-hour Average Concentration at ¼-mile is compared to the NAAQS of 150 $\mu g/m^3$
The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022.

SECTION 5. CONCLUSIONS

This study evaluated three (3) scenarios, current operations (Section 2), future HMA plant operations (Section 3), and concrete plant operations[5] (Section 4). Emission rates from these operations were estimated by using both current and historic air monitoring data from around the quarry pit as well as general modeled values from USEPA AP-42 (USEPA 1995b). Emission rate estimates were then input into SCREEN3 to model dust migration to offsite residential receptor locations. SCREEN3 is a single source Gaussian plume model that provides maximum ground-level concentrations for point, area, flare, and volume sources, as well as concentrations in the cavity zone, and concentrations due to inversion break-up and shoreline fumigation. SCREEN3 is a screening version of the ISC3 model. SCREEN3 determines 1-hour maximum chemical concentrations under worst-case wind conditions. SCREEN3 also does not account for site-specific terrain. As the dust generating activities are within a quarry pit, it is likely that the modeling performed overestimates the dust generated and transported to receptor locations.

The estimated 24-hour average concentrations estimated for the concrete plant was added to the estimates for quarry operations and the HMA plant to evaluate a cumulative estimate for the future operations at the Site. These cumulative estimates are provided in Table 5-1. The resulting estimated 24-hour average concentrations for all dust generating activities did not exceed the NAAQS of 150 µg/m^3.

TABLE 5-1
Cumulative Future Concrete Plant, HMA Plant, and Quarry Operations
PM10 Respirable Dust Concentrations

	Estimated 24-hour Average Concentration at ¼-mile (µg/m^3)	National Ambient Air Quality Standard (PM10) – 24-hour Average
Current Quarry Operations + Concrete Plant Operations[1]	36.31	150
Current Quarry Operations + HMA Plant + Concrete Plant Operation	73.64	150

Notes:
Estimated 24-hour Average Concentration at ¼-mile is compared to the NAAQS of 150 µg/m^3
[1]The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022

[5] The Ready-Mix Concrete Plant has since been completed and has been in operation since April 2022.

SECTION 6. REFERENCES

United States Environmental Protection Agency (EPA), 1992. Screening Procedures for Estimating the Air Quality Impact of Stational Sources Revised. Office of Air Quality Palling and Standards. EPA 454/R-92-019. October.

EPA. 1995a. SCREEN3 Model User's Guide. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-454/B-95-004. September.

EPA, 1995b. EPA Office of Air Quality Planning and Standards: Compilation of Air Pollutant Emission Factors, AP-42 Fifth Edition, January 1995. Updates provided in http://www.epa.gov/ttnchie1/ap42/.

EPA, 1997. 40 CFR Part 50 National Ambient Air Quality Standards for Particulate Matter.

EPA, 2003. Guidance for Obtaining Representative Laboratory Analytical Subsamples from Particulate Laboratory Samples EPA/600/R-03/027, November, 2003.

EPA, 2013. SCREEN3 (dated 13043), screening version of ISC3 air dispersion model

Appendix **A**
Dust Monitoring Data

2019 Air Monitoring Data

Appendix A
Dust Monitoring Data
2019 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, Jan 1 2019	20	98	-	-	N/A	N/A	32	124	N/A	N/A	-	-	-	-
Wed, Jan 2 2019	33	142	-	-	N/A	N/A	32	72	N/A	N/A	-	-	-	-
Thu, Jan 3 2019	27	113	-	-	N/A	N/A	34	140	N/A	N/A	-	-	-	-
Fri, Jan 4 2019	27	103	-	-	N/A	N/A	39	160	N/A	N/A	-	-	-	-
Sat, Jan 5 2019	26	103	-	-	N/A	N/A	28	85	N/A	N/A	-	-	-	-
Sun, Jan 6 2019	27	171	-	-	N/A	N/A	45	482	N/A	N/A	-	-	-	-
Mon, Jan 7 2019	31	139	-	-	N/A	N/A	37	152	N/A	N/A	-	-	-	-
Tue, Jan 8 2019	42	180	-	-	N/A	N/A	21	77	N/A	N/A	-	-	-	-
Wed, Jan 9 2019	43	224	-	-	N/A	N/A	24	76	N/A	N/A	-	-	-	-
Thu, Jan 10 2019	35	165	-	-	N/A	N/A	24	71	N/A	N/A	-	-	-	-
Fri, Jan 11 2019	36	177	-	-	N/A	N/A	23	105	N/A	N/A	-	-	-	-
Sat, Jan 12 2019	29	163	-	-	N/A	N/A	25	150	N/A	N/A	-	-	-	-
Sun, Jan 13 2019	17	101	-	-	N/A	N/A	17	66	N/A	N/A	-	-	-	-
Mon, Jan 14 2019	44	204	-	-	N/A	N/A	27	89	N/A	N/A	-	-	-	-
Tue, Jan 15 2019	51	242	-	-	N/A	N/A	30	117	N/A	N/A	-	-	-	-
Wed, Jan 16 2019	71	277	-	-	N/A	N/A	22	60	N/A	N/A	-	-	-	-
Thu, Jan 17 2019	27	162	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Jan 24 2019	54	197	-	-	-	-	-	-	-	-	-	-	-	-
Fri, Jan 25 2019	36	219	-	-	-	-	-	-	-	-	-	-	-	-
Sat, Jan 26 2019	25	104	-	-	-	-	-	-	-	-	-	-	-	-
Sun, Jan 27 2019	19	96	-	-	-	-	-	-	-	-	-	-	-	-
Mon, Jan 28 2019	33	146	-	-	-	-	-	-	-	-	-	-	-	-
Tue, Jan 29 2019	26	92	-	-	-	-	-	-	-	-	-	-	-	-
Wed, Jan 30 2019	21	119	-	-	-	-	-	-	-	-	-	-	-	-
Thu, Jan 31 2019	17	76	-	-	-	-	-	-	-	-	-	-	-	-
Fri, Feb 1 2019	21	83	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sat, Feb 2 2019	18	78	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sun, Feb 3 2019	20	115	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Mon, Feb 4 2019	22	114	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Tue, Feb 5 2019	37	150	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Wed, Feb 6 2019	37	218	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Feb 7 2019	24	107	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Fri, Feb 8 2019	23	84	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sat, Feb 9 2019	21	85	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sun, Feb 10 2019	31	145	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Mon, Feb 11 2019	28	118	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Tue, Feb 12 2019	22	88	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Wed, Feb 13 2019	18	93	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Feb 14 2019	18	91	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Fri, Feb 15 2019	23	99	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sat, Feb 16 2019	18	72	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sun, Feb 17 2019	11	62	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Mon, Feb 18 2019	30	122	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Tue, Feb 19 2019	11	56	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Wed, Feb 20 2019	39	197	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Feb 21 2019	56	179	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Fri, Feb 22 2019	43	217	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sat, Feb 23 2019	31	189	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sun, Feb 24 2019	20	89	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Mon, Feb 25 2019	18	97	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Tue, Feb 26 2019	22	97	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Wed, Feb 27 2019	27	268	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Feb 28 2019	27	114	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Fri, Mar 1 2019	24	107	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sat, Mar 2 2019	27	135	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Sun, Mar 3 2019	20	109	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Mon, Mar 4 2019	27	133	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Tue, Mar 5 2019	20	89	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Wed, Mar 6 2019	18	112	-	-	N/A	N/A	N/A	N/A	N/A	N/A	-	-	-	-
Thu, Mar 7 2019	28	103	-	-	N/A	N/A	125	653	N/A	N/A	-	-	-	-
Fri, Mar 8 2019	25	105	-	-	N/A	N/A	91	664	N/A	N/A	-	-	-	-
Sat, Mar 9 2019	21	101	-	-	N/A	N/A	38	364	N/A	N/A	-	-	-	-
Sun, Mar 10 2019	16	80	-	-	N/A	N/A	33	80	N/A	N/A	-	-	-	-
Mon, Mar 11 2019	38	115	-	-	N/A	N/A	63	161	N/A	N/A	-	-	-	-
Tue, Mar 12 2019	23	106	-	-	N/A	N/A	27	163	N/A	N/A	-	-	-	-
Wed, Mar 13 2019	31	203	-	-	N/A	N/A	22	69	N/A	N/A	-	-	-	-
Thu, Mar 14 2019	33	181	-	-	N/A	N/A	21	85	N/A	N/A	-	-	-	-
Fri, Mar 15 2019	35	193	-	-	N/A	N/A	20	94	N/A	N/A	-	-	-	-
Sat, Mar 16 2019	32	156	-	-	N/A	N/A	20	72	N/A	N/A	-	-	-	-

Appendix A
Dust Monitoring Data
2019 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³
Sun, Mar 17 2019	23	83	-	-	N/A	N/A	40	87	N/A	N/A	-	-	-	-
Mon, Mar 18 2019	31	136	-	-	N/A	N/A	29	72	N/A	N/A	-	-	-	-
Tue, Mar 19 2019	39	188	-	-	N/A	N/A	30	89	N/A	N/A	-	-	-	-
Wed, Mar 20 2019	44	163	-	-	N/A	N/A	37	83	N/A	N/A	-	-	-	-
Thu, Mar 21 2019	42	194	-	-	N/A	N/A	25	103	N/A	N/A	-	-	-	-
Fri, Mar 22 2019	55	238	-	-	36	543	22	73	N/A	N/A	-	-	-	-
Sat, Mar 23 2019	18	113	-	-	21	143	16	115	N/A	N/A	-	-	-	-
Sun, Mar 24 2019	31	158	-	-	31	132	25	102	N/A	N/A	-	-	-	-
Mon, Mar 25 2019	40	192	-	-	37	119	28	95	N/A	N/A	-	-	-	-
Tue, Mar 26 2019	36	180	-	-	32	127	27	118	N/A	N/A	-	-	-	-
Wed, Mar 27 2019	65	324	-	-	48	141	31	100	N/A	N/A	-	-	-	-
Thu, Mar 28 2019	37	146	-	-	28	86	38	224	N/A	N/A	-	-	-	-
Fri, Mar 29 2019	53	275	-	-	29	104	27	83	N/A	N/A	-	-	-	-
Sat, Mar 30 2019	42	234	-	-	36	93	38	90	N/A	N/A	-	-	-	-
Sun, Mar 31 2019	26	136	-	-	31	115	31	151	N/A	N/A	-	-	-	-
Mon, Apr 1 2019	57	296	-	-	33	110	31	91	N/A	N/A	-	-	-	-
Tue, Apr 2 2019	48	420	-	-	44	121	38	104	N/A	N/A	-	-	-	-
Wed, Apr 3 2019	125	686	-	-	38	116	36	94	N/A	N/A	-	-	-	-
Thu, Apr 4 2019	57	182	-	-	46	156	39	109	N/A	N/A	-	-	-	-
Fri, Apr 5 2019	61	378	-	-	39	101	40	138	N/A	N/A	-	-	-	-
Sat, Apr 6 2019	38	147	-	-	35	121	33	143	N/A	N/A	-	-	-	-
Sun, Apr 7 2019	29	164	-	-	29	92	27	88	N/A	N/A	-	-	-	-
Mon, Apr 8 2019	59	308	-	-	35	121	34	167	N/A	N/A	-	-	-	-
Tue, Apr 9 2019	41	176	-	-	29	95	31	113	N/A	N/A	-	-	-	-
Wed, Apr 10 2019	29	165	-	-	65	324	55	394	N/A	N/A	-	-	-	-
Thu, Apr 11 2019	35	122	-	-	85	323	72	223	N/A	N/A	-	-	-	-
Fri, Apr 12 2019	36	116	-	-	80	713	72	495	N/A	N/A	-	-	-	-
Sat, Apr 13 2019	31	120	-	-	43	104	39	90	N/A	N/A	-	-	-	-
Sun, Apr 14 2019	26	90	-	-	71	342	36	76	N/A	N/A	-	-	-	-
Mon, Apr 15 2019	42	409	-	-	65	332	47	193	N/A	N/A	-	-	-	-
Tue, Apr 16 2019	44	182	-	-	28	78	26	78	N/A	N/A	-	-	-	-
Wed, Apr 17 2019	34	175	-	-	29	136	37	182	N/A	N/A	-	-	-	-
Thu, Apr 18 2019	43	185	-	-	33	194	29	141	N/A	N/A	-	-	-	-
Fri, Apr 19 2019	37	161	-	-	40	135	31	95	N/A	N/A	-	-	-	-
Sat, Apr 20 2019	26	135	-	-	34	131	34	189	N/A	N/A	-	-	-	-
Sun, Apr 21 2019	27	103	-	-	26	80	32	254	N/A	N/A	-	-	-	-
Mon, Apr 22 2019	36	162	-	-	33	87	35	97	N/A	N/A	-	-	-	-
Tue, Apr 23 2019	38	166	-	-	58	234	43	99	N/A	N/A	-	-	-	-
Wed, Apr 24 2019	42	172	-	-	47	141	36	105	N/A	N/A	-	-	-	-
Thu, Apr 25 2019	41	164	-	-	29	96	25	76	N/A	N/A	-	-	-	-
Fri, Apr 26 2019	46	206	-	-	32	142	35	189	N/A	N/A	-	-	-	-
Sat, Apr 27 2019	26	199	-	-	23	105	29	157	N/A	N/A	-	-	-	-
Sun, Apr 28 2019	20	138	-	-	25	141	21	115	N/A	N/A	-	-	-	-
Mon, Apr 29 2019	22	129	-	-	29	168	29	237	N/A	N/A	-	-	-	-
Tue, Apr 30 2019	30	213	-	-	38	244	23	97	N/A	N/A	-	-	-	-
Wed, May 1 2019	28	122	-	-	28	110	25	59	N/A	N/A	-	-	-	-
Thu, May 2 2019	29	139	-	-	25	76	26	107	N/A	N/A	-	-	-	-
Fri, May 3 2019	38	172	-	-	28	87	27	80	N/A	N/A	-	-	-	-
Sat, May 4 2019	2	19	-	-	12	27	17	41	N/A	N/A	-	-	-	-
Sun, May 5 2019	18	99	-	-	23	79	25	101	N/A	N/A	-	-	-	-
Mon, May 6 2019	32	152	-	-	22	80	19	67	N/A	N/A	-	-	-	-
Tue, May 7 2019	39	200	-	-	19	89	19	76	N/A	N/A	-	-	-	-
Wed, May 8 2019	29	157	-	-	17	80	18	76	N/A	N/A	-	-	-	-
Thu, May 9 2019	35	156	-	-	21	111	17	88	N/A	N/A	-	-	-	-
Fri, May 10 2019	17	139	-	-	28	124	29	226	N/A	N/A	-	-	-	-
Sat, May 11 2019	-	-	-	-	19	87	17	88	N/A	N/A	-	-	-	-
Sun, May 12 2019	-	-	-	-	23	81	18	79	N/A	N/A	-	-	-	-
Mon, May 13 2019	-	-	-	-	27	113	23	97	N/A	N/A	-	-	-	-
Tue, May 14 2019	-	-	-	-	22	111	27	131	N/A	N/A	-	-	-	-
Wed, May 15 2019	-	-	-	-	35	169	38	243	N/A	N/A	-	-	-	-
Thu, May 16 2019	-	-	-	-	40	136	35	106	N/A	N/A	-	-	-	-
Fri, May 17 2019	-	-	-	-	25	106	25	91	N/A	N/A	-	-	-	-
Sat, May 18 2019	-	-	-	-	24	73	31	249	N/A	N/A	-	-	-	-
Sun, May 19 2019	-	-	-	-	19	63	20	78	N/A	N/A	-	-	-	-
Mon, May 20 2019	-	-	-	-	42	106	30	94	N/A	N/A	-	-	-	-
Tue, May 21 2019	-	-	-	-	31	126	36	142	N/A	N/A	-	-	-	-
Wed, May 22 2019	-	-	-	-	38	114	36	86	N/A	N/A	-	-	-	-
Thu, May 23 2019	31	161	-	-	29	96	32	96	N/A	N/A	-	-	-	-
Fri, May 24 2019	37	189	-	-	27	149	29	142	N/A	N/A	-	-	-	-

Appendix A
Dust Monitoring Data
2019 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, May 25 2019	27	113	-	-	25	75	27	63	N/A	N/A	-	-	-	-
Sun, May 26 2019	32	147	-	-	24	78	26	90	N/A	N/A	-	-	-	-
Mon, May 27 2019	28	160	-	-	37	159	44	207	N/A	N/A	-	-	-	-
Tue, May 28 2019	26	162	-	-	24	114	24	101	N/A	N/A	-	-	-	-
Wed, May 29 2019	34	210	-	-	30	91	25	100	N/A	N/A	-	-	-	-
Thu, May 30 2019	41	312	-	-	35	112	29	96	N/A	N/A	-	-	-	-
Fri, May 31 2019	39	168	-	-	37	142	41	269	N/A	N/A	-	-	-	-
Sat, Jun 1 2019	36	197	-	-	46	455	33	97	N/A	N/A	-	-	-	-
Sun, Jun 2 2019	27	124	-	-	24	71	27	69	N/A	N/A	-	-	-	-
Mon, Jun 3 2019	45	186	-	-	44	217	80	1004	N/A	N/A	-	-	-	-
Tue, Jun 4 2019	41	199	-	-	39	151	35	190	N/A	N/A	-	-	-	-
Wed, Jun 5 2019	37	157	-	-	36	117	33	113	N/A	N/A	-	-	-	-
Thu, Jun 6 2019	90	293	-	-	33	140	34	109	N/A	N/A	-	-	-	-
Fri, Jun 7 2019	58	243	-	-	30	123	36	186	N/A	N/A	-	-	-	-
Sat, Jun 8 2019	29	121	-	-	23	66	24	80	N/A	N/A	-	-	-	-
Sun, Jun 9 2019	29	141	-	-	28	91	25	98	N/A	N/A	-	-	-	-
Mon, Jun 10 2019	48	239	-	-	31	129	29	101	N/A	N/A	-	-	-	-
Tue, Jun 11 2019	34	130	-	-	24	71	28	88	N/A	N/A	-	-	-	-
Wed, Jun 12 2019	41	187	-	-	31	95	27	89	N/A	N/A	-	-	-	-
Thu, Jun 13 2019	49	218	-	-	32	124	28	93	N/A	N/A	-	-	-	-
Fri, Jun 14 2019	39	151	-	-	78	382	42	154	N/A	N/A	-	-	-	-
Sat, Jun 15 2019	37	162	-	-	35	185	27	89	N/A	N/A	-	-	-	-
Sun, Jun 16 2019	25	127	-	-	25	77	26	69	N/A	N/A	-	-	-	-
Mon, Jun 17 2019	52	218	-	-	41	129	36	197	N/A	N/A	-	-	-	-
Tue, Jun 18 2019	35	145	-	-	43	157	31	91	N/A	N/A	-	-	-	-
Wed, Jun 19 2019	41	152	-	-	32	113	35	94	N/A	N/A	-	-	-	-
Thu, Jun 20 2019	53	303	-	-	28	77	26	96	N/A	N/A	-	-	-	-
Fri, Jun 21 2019	32	177	-	-	27	90	21	113	N/A	N/A	-	-	-	-
Sat, Jun 22 2019	34	135	-	-	29	117	32	124	N/A	N/A	-	-	-	-
Sun, Jun 23 2019	29	155	-	-	35	213	44	309	N/A	N/A	-	-	-	-
Mon, Jun 24 2019	22	182	-	-	31	110	52	283	N/A	N/A	-	-	-	-
Tue, Jun 25 2019	12	88	-	-	19	94	76	497	N/A	N/A	-	-	-	-
Wed, Jun 26 2019	23	125	-	-	22	85	50	499	N/A	N/A	-	-	-	-
Thu, Jun 27 2019	29	194	-	-	44	210	56	299	N/A	N/A	-	-	-	-
Fri, Jun 28 2019	34	177	-	-	27	88	40	209	N/A	N/A	-	-	-	-
Sat, Jun 29 2019	33	176	-	-	20	77	19	63	N/A	N/A	-	-	-	-

Average	33	163	-	-	34	141	33	151	-	-	-	-	-	-
PM10 standard (annua	50		50		50		50		50		50		50	
Max	125	686	0	0	85	713	125	1004	0	0	0	0	0	0
2nd Highest 24-hr	90		-		80		91		-		-		-	
PM10 standard (24 hr)	150		150		150		150		150		150		150	
No. of Exceedances	0		0		0		0		0		0		0	
No. of Days	162		0		100		131		0		0		0	

2013 - 2018 Air Monitoring Data

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, Jan 1 2013	10	76	10	76	17	115	28	284	20	230	20	140
Wed, Jan 2 2013	10	36	10	36	18	83	15	57	14	122	15	49
Thu, Jan 3 2013	10	45	10	45	17	94	38	425	15	72	23	280
Fri, Jan 4 2013	16	81	16	81	33	226	52	526	16	65	39	217
Sat, Jan 5 2013	18	91	18	91	25	129	66	866	16	55	33	237
Sun, Jan 6 2013	17	70	17	70	24	109	31	234	20	172	25	92
Mon, Jan 7 2013	15	83	15	83	28	187	30	167	17	65	26	103
Tue, Jan 8 2013	20	119	20	119	48	516	24	123	23	287	27	119
Wed, Jan 9 2013	15	82	15	82	26	186	17	84	20	225	20	107
Thu, Jan 10 2013	17	72	17	72	26	164	22	78	26	479	25	127
Fri, Jan 11 2013	17	72	17	72	26	171	25	90	17	66	24	96
Sat, Jan 12 2013	15	196	15	196	18	100	25	225	19	82	20	75
Sun, Jan 13 2013	13	56	13	56	17	62	29	289	22	140	23	97
Mon, Jan 14 2013	12	47	12	47	15	50	47	664	21	203	22	111
Tue, Jan 15 2013	16	107	16	107	20	152	19	83	28	227	24	114
Wed, Jan 16 2013	19	64	19	64	26	166	29	158	29	224	29	160
Thu, Jan 17 2013	16	47	16	47	17	51	21	144	33	399	22	67
Fri, Jan 18 2013	16	66	16	66	19	62	26	153	40	193	31	212
Sat, Jan 19 2013	34	170	34	170	30	141	46	360	32	126	49	421
Sun, Jan 20 2013	47	510	47	510	29	98	46	432	33	115	42	656
Mon, Jan 21 2013	37	783	37	783	26	133	32	278	29	208	32	285
Tue, Jan 22 2013	20	134	20	134	21	78	24	106	20	63	24	76
Wed, Jan 23 2013	13	45	13	45	15	45	20	151	14	58	18	55
Thu, Jan 24 2013	8	34	8	34	11	40	12	53	11	50	13	46
Fri, Jan 25 2013	19	58	19	58	24	109	33	249	19	49	28	129
Sat, Jan 26 2013	38	1013	38	1013	24	85	51	516	21	54	29	144
Sun, Jan 27 2013	15	48	15	48	17	76	48	696	35	111	25	129
Mon, Jan 28 2013	10	33	10	33	11	40	19	227	32	128	17	184
Tue, Jan 29 2013	9	41	9	41	15	50	16	76	53	387	17	87
Wed, Jan 30 2013	18	48	18	48	20	51	20	59	90	772	24	74
Thu, Jan 31 2013	14	40	14	40	21	67	25	78	N/A	N/A	27	121
Fri, Feb 1 2013	13	46	13	46	20	92	21	138	73	788	22	109
Sat, Feb 2 2013	17	46	17	46	25	81	22	110	29	249	21	67
Sun, Feb 3 2013	17	43	17	43	24	61	23	107	34	255	23	70
Mon, Feb 4 2013	15	57	15	57	25	77	37	442	43	125	26	92
Tue, Feb 5 2013	16	76	16	76	22	70	22	131	32	147	24	92
Wed, Feb 6 2013	12	54	12	54	14	54	23	128	25	77	23	184
Thu, Feb 7 2013	17	93	17	93	25	115	20	189	31	153	21	175
Fri, Feb 8 2013	14	53	14	53	19	49	19	82	33	315	23	117
Sat, Feb 9 2013	13	54	13	54	12	41	17	82	20	162	21	98
Sun, Feb 10 2013	11	44	11	44	11	46	22	170	18	125	21	147
Mon, Feb 11 2013	13	58	13	58	15	51	26	175	20	138	26	136
Tue, Feb 12 2013	13	39	13	39	14	43	19	112	24	147	23	139
Wed, Feb 13 2013	15	85	15	85	14	46	21	102	25	234	25	195
Thu, Feb 14 2013	12	47	12	47	12	43	26	129	19	148	21	132
Fri, Feb 15 2013	16	79	16	79	19	62	26	199	19	58	20	86
Sat, Feb 16 2013	15	57	15	57	28	64	21	95	15	268	26	152
Sun, Feb 17 2013	18	137	18	137	59	416	123	1002	15	51	89	1012
Mon, Feb 18 2013	17	59	17	59	36	107	68	790	21	228	36	203
Tue, Feb 19 2013	14	54	14	54	22	59	27	132	22	177	22	91
Wed, Feb 20 2013	18	68	18	68	26	110	42	446	25	177	36	165
Thu, Feb 21 2013	11	43	11	43	20	237	15	65	21	234	16	63
Fri, Feb 22 2013	11	62	11	62	10	35	15	73	19	351	18	167
Sat, Feb 23 2013	13	74	13	74	15	37	30	225	17	88	27	178
Sun, Feb 24 2013	13	44	13	44	18	40	28	416	19	131	24	180
Mon, Feb 25 2013	12	46	12	46	24	117	23	120	18	122	23	114
Tue, Feb 26 2013	11	44	11	44	18	59	29	202	16	76	25	152
Wed, Feb 27 2013	15	48	15	48	29	70	91	1001	25	204	45	263
Thu, Feb 28 2013	15	69	15	69	33	98	48	472	32	228	36	158
Fri, Mar 1 2013	29	139	29	139	39	321	97	502	20	61	59	237
Sat, Mar 2 2013	20	55	20	55	27	94	32	125	21	40	27	68
Sun, Mar 3 2013	15	42	15	42	19	49	32	264	15	31	21	58
Mon, Mar 4 2013	16	49	16	49	22	63	39	246	16	40	30	93

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, Mar 5 2013	19	85	19	85	24	65	40	205	19	72	32	94
Wed, Mar 6 2013	18	53	18	53	23	74	36	210	55	661	30	89
Thu, Mar 7 2013	14	45	14	45	17	68	22	88	18	51	29	138
Fri, Mar 8 2013	17	53	17	53	19	45	20	69	23	74	73	1017
Sat, Mar 9 2013	16	45	16	45	17	40	18	47	19	40	112	1015
Sun, Mar 10 2013	9	28	9	28	11	40	10	43	10	28	11	27
Mon, Mar 11 2013	16	49	16	49	24	45	24	76	25	50	29	66
Tue, Mar 12 2013	15	60	15	60	18	57	20	72	18	36	22	67
Wed, Mar 13 2013	14	46	14	46	16	44	21	97	16	38	21	68
Thu, Mar 14 2013	16	50	16	50	17	51	21	78	16	40	22	64
Fri, Mar 15 2013	13	47	13	47	15	46	16	58	32	149	19	59
Sat, Mar 16 2013	14	40	14	40	16	46	18	54	17	41	19	59
Sun, Mar 17 2013	13	44	13	44	13	42	16	56	12	33	17	55
Mon, Mar 18 2013	12	49	12	49	14	42	25	86	14	42	21	74
Tue, Mar 19 2013	12	36	12	36	14	36	38	163	14	83	22	81
Wed, Mar 20 2013	14	38	14	38	15	47	19	64	17	44	19	68
Thu, Mar 21 2013	13	37	13	37	15	33	18	50	12	31	19	44
Fri, Mar 22 2013	14	167	14	167	13	46	13	59	23	104	17	65
Sat, Mar 23 2013	8	39	8	39	10	32	10	40	9	24	12	43
Sun, Mar 24 2013	6	20	6	20	9	44	7	22	8	24	8	30
Mon, Mar 25 2013	7	22	7	22	17	52	17	59	15	40	18	59
Tue, Mar 26 2013	14	53	14	53	15	51	16	68	15	39	19	63
Wed, Mar 27 2013	6	27	6	27	9	40	8	40	8	24	10	42
Thu, Mar 28 2013	10	35	10	35	15	60	23	88	9	26	21	72
Fri, Mar 29 2013	10	33	10	33	13	36	20	88	10	23	17	59
Sat, Mar 30 2013	11	39	11	39	12	41	14	56	12	27	15	56
Sun, Mar 31 2013	37	406	37	406	28	53	76	857	25	38	32	67
Mon, Apr 1 2013	20	57	20	57	20	45	27	82	22	51	29	162
Tue, Apr 2 2013	20	52	20	52	20	61	41	189	17	41	29	70
Wed, Apr 3 2013	12	47	12	47	13	41	23	156	11	33	17	58
Thu, Apr 4 2013	17	64	17	64	18	54	24	110	19	52	24	101
Fri, Apr 5 2013	24	65	24	65	27	65	30	90	22	44	35	98
Sat, Apr 6 2013	17	56	17	56	19	44	23	88	18	39	22	58
Sun, Apr 7 2013	20	47	20	47	22	50	28	103	21	42	27	70
Mon, Apr 8 2013	19	52	19	52	25	70	26	82	16	36	31	105
Tue, Apr 9 2013	18	60	18	60	24	71	22	75	18	47	27	106
Wed, Apr 10 2013	23	82	23	82	36	173	45	387	26	108	37	247
Thu, Apr 11 2013	17	54	17	54	20	56	24	124	20	50	24	77
Fri, Apr 12 2013	23	70	23	70	27	57	28	95	20	32	30	62
Sat, Apr 13 2013	22	44	22	44	26	45	25	60	N/A	N/A	28	56
Sun, Apr 14 2013	13	49	13	49	16	45	15	47	N/A	N/A	18	44
Mon, Apr 15 2013	5	27	5	27	11	36	11	46	10	33	12	41
Tue, Apr 16 2013	11	41	11	41	14	42	17	57	2	3	19	58
Wed, Apr 17 2013	12	48	12	48	24	107	21	86	2	2	27	122
Thu, Apr 18 2013	16	71	16	71	27	93	35	157	2	2	34	139
Fri, Apr 19 2013	10	43	10	43	16	53	26	147	2	3	23	93
Sat, Apr 20 2013	15	48	15	48	18	44	19	71	N/A	N/A	22	61
Sun, Apr 21 2013	13	54	13	54	17	49	16	81	N/A	N/A	19	59
Mon, Apr 22 2013	11	32	11	32	18	54	14	42	35	616	18	47
Tue, Apr 23 2013	12	37	12	37	15	40	16	43	17	36	19	54
Wed, Apr 24 2013	8	40	8	40	10	39	13	61	10	34	14	49
Thu, Apr 25 2013	15	44	15	44	20	66	38	181	16	31	35	142
Fri, Apr 26 2013	18	108	18	108	21	61	37	210	14	37	32	125
Sat, Apr 27 2013	15	48	15	48	16	45	22	104	18	46	21	66
Sun, Apr 28 2013	15	53	15	53	17	51	19	74	18	43	20	59
Mon, Apr 29 2013	12	34	12	34	14	42	17	58	16	31	19	47
Tue, Apr 30 2013	11	44	11	44	14	46	19	81	13	31	24	98
Wed, May 1 2013	15	51	15	51	20	70	33	154	14	30	28	107
Thu, May 2 2013	9	38	9	38	13	48	15	60	13	35	17	61
Fri, May 3 2013	13	54	13	54	15	46	18	64	98	1006	21	54
Sat, May 4 2013	11	52	11	52	13	46	15	73	13	28	17	61
Sun, May 5 2013	9	26	9	26	11	23	10	43	12	26	12	27
Mon, May 6 2013	7	34	7	34	13	51	17	50	13	37	19	60

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, May 7 2013	16	56	16	56	18	52	20	86	16	32	26	82
Wed, May 8 2013	14	41	14	41	22	65	26	127	19	83	33	148
Thu, May 9 2013	11	54	11	54	14	45	15	71	14	57	18	62
Fri, May 10 2013	9	46	9	46	11	44	14	68	13	55	14	60
Sat, May 11 2013	11	40	11	40	13	39	21	97	13	30	33	542
Sun, May 12 2013	8	25	8	25	12	60	21	108	9	22	18	56
Mon, May 13 2013	12	49	12	49	23	215	22	123	11	28	22	116
Tue, May 14 2013	18	67	18	67	26	112	31	101	14	35	51	625
Wed, May 15 2013	16	49	16	49	25	82	25	83	16	33	31	108
Thu, May 16 2013	25	72	25	72	30	74	42	134	19	33	42	157
Fri, May 17 2013	19	43	19	43	23	49	34	171	22	72	31	94
Sat, May 18 2013	16	55	16	55	18	58	54	545	19	53	26	82
Sun, May 19 2013	21	97	21	97	22	162	52	591	14	37	41	208
Mon, May 20 2013	24	76	24	76	16	43	27	207	21	73	21	64
Tue, May 21 2013	15	46	15	46	16	59	24	83	18	37	27	100
Wed, May 22 2013	13	48	13	48	16	48	29	179	15	33	25	102
Thu, May 23 2013	22	66	22	66	24	62	26	90	26	76	31	94
Fri, May 24 2013	13	50	13	50	18	70	34	214	11	25	32	134
Sat, May 25 2013	15	89	15	89	23	137	78	338	14	54	81	875
Sun, May 26 2013	15	41	15	41	17	39	25	77	16	30	24	97
Mon, May 27 2013	14	40	14	40	15	41	23	79	13	30	19	56
Tue, May 28 2013	10	53	10	53	15	52	26	130	10	32	19	73
Wed, May 29 2013	10	44	10	44	11	41	15	68	12	29	15	52
Thu, May 30 2013	12	46	12	46	14	68	17	61	12	32	19	74
Fri, May 31 2013	2	14	2	14	16	52	20	131	9	25	21	79
Sat, Jun 1 2013	N/A	N/A	N/A	N/A	15	57	17	61	11	31	17	55
Sun, Jun 2 2013	N/A	N/A	N/A	N/A	14	41	19	130	11	25	16	39
Mon, Jun 3 2013	N/A	N/A	N/A	N/A	33	107	50	211	21	69	43	162
Tue, Jun 4 2013	N/A	N/A	N/A	N/A	29	95	46	172	18	42	42	131
Wed, Jun 5 2013	N/A	N/A	N/A	N/A	23	68	61	326	15	43	51	265
Thu, Jun 6 2013	5	20	5	20	27	70	53	159	21	62	42	147
Fri, Jun 7 2013	14	44	14	44	31	100	108	392	19	38	50	174
Sat, Jun 8 2013	12	55	12	55	20	48	45	457	17	34	24	63
Sun, Jun 9 2013	1	8	1	8	13	36	28	110	12	32	24	177
Mon, Jun 10 2013	2	15	2	15	20	67	52	216	13	32	39	127
Tue, Jun 11 2013	13	36	13	36	16	37	20	62	15	28	20	55
Wed, Jun 12 2013	5	37	5	37	35	144	61	266	15	43	58	267
Thu, Jun 13 2013	6	48	6	48	19	73	37	218	14	84	36	158
Fri, Jun 14 2013	7	47	7	47	17	50	31	121	16	66	29	90
Sat, Jun 15 2013	1	3	1	3	15	47	22	89	12	59	20	96
Sun, Jun 16 2013	3	17	3	17	12	35	16	52	11	25	16	45
Mon, Jun 17 2013	1	18	1	18	26	139	37	227	22	124	36	158
Tue, Jun 18 2013	1	2	1	2	35	157	95	397	2	2	52	299
Wed, Jun 19 2013	1	2	1	2	19	45	24	75	2	3	27	80
Thu, Jun 20 2013	11	39	11	39	16	57	27	105	N/A	N/A	29	130
Fri, Jun 21 2013	3	28	3	28	15	58	25	109	N/A	N/A	27	117
Sat, Jun 22 2013	12	32	12	32	18	56	34	165	N/A	N/A	25	108
Sun, Jun 23 2013	5	35	5	35	9	52	13	52	2	2	11	44
Mon, Jun 24 2013	9	44	9	44	19	86	27	115	2	2	23	89
Tue, Jun 25 2013	4	34	4	34	9	37	12	48	2	2	13	52
Wed, Jun 26 2013	9	29	9	29	14	49	26	92	2	2	25	92
Thu, Jun 27 2013	10	40	10	40	16	58	30	120	2	2	32	120
Fri, Jun 28 2013	7	28	7	28	12	48	27	155	2	3	20	78
Sat, Jun 29 2013	1	2	1	2	17	104	22	93	2	2	26	170
Sun, Jun 30 2013	N/A	N/A	N/A	N/A	12	34	20	68	2	2	18	68
Mon, Jul 1 2013	N/A	N/A	N/A	N/A	16	63	25	88	2	2	23	100
Tue, Jul 2 2013	N/A	N/A	N/A	N/A	17	60	22	99	2	2	22	95
Wed, Jul 3 2013	1	2	1	2	21	55	23	80	4	5	27	79
Thu, Jul 4 2013	N/A	N/A	N/A	N/A	13	35	47	395	2	2	24	84
Fri, Jul 5 2013	1	2	1	2	14	44	99	366	2	2	38	209
Sat, Jul 6 2013	1	2	1	2	9	36	17	86	2	2	19	293
Sun, Jul 7 2013	N/A	N/A	N/A	N/A	9	35	N/A	N/A	2	2	23	264
Mon, Jul 8 2013	N/A	N/A	N/A	N/A	23	80	N/A	N/A	2	3	30	116

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, Jul 9 2013	N/A	N/A	N/A	N/A	53	172	10	11	3	3	64	228
Wed, Jul 10 2013	N/A	N/A	N/A	N/A	54	233	98	431	3	3	64	259
Thu, Jul 11 2013	N/A	N/A	N/A	N/A	36	155	60	278	2	2	55	252
Fri, Jul 12 2013	N/A	N/A	N/A	N/A	25	136	53	268	2	2	34	189
Sat, Jul 13 2013	N/A	N/A	N/A	N/A	14	36	20	70	2	2	17	49
Sun, Jul 14 2013	N/A	N/A	N/A	N/A	12	32	16	52	2	2	17	53
Mon, Jul 15 2013	N/A	N/A	N/A	N/A	21	56	24	88	2	2	31	119
Tue, Jul 16 2013	N/A	N/A	N/A	N/A	21	73	3	3	2	2	36	134
Wed, Jul 17 2013	N/A	N/A	N/A	N/A	37	157	34	142	4	5	42	152
Thu, Jul 18 2013	N/A	N/A	N/A	N/A	31	134	44	164	36	150	46	233
Fri, Jul 19 2013	N/A	N/A	N/A	N/A	23	113	23	86	36	697	24	82
Sat, Jul 20 2013	N/A	N/A	N/A	N/A	13	40	17	74	12	28	16	51
Sun, Jul 21 2013	N/A	N/A	N/A	N/A	12	31	16	66	9	28	16	63
Mon, Jul 22 2013	N/A	N/A	N/A	N/A	25	111	24	109	N/A	N/A	22	93
Tue, Jul 23 2013	N/A	N/A	N/A	N/A	14	53	N/A	N/A	N/A	N/A	18	88
Wed, Jul 24 2013	N/A	N/A	N/A	N/A	35	117	N/A	N/A	N/A	N/A	32	115
Thu, Jul 25 2013	N/A	N/A	N/A	N/A	61	343	N/A	N/A	N/A	N/A	38	164
Fri, Jul 26 2013	N/A	N/A	N/A	N/A	47	307	N/A	N/A	26	175	43	173
Sat, Jul 27 2013	N/A	N/A	N/A	N/A	42	150	N/A	N/A	13	24	17	62
Sun, Jul 28 2013	N/A	N/A	N/A	N/A	15	44	N/A	N/A	13	23	14	44
Mon, Jul 29 2013	N/A	N/A	N/A	N/A	77	514	N/A	N/A	10	30	22	105
Tue, Jul 30 2013	N/A	N/A	N/A	N/A	17	54	N/A	N/A	14	39	20	82
Wed, Jul 31 2013	N/A	N/A	N/A	N/A	45	151	3	3	13	27	31	134
Thu, Aug 1 2013	N/A	N/A	N/A	N/A	47	311	49	463	5	19	37	134
Fri, Aug 2 2013	N/A	N/A	N/A	N/A	34	128	36	163	12	13	42	191
Sat, Aug 3 2013	N/A	N/A	N/A	N/A	13	41	20	254	N/A	N/A	14	45
Sun, Aug 4 2013	N/A	N/A	N/A	N/A	13	37	18	88	N/A	N/A	14	46
Mon, Aug 5 2013	N/A	N/A	N/A	N/A	35	181	73	540	N/A	N/A	38	146
Tue, Aug 6 2013	N/A	N/A	N/A	N/A	55	247	46	179	N/A	N/A	39	151
Wed, Aug 7 2013	N/A	N/A	N/A	N/A	55	383	95	1001	N/A	N/A	39	150
Thu, Aug 8 2013	N/A	N/A	N/A	N/A	41	219	135	1001	N/A	N/A	55	228
Fri, Aug 9 2013	N/A	N/A	N/A	N/A	37	271	141	1001	N/A	N/A	66	308
Sat, Aug 10 2013	N/A	N/A	N/A	N/A	16	69	14	55	N/A	N/A	13	40
Sun, Aug 11 2013	N/A	N/A	N/A	N/A	15	39	15	46	N/A	N/A	16	48
Mon, Aug 12 2013	N/A	N/A	N/A	N/A	32	131	58	411	N/A	N/A	56	390
Tue, Aug 13 2013	N/A	N/A	N/A	N/A	29	93	53	233	N/A	N/A	37	163
Wed, Aug 14 2013	N/A	N/A	N/A	N/A	35	117	42	158	N/A	N/A	48	196
Thu, Aug 15 2013	N/A	N/A	N/A	N/A	41	130	68	456	N/A	N/A	52	232
Fri, Aug 16 2013	N/A	N/A	N/A	N/A	33	108	55	262	N/A	N/A	44	174
Sat, Aug 17 2013	N/A	N/A	N/A	N/A	26	87	39	194	N/A	N/A	31	117
Sun, Aug 18 2013	N/A	N/A	N/A	N/A	15	45	45	260	N/A	N/A	26	126
Mon, Aug 19 2013	N/A	N/A	N/A	N/A	30	127	41	275	N/A	N/A	39	139
Tue, Aug 20 2013	2	12	2	12	22	104	22	77	N/A	N/A	76	632
Wed, Aug 21 2013	N/A	N/A	N/A	N/A	17	83	17	60	N/A	N/A	24	104
Thu, Aug 22 2013	N/A	N/A	N/A	N/A	21	91	18	71	N/A	N/A	24	86
Fri, Aug 23 2013	N/A	N/A	N/A	N/A	31	129	59	301	N/A	N/A	41	174
Sat, Aug 24 2013	N/A	N/A	N/A	N/A	18	45	142	1001	N/A	N/A	49	341
Sun, Aug 25 2013	N/A	N/A	N/A	N/A	28	84	178	1001	N/A	N/A	78	664
Mon, Aug 26 2013	N/A	N/A	N/A	N/A	56	245	90	477	N/A	N/A	66	257
Tue, Aug 27 2013	N/A	N/A	N/A	N/A	33	108	102	576	150	738	53	172
Wed, Aug 28 2013	N/A	N/A	N/A	N/A	17	62	94	610	64	625	79	1014
Thu, Aug 29 2013	N/A	N/A	N/A	N/A	31	167	21	78	16	96	41	199
Fri, Aug 30 2013	N/A	N/A	N/A	N/A	24	141	31	175	13	47	40	246
Sat, Aug 31 2013	N/A	N/A	N/A	N/A	14	43	20	86	18	66	18	75
Sun, Sep 1 2013	N/A	N/A	N/A	N/A	17	44	16	47	25	179	17	50
Mon, Sep 2 2013	N/A	N/A	N/A	N/A	16	44	20	65	20	80	18	53
Tue, Sep 3 2013	N/A	N/A	N/A	N/A	19	90	32	176	20	147	29	177
Wed, Sep 4 2013	N/A	N/A	N/A	N/A	32	555	40	291	20	137	28	114
Thu, Sep 5 2013	N/A	N/A	N/A	N/A	22	155	30	201	18	51	28	167
Fri, Sep 6 2013	N/A	N/A	N/A	N/A	14	65	20	110	15	90	22	79
Sat, Sep 7 2013	N/A	N/A	N/A	N/A	12	51	12	49	18	102	14	51
Sun, Sep 8 2013	N/A	N/A	N/A	N/A	15	40	16	53	20	42	18	55
Mon, Sep 9 2013	6	7	6	7	26	102	32	160	18	73	40	163

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Tue, Sep 10 2013	1	2	1	2	30	185	41	187	91	1007	38	214
Wed, Sep 11 2013	22	587	22	587	15	54	23	102	14	54	21	105
Thu, Sep 12 2013	9	36	9	36	14	63	29	254	17	91	21	91
Fri, Sep 13 2013	12	48	12	48	13	48	14	58	21	77	16	54
Sat, Sep 14 2013	12	32	12	32	15	41	18	58	24	51	20	65
Sun, Sep 15 2013	8	27	8	27	11	32	16	47	17	73	16	57
Mon, Sep 16 2013	14	37	14	37	29	94	78	594	20	158	36	122
Tue, Sep 17 2013	16	46	16	46	24	100	35	162	40	564	32	207
Wed, Sep 18 2013	17	52	17	52	36	159	39	158	22	77	34	140
Thu, Sep 19 2013	13	33	13	33	20	65	56	689	19	57	23	59
Fri, Sep 20 2013	13	40	13	40	23	112	92	962	25	337	25	80
Sat, Sep 21 2013	11	34	11	34	23	264	18	60	25	331	22	139
Sun, Sep 22 2013	9	29	9	29	11	30	14	42	16	57	15	46
Mon, Sep 23 2013	15	51	15	51	22	89	104	797	14	52	31	110
Tue, Sep 24 2013	12	39	12	39	21	70	164	1001	22	88	31	156
Wed, Sep 25 2013	14	48	14	48	24	129	42	320	23	115	40	193
Thu, Sep 26 2013	11	40	11	40	15	59	17	73	24	217	18	66
Fri, Sep 27 2013	22	132	22	132	37	572	29	249	20	54	31	266
Sat, Sep 28 2013	15	46	15	46	18	44	27	154	45	549	24	70
Sun, Sep 29 2013	9	34	9	34	12	36	17	72	18	49	15	46
Mon, Sep 30 2013	14	49	14	49	19	78	28	97	25	80	29	147
Tue, Oct 1 2013	16	45	16	45	24	105	27	117	26	101	27	84
Wed, Oct 2 2013	19	62	19	62	29	120	53	472	24	72	29	101
Thu, Oct 3 2013	16	55	16	55	28	121	27	133	26	71	30	129
Fri, Oct 4 2013	16	44	16	44	23	78	54	347	30	118	33	118
Sat, Oct 5 2013	11	33	11	33	15	49	16	53	19	91	17	52
Sun, Oct 6 2013	9	24	9	24	11	28	36	464	23	141	27	214
Mon, Oct 7 2013	16	46	16	46	23	71	29	110	23	66	27	100
Tue, Oct 8 2013	23	94	23	94	29	114	53	303	35	314	45	232
Wed, Oct 9 2013	18	49	18	49	28	76	46	191	45	499	43	147
Thu, Oct 10 2013	14	42	14	42	25	105	25	112	20	58	32	129
Fri, Oct 11 2013	11	37	11	37	14	44	16	58	29	163	18	60
Sat, Oct 12 2013	12	38	12	38	15	51	15	56	27	79	19	66
Sun, Oct 13 2013	13	52	13	52	15	56	16	68	21	70	19	76
Mon, Oct 14 2013	11	44	11	44	12	57	16	68	24	235	17	81
Tue, Oct 15 2013	8	42	8	42	11	47	14	56	20	100	16	67
Wed, Oct 16 2013	11	35	11	35	19	84	23	90	19	89	27	139
Thu, Oct 17 2013	11	31	11	31	15	44	18	62	27	69	19	59
Fri, Oct 18 2013	10	41	10	41	16	87	15	61	25	63	19	72
Sat, Oct 19 2013	11	41	11	41	14	46	15	64	34	470	47	422
Sun, Oct 20 2013	11	45	11	45	12	50	15	64	24	96	16	72
Mon, Oct 21 2013	13	41	13	41	16	47	71	503	41	274	29	106
Tue, Oct 22 2013	11	51	11	51	17	87	28	185	20	163	24	110
Wed, Oct 23 2013	13	42	13	42	16	58	56	440	20	92	29	163
Thu, Oct 24 2013	13	45	13	45	20	76	22	91	16	52	26	111
Fri, Oct 25 2013	12	43	12	43	17	75	25	96	24	73	21	97
Sat, Oct 26 2013	13	38	13	38	16	50	19	66	31	127	19	66
Sun, Oct 27 2013	12	46	12	46	16	68	14	61	28	283	18	71
Mon, Oct 28 2013	12	50	12	50	15	57	19	81	25	107	27	236
Tue, Oct 29 2013	12	39	12	39	17	67	20	77	19	58	26	102
Wed, Oct 30 2013	10	45	10	45	17	72	20	97	18	56	19	80
Thu, Oct 31 2013	12	43	12	43	18	61	25	116	25	116	24	100
Sun, Dec 29 2013	17	51	17	51	N/A	N/A	8	30	30	93	20	73
Mon, Dec 30 2013	13	53	13	53	N/A	N/A	14	119	21	65	23	112
Tue, Dec 31 2013	13	44	13	44	N/A	N/A	10	50	30	171	25	150
Wed, Jan 1 2014	17	53	13	38	N/A	N/A	10	49	33	126	20	70
Thu, Jan 2 2014	25	85	14	36	N/A	N/A	7	35	54	347	16	53
Fri, Jan 3 2014	16	46	12	51	N/A	N/A	8	29	29	333	18	66
Sat, Jan 4 2014	17	42	15	33	N/A	N/A	18	47	39	563	18	51
Sun, Jan 5 2014	13	32	11	25	N/A	N/A	33	309	20	79	33	477
Mon, Jan 6 2014	18	40	21	83	4	14	82	395	33	127	68	292
Tue, Jan 7 2014	31	233	22	70	33	147	70	961	16	46	42	255
Wed, Jan 8 2014	20	61	25	112	47	280	32	324	17	38	60	360

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Thu, Jan 9 2014	23	76	11	44	20	189	19	73	9	32	46	390
Fri, Jan 10 2014	13	43	19	113	20	137	24	242	9	37	48	287
Sat, Jan 11 2014	24	144	12	52	15	77	16	105	15	107	42	265
Sun, Jan 12 2014	22	113	13	35	16	37	12	46	16	32	38	497
Mon, Jan 13 2014	25	87	15	41	17	57	4	10	18	41	31	358
Tue, Jan 14 2014	16	41	9	38	10	29	N/A	N/A	12	32	14	51
Wed, Jan 15 2014	22	94	10	53	18	120	N/A	N/A	12	37	16	96
Thu, Jan 16 2014	27	135	11	32	12	32	N/A	N/A	15	57	15	52
Fri, Jan 17 2014	35	113	14	55	15	59	187	1001	14	30	18	57
Sat, Jan 18 2014	23	65	12	46	15	57	14	55	15	32	21	85
Sun, Jan 19 2014	20	54	10	36	13	53	13	43	10	30	16	77
Mon, Jan 20 2014	17	57	8	40	12	64	16	108	10	33	17	89
Tue, Jan 21 2014	31	74	13	35	17	65	15	41	15	36	16	45
Wed, Jan 22 2014	23	58	21	51	28	78	12	44	30	120	24	65
Thu, Jan 23 2014	32	79	27	51	34	109	17	51	32	62	36	145
Fri, Jan 24 2014	35	146	18	41	18	42	18	54	36	122	25	76
Sat, Jan 25 2014	28	120	16	35	19	47	12	44	22	86	68	709
Sun, Jan 26 2014	39	458	13	53	16	43	5	21	16	39	17	58
Mon, Jan 27 2014	14	54	10	37	23	128	12	62	12	26	22	135
Tue, Jan 28 2014	22	79	22	84	25	78	79	379	16	58	44	208
Wed, Jan 29 2014	16	51	10	33	20	102	28	81	9	19	23	142
Thu, Jan 30 2014	29	74	11	41	15	51	7	37	14	48	20	78
Fri, Jan 31 2014	37	145	13	58	16	54	7	34	15	41	19	75
Sat, Feb 1 2014	21	62	10	44	11	36	9	9	11	36	13	45
Sun, Feb 2 2014	18	66	10	42	14	43	32	231	13	51	17	56
Mon, Feb 3 2014	26	79	14	53	22	81	6	32	16	49	21	78
Tue, Feb 4 2014	14	42	6	20	7	32	N/A	N/A	9	73	8	23
Wed, Feb 5 2014	29	133	13	40	15	45	137	281	20	61	18	48
Thu, Feb 6 2014	31	80	10	38	13	45	5	19	13	33	15	43
Fri, Feb 7 2014	26	129	5	30	12	48	13	59	12	70	18	87
Sat, Feb 8 2014	21	83	6	45	12	59	9	55	10	93	20	103
Sun, Feb 9 2014	26	91	8	33	10	31	6	32	11	90	15	53
Mon, Feb 10 2014	31	113	14	37	16	52	5	22	18	48	19	61
Tue, Feb 11 2014	34	90	15	47	19	94	6	41	18	76	24	108
Wed, Feb 12 2014	32	101	12	44	17	59	10	36	13	38	21	134
Thu, Feb 13 2014	42	191	16	42	19	50	55	431	22	132	31	75
Fri, Feb 14 2014	19	47	9	25	13	35	N/A	N/A	11	24	15	41
Sat, Feb 15 2014	35	355	13	44	13	46	13	42	11	51	18	78
Sun, Feb 16 2014	18	47	13	33	14	39	N/A	N/A	16	34	16	33
Mon, Feb 17 2014	22	81	15	34	17	74	3	4	21	118	18	56
Tue, Feb 18 2014	38	117	12	53	20	126	4	4	14	37	18	54
Wed, Feb 19 2014	N/A	N/A	13	55	18	72	5	5	18	107	19	84
Thu, Feb 20 2014	N/A	N/A	11	42	11	94	4	4	14	32	20	109
Fri, Feb 21 2014	N/A	N/A	14	42	18	55	4	4	18	47	22	132
Sat, Feb 22 2014	N/A	N/A	19	51	21	52	N/A	N/A	22	58	24	81
Sun, Feb 23 2014	N/A	N/A	11	42	12	43	N/A	N/A	12	54	18	102
Mon, Feb 24 2014	N/A	N/A	16	57	53	275	4	4	12	30	57	295
Tue, Feb 25 2014	27	90	15	52	31	135	3	3	13	30	29	134
Wed, Feb 26 2014	36	115	17	59	28	134	4	4	19	58	41	190
Thu, Feb 27 2014	39	100	27	88	43	186	N/A	N/A	22	73	54	200
Fri, Feb 28 2014	61	209	19	49	20	46	4	4	23	60	24	53
Sat, Mar 1 2014	52	54	12	58	11	43	N/A	N/A	12	54	16	91
Sun, Mar 2 2014	N/A	N/A	11	26	12	28	N/A	N/A	12	27	12	27
Mon, Mar 3 2014	N/A	N/A	22	42	26	68	N/A	N/A	34	75	27	50
Tue, Mar 4 2014	N/A	N/A	23	58	28	76	N/A	N/A	42	132	32	106
Wed, Mar 5 2014	73	200	23	65	44	445	N/A	N/A	25	57	35	185
Thu, Mar 6 2014	60	195	17	48	19	64	N/A	N/A	20	42	25	88
Fri, Mar 7 2014	31	108	10	36	12	40	N/A	N/A	13	51	14	63
Sat, Mar 8 2014	20	82	7	59	8	50	N/A	N/A	13	171	12	58
Sun, Mar 9 2014	N/A	N/A	6	23	8	30	N/A	N/A	9	35	12	43
Mon, Mar 10 2014	41	194	12	52	27	196	N/A	N/A	12	43	23	144
Tue, Mar 11 2014	34	147	13	40	57	259	N/A	N/A	13	50	24	82
Wed, Mar 12 2014	37	126	16	57	38	166	N/A	N/A	13	39	34	105

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Thu, Mar 13 2014	39	41	16	58	25	87	N/A	N/A	14	49	30	112
Fri, Mar 14 2014	N/A	N/A	11	58	15	50	N/A	N/A	13	69	19	99
Sat, Mar 15 2014	N/A	N/A	16	45	32	149	N/A	N/A	18	55	33	114
Sun, Mar 16 2014	N/A	N/A	15	34	25	82	N/A	N/A	20	127	39	265
Mon, Mar 17 2014	N/A	N/A	14	38	21	64	N/A	N/A	14	33	26	92
Tue, Mar 18 2014	30	74	11	38	21	97	N/A	N/A	10	25	25	123
Wed, Mar 19 2014	34	130	18	111	40	288	N/A	N/A	17	121	48	280
Thu, Mar 20 2014	34	163	14	56	24	126	N/A	N/A	12	39	53	220
Fri, Mar 21 2014	34	209	16	63	25	104	N/A	N/A	14	50	31	117
Sat, Mar 22 2014	34	261	13	50	22	113	N/A	N/A	20	137	34	139
Sun, Mar 23 2014	15	45	9	32	13	36	N/A	N/A	13	81	18	68
Mon, Mar 24 2014	26	58	18	86	32	169	N/A	N/A	16	61	43	158
Tue, Mar 25 2014	24	68	17	73	31	96	N/A	N/A	15	52	36	124
Wed, Mar 26 2014	28	67	12	37	17	60	N/A	N/A	14	55	20	77
Thu, Mar 27 2014	51	173	12	46	15	42	N/A	N/A	14	51	19	70
Fri, Mar 28 2014	27	83	12	51	17	70	N/A	N/A	23	222	23	92
Sat, Mar 29 2014	21	128	12	61	20	91	N/A	N/A	11	43	21	98
Sun, Mar 30 2014	15	47	11	31	13	38	N/A	N/A	12	47	19	60
Mon, Mar 31 2014	20	66	16	65	26	91	N/A	N/A	15	73	39	201
Tue, Apr 1 2014	18	73	15	61	30	185	N/A	N/A	15	40	40	222
Wed, Apr 2 2014	20	56	16	54	29	116	N/A	N/A	5	7	46	251
Thu, Apr 3 2014	23	72	29	96	55	206	N/A	N/A	46	495	69	219
Fri, Apr 4 2014	28	65	23	58	37	138	N/A	N/A	18	53	49	150
Sat, Apr 5 2014	27	88	19	58	22	63	N/A	N/A	25	60	43	271
Sun, Apr 6 2014	19	51	13	43	16	55	N/A	N/A	13	30	21	68
Mon, Apr 7 2014	18	48	20	53	29	106	N/A	N/A	16	40	33	101
Tue, Apr 8 2014	20	52	34	151	51	197	356	1004	27	148	101	484
Wed, Apr 9 2014	35	249	23	66	38	111	N/A	N/A	19	41	49	171
Thu, Apr 10 2014	21	67	17	51	29	163	N/A	N/A	14	32	31	93
Fri, Apr 11 2014	33	115	13	47	31	107	-	-	17	101	33	218
Sat, Apr 12 2014	14	41	13	56	18	68	-	-	8	33	17	59
Sun, Apr 13 2014	18	36	21	43	32	104	-	-	32	145	40	261
Mon, Apr 14 2014	27	72	36	128	63	213	-	-	39	127	117	507
Tue, Apr 15 2014	23	63	22	68	44	142	266	488	22	53	58	220
Wed, Apr 16 2014	18	50	20	73	30	95	148	325	20	67	35	122
Thu, Apr 17 2014	22	55	18	71	26	80	32	137	16	45	33	110
Fri, Apr 18 2014	21	59	15	47	22	78	N/A	N/A	14	53	29	124
Sat, Apr 19 2014	20	48	19	44	29	68	N/A	N/A	19	46	29	89
Sun, Apr 20 2014	19	50	10	31	18	76	-	-	11	34	14	53
Mon, Apr 21 2014	15	44	11	36	15	102	29	124	10	28	22	116
Tue, Apr 22 2014	19	67	20	52	40	270	186	533	21	79	62	245
Wed, Apr 23 2014	19	47	21	53	24	82	158	453	20	46	47	140
Thu, Apr 24 2014	18	45	17	57	28	169	148	315	14	46	49	192
Fri, Apr 25 2014	17	52	20	53	30	125	N/A	N/A	17	38	50	179
Sat, Apr 26 2014	13	43	13	44	20	82	N/A	N/A	12	35	37	168
Sun, Apr 27 2014	14	38	13	36	9	31	-	-	15	44	18	41
Mon, Apr 28 2014	39	192	12	39	8	26	-	-	13	42	20	94
Tue, Apr 29 2014	24	67	20	60	29	96	170	255	16	52	44	169
Wed, Apr 30 2014	20	56	20	43	24	58	206	880	20	38	40	127
Thu, May 1 2014	23	57	23	66	31	119	149	468	19	39	35	133
Fri, May 2 2014	17	54	12	42	10	50	13	50	12	30	21	116
Sat, May 3 2014	13	56	12	36	9	74	21	80	14	54	18	50
Sun, May 4 2014	23	80	17	49	12	35	30	111	19	51	22	49
Mon, May 5 2014	40	169	16	38	13	41	22	109	18	39	22	77
Tue, May 6 2014	35	138	17	51	15	37	22	72	18	62	24	79
Wed, May 7 2014	31	111	21	60	15	38	40	155	22	63	27	79
Thu, May 8 2014	28	93	35	1013	12	36	34	93	23	47	26	80
Fri, May 9 2014	35	130	20	52	9	21	32	104	24	53	30	87
Sat, May 10 2014	19	72	15	45	11	32	27	93	19	70	23	69
Sun, May 11 2014	13	55	10	39	5	26	22	113	9	33	14	49
Mon, May 12 2014	20	58	19	56	23	70	45	188	15	30	53	231
Tue, May 13 2014	23	57	23	59	30	123	57	221	18	35	55	225
Wed, May 14 2014	57	396	17	48	11	42	46	283	21	54	25	82

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Thu, May 15 2014	66	538	14	149	8	34	21	77	14	47	25	101
Fri, May 16 2014	39	134	16	48	16	55	31	134	13	38	31	116
Sat, May 17 2014	19	55	15	42	12	40	27	112	25	111	22	65
Sun, May 18 2014	28	227	16	68	10	37	30	141	17	53	22	91
Mon, May 19 2014	32	152	17	47	13	34	42	217	19	34	22	54
Tue, May 20 2014	33	132	15	52	12	63	31	117	16	41	20	76
Wed, May 21 2014	43	127	19	50	15	38	33	94	21	44	27	85
Thu, May 22 2014	44	183	16	58	11	27	26	80	15	51	27	141
Fri, May 23 2014	53	185	16	37	11	28	33	141	16	36	23	104
Sat, May 24 2014	20	60	14	46	8	37	31	157	14	44	18	59
Sun, May 25 2014	17	51	10	44	4	16	18	62	8	41	12	53
Mon, May 26 2014	12	43	10	37	7	28	19	62	11	30	14	45
Tue, May 27 2014	18	54	13	38	13	70	45	186	12	44	37	153
Wed, May 28 2014	23	57	13	32	17	45	26	94	13	30	23	60
Thu, May 29 2014	25	77	16	78	24	84	35	113	12	49	31	105
Fri, May 30 2014	24	79	17	60	20	84	67	440	13	54	37	113
Sat, May 31 2014	21	164	11	27	8	22	21	61	12	48	17	47
Sun, Jun 1 2014	15	41	10	32	7	22	28	266	12	49	17	56
Mon, Jun 2 2014	39	123	15	46	9	23	34	226	15	38	23	110
Tue, Jun 3 2014	25	69	15	41	12	35	24	92	17	48	22	77
Wed, Jun 4 2014	21	49	16	53	29	141	39	117	14	34	46	175
Thu, Jun 5 2014	N/A	N/A	16	60	13	54	61	392	14	42	30	102
Fri, Jun 6 2014	N/A	N/A	10	40	7	23	26	142	10	32	17	60
Sat, Jun 7 2014	-	-	12	29	8	21	41	286	18	97	19	54
Sun, Jun 8 2014	-	-	10	31	7	23	23	130	14	82	17	44
Mon, Jun 9 2014	-	-	15	46	10	41	31	116	10	40	27	93
Tue, Jun 10 2014	-	-	13	56	15	48	129	901	12	53	32	167
Wed, Jun 11 2014	-	-	13	32	15	38	33	197	16	55	21	66
Thu, Jun 12 2014	-	-	21	53	25	59	141	757	33	383	58	305
Fri, Jun 13 2014	-	-	23	66	32	97	158	710	54	326	80	578
Sat, Jun 14 2014	-	-	16	43	21	51	233	1004	45	280	56	251
Sun, Jun 15 2014	-	-	10	31	14	34	37	152	21	129	22	87
Mon, Jun 16 2014	43	82	20	66	29	92	61	264	22	73	37	131
Tue, Jun 17 2014	18	53	11	57	22	112	26	110	10	29	30	115
Wed, Jun 18 2014	-	-	13	45	23	77	49	189	12	53	50	202
Thu, Jun 19 2014	-	-	16	55	25	87	48	206	14	45	49	247
Fri, Jun 20 2014	-	-	13	47	23	92	49	358	11	38	42	268
Sat, Jun 21 2014	-	-	7	28	9	40	14	50	10	33	14	54
Sun, Jun 22 2014	-	-	7	56	9	33	14	62	8	32	13	64
Mon, Jun 23 2014	-	-	12	45	20	107	38	148	11	36	30	136
Tue, Jun 24 2014	-	-	13	55	14	45	40	215	11	36	26	98
Wed, Jun 25 2014	-	-	13	47	19	98	37	190	12	51	29	207
Thu, Jun 26 2014	-	-	15	46	24	90	45	191	13	46	38	161
Fri, Jun 27 2014	-	-	11	35	14	59	26	160	11	51	20	135
Sat, Jun 28 2014	-	-	9	105	8	33	14	61	9	44	15	63
Sun, Jun 29 2014	-	-	6	21	8	31	15	66	8	47	13	50
Mon, Jun 30 2014	29	67	15	74	29	129	27	136	10	49	37	171
Tue, Jul 1 2014	44	151	11	49	13	51	30	162	12	61	18	73
Wed, Jul 2 2014	23	63	13	52	19	79	24	124	12	52	29	162
Thu, Jul 3 2014	17	58	11	43	18	69	66	925	11	36	32	171
Fri, Jul 4 2014	15	37	9	27	12	35	47	735	11	42	19	59
Sat, Jul 5 2014	13	44	8	32	8	36	18	86	9	36	13	47
Sun, Jul 6 2014	14	40	7	26	9	30	20	93	10	41	15	52
Mon, Jul 7 2014	17	74	10	50	13	57	24	110	11	38	21	119
Tue, Jul 8 2014	21	52	13	51	22	95	30	118	12	41	33	149
Wed, Jul 9 2014	20	67	14	64	26	128	25	90	12	48	35	105
Thu, Jul 10 2014	20	52	17	52	28	108	40	264	14	42	41	173
Fri, Jul 11 2014	20	56	13	40	17	59	27	94	12	43	26	89
Sat, Jul 12 2014	17	52	10	43	13	41	27	198	12	54	20	65
Sun, Jul 13 2014	16	51	9	27	11	30	14	59	12	47	17	56
Mon, Jul 14 2014	16	63	10	42	12	49	23	97	9	38	19	63
Tue, Jul 15 2014	23	60	13	34	17	53	28	129	12	51	39	177
Wed, Jul 16 2014	23	60	14	44	19	122	33	131	13	47	34	163

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Thu, Jul 17 2014	21	56	15	41	16	53	23	89	14	41	23	57
Fri, Jul 18 2014	-	-	-	-	11	36	-	-	-	-	-	-
Sat, Jul 19 2014	-	-	-	-	11	52	-	-	-	-	-	-
Sun, Jul 20 2014	-	-	-	-	8	24	-	-	-	-	-	-
Mon, Jul 21 2014	-	-	-	-	4	10	-	-	-	-	-	-
Tue, Jul 22 2014	-	-	-	-	4	5	-	-	-	-	-	-
Wed, Jul 23 2014	-	-	-	-	3	4	-	-	-	-	-	-
Thu, Jul 24 2014	-	-	-	-	N/A	N/A	-	-	-	-	-	-
Mon, Jul 28 2014	-	-	-	-	3	3	-	-	-	-	-	-
Thu, Jul 31 2014	-	-	-	-	9	29	-	-	-	-	-	-
Fri, Aug 1 2014	-	-	-	-	26	100	-	-	-	-	-	-
Sat, Aug 2 2014	-	-	-	-	13	32	-	-	-	-	-	-
Sun, Aug 3 2014	-	-	-	-	18	34	-	-	-	-	-	-
Mon, Aug 4 2014	-	-	-	-	N/A	N/A	-	-	-	-	-	-
Tue, Aug 5 2014	-	-	-	-	N/A	N/A	-	-	-	-	-	-
Wed, Aug 6 2014	-	-	-	-	N/A	N/A	-	-	-	-	-	-
Mon, Aug 18 2014	22	64	23	74	-	-	169	844	40	182	61	208
Tue, Aug 19 2014	21	74	13	71	11	11	28	115	5	15	32	131
Wed, Aug 20 2014	29	103	20	78	76	195	30	168	29	156	59	294
Thu, Aug 21 2014	25	81	17	78	32	131	25	104	14	90	39	191
Fri, Aug 22 2014	20	60	13	47	22	82	84	1005	8	52	50	276
Sat, Aug 23 2014	14	69	11	31	23	129	24	124	14	39	21	70
Sun, Aug 24 2014	17	62	8	40	20	129	16	82	12	55	17	55
Mon, Aug 25 2014	23	73	17	79	31	137	27	189	15	88	41	170
Tue, Aug 26 2014	21	71	13	45	18	58	32	160	15	47	28	116
Wed, Aug 27 2014	29	78	25	100	36	112	46	164	18	62	52	184
Thu, Aug 28 2014	27	79	14	48	26	81	25	94	14	60	27	90
Fri, Aug 29 2014	31	99	12	49	15	53	18	85	18	115	22	78
Sat, Aug 30 2014	18	48	9	41	11	35	16	71	22	345	18	69
Sun, Aug 31 2014	17	41	11	39	43	634	11	59	13	58	17	70
Mon, Sep 1 2014	18	60	13	48	14	47	18	73	15	55	21	82
Tue, Sep 2 2014	45	147	11	43	14	45	16	67	15	54	21	84
Wed, Sep 3 2014	34	91	18	87	27	119	22	95	5	15	34	118
Thu, Sep 4 2014	32	99	14	59	20	113	26	167	11	58	35	147
Fri, Sep 5 2014	40	112	12	51	17	67	20	98	11	49	34	167
Sat, Sep 6 2014	16	48	7	42	9	38	10	65	9	54	16	70
Sun, Sep 7 2014	17	51	10	39	11	36	14	89	11	45	20	94
Mon, Sep 8 2014	45	137	17	65	26	118	76	793	33	450	65	432
Tue, Sep 9 2014	50	137	14	52	20	77	23	109	42	306	60	526
Wed, Sep 10 2014	41	148	12	57	15	78	16	110	15	60	27	182
Thu, Sep 11 2014	39	94	17	60	29	102	24	139	5	21	46	198
Fri, Sep 12 2014	40	201	11	43	16	75	23	199	13	57	22	90
Sat, Sep 13 2014	18	68	9	42	11	49	10	68	15	115	24	163
Sun, Sep 14 2014	15	55	10	56	11	41	52	365	16	74	37	237
Mon, Sep 15 2014	35	147	12	63	20	113	28	118	12	54	31	135
Tue, Sep 16 2014	30	94	12	74	20	116	19	101	12	64	26	140
Wed, Sep 17 2014	38	136	12	56	15	53	18	87	14	72	22	98
Thu, Sep 18 2014	33	159	10	51	14	68	18	114	12	59	19	102
Fri, Sep 19 2014	40	124	10	66	13	54	18	95	13	53	20	91
Sat, Sep 20 2014	22	151	9	38	10	37	11	75	9	40	16	80
Sun, Sep 21 2014	42	326	11	37	12	43	14	85	13	55	20	94
Mon, Sep 22 2014	23	75	13	50	18	56	23	92	12	39	31	128
Tue, Sep 23 2014	28	100	14	63	27	90	61	348	11	43	52	289
Wed, Sep 24 2014	25	63	13	46	24	83	65	493	12	44	34	123
Thu, Sep 25 2014	23	64	15	53	22	81	38	135	5	22	37	146
Fri, Sep 26 2014	32	135	10	46	16	67	27	106	11	47	31	111
Sat, Sep 27 2014	18	45	12	35	21	160	24	104	14	39	19	75
Sun, Sep 28 2014	12	53	12	55	14	53	22	185	13	54	18	73
Mon, Sep 29 2014	35	135	14	54	16	56	40	206	20	115	28	109
Tue, Sep 30 2014	49	180	12	65	13	47	19	141	16	52	21	83
Wed, Oct 1 2014	30	87	9	45	14	55	17	75	14	73	17	86
Thu, Oct 2 2014	28	121	12	42	19	75	17	90	16	63	22	93
Fri, Oct 3 2014	32	82	20	158	22	98	22	97	11	54	27	124

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Oct 4 2014	28	81	10	46	11	32	23	204	6	44	18	71
Sun, Oct 5 2014	18	45	13	45	15	49	26	80	14	53	22	78
Mon, Oct 6 2014	25	80	14	55	16	52	27	112	18	47	22	73
Tue, Oct 7 2014	42	166	13	40	16	70	21	73	15	48	19	77
Wed, Oct 8 2014	47	258	12	46	15	49	14	76	14	71	28	153
Thu, Oct 9 2014	32	75	9	39	14	45	34	160	9	40	28	111
Fri, Oct 10 2014	24	65	12	53	20	87	31	133	12	45	31	102
Sat, Oct 11 2014	17	72	14	36	17	47	29	91	18	57	21	65
Sun, Oct 12 2014	15	47	13	34	17	40	75	318	18	70	23	68
Mon, Oct 13 2014	16	45	12	41	16	60	65	636	12	38	38	224
Tue, Oct 14 2014	21	69	14	47	16	59	34	244	13	64	23	93
Wed, Oct 15 2014	33	110	14	62	17	59	20	96	17	62	28	114
Thu, Oct 16 2014	31	86	11	33	16	43	23	73	11	34	24	82
Fri, Oct 17 2014	25	111	13	55	18	55	35	136	13	50	26	82
Sat, Oct 18 2014	14	39	9	33	11	34	42	220	10	38	12	52
Sun, Oct 19 2014	8	25	4	19	6	20	10	46	6	26	7	19
Mon, Oct 20 2014	16	53	11	29	13	39	21	64	14	37	20	57
Tue, Oct 21 2014	52	153	13	50	17	66	23	90	14	47	30	168
Wed, Oct 22 2014	35	137	8	42	11	48	20	79	9	42	17	86
Thu, Oct 23 2014	30	100	14	60	22	92	26	85	11	36	26	98
Fri, Oct 24 2014	32	90	14	52	16	64	23	102	13	72	26	129
Sat, Oct 25 2014	22	102	12	56	11	38	18	70	11	43	15	68
Sun, Oct 26 2014	17	44	14	44	15	33	21	55	20	78	20	62
Mon, Oct 27 2014	21	87	14	62	22	90	28	90	13	42	37	195
Tue, Oct 28 2014	26	99	12	48	18	60	28	111	17	146	28	118
Wed, Oct 29 2014	29	103	12	57	21	69	29	121	20	186	30	120
Thu, Oct 30 2014	17	47	14	53	19	63	26	97	11	44	27	116
Fri, Oct 31 2014	17	43	15	50	22	62	42	228	21	103	30	116
Sat, Nov 1 2014	20	80	16	41	N/A	N/A	30	72	19	41	23	69
Sun, Nov 2 2014	19	48	13	46	19	69	29	78	14	50	19	80
Mon, Nov 3 2014	23	123	16	44	24	101	27	109	16	38	26	108
Tue, Nov 4 2014	21	98	22	125	28	95	35	143	18	55	32	117
Wed, Nov 5 2014	18	65	17	67	22	99	33	127	14	35	25	123
Thu, Nov 6 2014	33	164	18	63	N/A	N/A	23	135	17	65	27	96
Fri, Nov 7 2014	26	112	13	54	N/A	N/A	28	145	20	79	27	132
Sat, Nov 8 2014	30	123	16	46	26	86	32	155	17	48	32	237
Sun, Nov 9 2014	17	62	13	50	26	160	23	145	14	45	20	111
Mon, Nov 10 2014	29	94	12	46	17	69	57	288	24	130	27	106
Tue, Nov 11 2014	23	66	10	44	17	61	131	1004	16	71	20	95
Wed, Nov 12 2014	47	178	9	41	N/A	N/A	23	102	12	53	25	101
Thu, Nov 13 2014	60	197	11	45	19	106	25	98	13	54	25	106
Fri, Nov 14 2014	26	65	9	34	12	38	18	85	15	74	16	70
Sat, Nov 15 2014	16	49	9	31	12	37	16	80	10	28	14	52
Sun, Nov 16 2014	22	160	11	27	18	51	17	57	12	36	16	49
Mon, Nov 17 2014	29	81	21	50	54	246	55	266	22	49	40	171
Tue, Nov 18 2014	33	100	21	58	41	125	74	292	20	49	51	182
Wed, Nov 19 2014	42	127	25	71	41	100	90	333	33	140	59	253
Thu, Nov 20 2014	46	144	21	49	32	69	44	134	23	63	33	92
Fri, Nov 21 2014	32	90	16	52	24	73	44	150	19	59	37	153
Sat, Nov 22 2014	28	102	18	56	28	73	31	154	22	50	29	87
Sun, Nov 23 2014	23	60	17	44	20	44	35	150	25	109	28	102
Mon, Nov 24 2014	16	53	9	24	13	30	33	174	19	80	16	45
Tue, Nov 25 2014	26	74	13	47	26	87	175	718	20	63	26	88
Wed, Nov 26 2014	33	155	13	50	29	127	113	558	22	100	49	249
Thu, Nov 27 2014	33	245	13	40	30	114	202	1004	48	757	46	302
Fri, Nov 28 2014	19	63	15	47	39	187	234	1004	27	266	109	703
Sat, Nov 29 2014	19	62	9	30	17	96	36	265	14	73	17	51
Sun, Nov 30 2014	16	48	10	34	13	42	19	123	14	41	17	65
Mon, Dec 1 2014	24	79	12	50	21	83	58	222	11	38	35	145
Tue, Dec 2 2014	23	83	12	57	19	96	63	244	16	74	27	114
Wed, Dec 3 2014	23	151	5	23	7	27	16	83	9	65	9	43
Thu, Dec 4 2014	48	165	8	27	12	48	17	57	14	57	17	63
Fri, Dec 5 2014	51	218	11	50	15	55	20	63	12	38	19	68

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Dec 6 2014	17	43	7	40	11	42	14	74	9	40	18	72
Sun, Dec 7 2014	27	91	9	39	10	33	19	74	11	38	19	69
Mon, Dec 8 2014	68	257	11	47	14	49	23	84	17	77	22	85
Tue, Dec 9 2014	49	238	20	114	29	147	33	74	25	85	31	186
Wed, Dec 10 2014	28	96	17	122	28	153	38	179	16	52	31	204
Thu, Dec 11 2014	33	106	15	45	12	24	37	124	14	39	41	190
Fri, Dec 12 2014	45	179	12	55	19	83	24	117	13	50	23	98
Sat, Dec 13 2014	25	167	10	38	20	70	81	678	12	61	26	125
Sun, Dec 14 2014	22	62	9	38	19	90	43	206	11	35	21	81
Mon, Dec 15 2014	36	79	14	51	30	132	73	954	13	52	34	148
Tue, Dec 16 2014	48	261	15	51	21	78	46	271	15	90	26	109
Wed, Dec 17 2014	48	169	12	37	17	49	28	187	17	90	23	75
Thu, Dec 18 2014	50	193	9	37	17	66	23	70	11	46	18	75
Fri, Dec 19 2014	52	235	14	45	19	54	28	94	13	41	12	42
Sat, Dec 20 2014	43	215	16	52	19	92	31	114	20	63	12	48
Sun, Dec 21 2014	26	87	15	43	17	45	32	105	20	60	17	209
Mon, Dec 22 2014	40	206	9	27	10	23	28	96	10	76	13	38
Tue, Dec 23 2014	39	154	14	41	30	90	160	904	17	63	57	346
Wed, Dec 24 2014	22	103	9	36	13	69	21	68	10	37	10	48
Thu, Dec 25 2014	20	56	7	33	10	33	23	189	11	39	8	41
Fri, Dec 26 2014	30	136	11	40	12	40	18	59	15	46	18	147
Sat, Dec 27 2014	22	74	17	46	18	56	31	120	19	59	18	126
Sun, Dec 28 2014	22	70	23	50	23	48	39	92	25	67	18	54
Mon, Dec 29 2014	43	206	21	63	25	70	72	829	22	48	29	99
Tue, Dec 30 2014	34	113	16	54	18	71	56	445	20	66	10	46
Wed, Dec 31 2014	30	252	15	42	17	51	22	65	24	72	13	85
Thu, Jan 1 2015	26	67	14	44	15	42	33	145	16	52	10	39
Fri, Jan 2 2015	37	135	13	45	15	65	39	363	12	39	35	409
Sat, Jan 3 2015	21	137	9	31	10	30	13	62	10	38	8	67
Sun, Jan 4 2015	28	210	12	40	14	58	17	57	14	52	7	24
Mon, Jan 5 2015	40	197	16	42	18	47	35	130	18	43	15	78
Tue, Jan 6 2015	34	153	19	35	24	62	35	163	21	45	15	40
Wed, Jan 7 2015	33	90	23	60	31	111	51	146	24	73	34	97
Thu, Jan 8 2015	41	169	16	45	18	44	37	116	19	49	34	141
Fri, Jan 9 2015	62	240	11	33	14	39	49	201	16	44	26	113
Sat, Jan 10 2015	17	77	10	55	11	36	22	82	13	40	19	71
Sun, Jan 11 2015	17	59	9	39	12	64	20	107	11	36	21	90
Mon, Jan 12 2015	47	155	9	51	11	35	16	71	13	39	19	82
Tue, Jan 13 2015	96	384	11	46	14	40	21	92	20	83	20	85
Wed, Jan 14 2015	33	154	16	52	17	48	30	96	19	46	22	72
Thu, Jan 15 2015	41	194	15	40	16	32	36	98	19	55	20	52
Fri, Jan 16 2015	22	107	7	42	8	32	18	85	10	32	14	76
Sat, Jan 17 2015	23	119	10	41	12	39	19	69	12	34	20	185
Sun, Jan 18 2015	28	67	13	48	14	38	23	83	15	45	43	1011
Mon, Jan 19 2015	24	71	12	37	14	35	26	73	15	42	29	366
Tue, Jan 20 2015	82	328	16	62	19	98	26	79	19	51	28	134
Wed, Jan 21 2015	92	301	12	33	14	53	30	142	24	209	22	77
Thu, Jan 22 2015	75	268	13	46	15	46	25	63	45	268	21	97
Fri, Jan 23 2015	60	249	8	54	10	34	26	121	12	34	15	82
Sat, Jan 24 2015	16	66	5	21	8	27	11	86	7	20	12	52
Sun, Jan 25 2015	14	47	5	21	11	37	14	50	6	28	13	52
Mon, Jan 26 2015	35	109	14	60	29	154	29	95	13	38	32	116
Tue, Jan 27 2015	36	146	12	45	15	48	19	58	13	37	18	82
Wed, Jan 28 2015	53	240	13	49	18	63	32	99	18	46	29	210
Thu, Jan 29 2015	36	97	14	62	15	46	30	205	19	45	17	65
Fri, Jan 30 2015	49	192	10	33	14	56	18	65	13	54	22	93
Sat, Jan 31 2015	23	52	12	42	14	46	26	77	14	45	39	118
Sun, Feb 1 2015	16	51	10	37	11	37	49	419	21	131	23	124
Mon, Feb 2 2015	57	236	17	46	18	40	44	140	20	47	24	88
Tue, Feb 3 2015	25	90	16	41	18	46	68	224	21	42	28	671
Wed, Feb 4 2015	49	195	15	40	15	41	44	433	20	57	28	174
Thu, Feb 5 2015	31	115	16	46	18	44	23	63	30	87	22	62
Fri, Feb 6 2015	25	91	16	36	N/A	N/A	24	172	32	137	22	69

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³
Sat, Feb 7 2015	25	64	20	43	N/A	N/A	28	68	25	57	29	79
Sun, Feb 8 2015	23	64	18	49	N/A	N/A	35	138	21	54	28	91
Mon, Feb 9 2015	75	537	16	47	N/A	N/A	127	764	22	138	190	1013
Tue, Feb 10 2015	27	76	19	41	N/A	N/A	27	98	37	121	24	74
Wed, Feb 11 2015	26	67	20	45	23	66	27	59	30	75	26	124
Thu, Feb 12 2015	47	192	20	50	20	55	27	80	20	49	26	77
Fri, Feb 13 2015	41	137	17	49	17	37	66	540	19	46	24	54
Sat, Feb 14 2015	20	55	15	37	16	37	35	194	16	32	28	738
Sun, Feb 15 2015	31	81	27	60	N/A	N/A	37	74	26	64	14	15
Mon, Feb 16 2015	27	69	24	63	N/A	N/A	40	102	25	53	N/A	N/A
Tue, Feb 17 2015	38	137	21	54	30	140	46	137	22	57	50	1012
Wed, Feb 18 2015	51	240	22	53	24	69	42	108	25	49	30	87
Thu, Feb 19 2015	57	216	20	60	21	52	46	287	22	55	28	130
Fri, Feb 20 2015	16	70	10	26	12	41	33	152	11	28	38	1011
Sat, Feb 21 2015	21	54	15	39	16	44	24	71	17	40	13	49
Sun, Feb 22 2015	28	76	15	43	16	41	60	353	17	49	13	46
Mon, Feb 23 2015	54	275	19	53	24	87	34	93	36	106	29	104
Tue, Feb 24 2015	38	129	19	68	24	69	44	156	N/A	N/A	30	101
Wed, Feb 25 2015	39	116	23	60	29	77	46	166	34	117	41	632
Thu, Feb 26 2015	60	235	12	51	14	48	35	122	19	161	12	47
Fri, Feb 27 2015	35	181	9	58	16	76	27	139	12	60	19	106
Sat, Feb 28 2015	23	130	8	43	32	285	33	142	9	30	6	24
Sun, Mar 1 2015	22	54	10	33	14	53	40	388	11	31	8	38
Mon, Mar 2 2015	35	109	12	50	18	83	33	184	14	59	27	109
Tue, Mar 3 2015	28	71	12	46	19	86	69	793	8	35	24	113
Wed, Mar 4 2015	21	56	9	30	13	45	40	249	11	31	29	170
Thu, Mar 5 2015	19	47	9	30	23	145	52	234	9	28	39	184
Fri, Mar 6 2015	76	512	12	35	34	138	102	402	13	36	30	153
Sat, Mar 7 2015	20	63	12	37	17	41	60	333	13	33	8	26
Sun, Mar 8 2015	17	49	9	35	13	35	32	220	11	29	6	25
Mon, Mar 9 2015	37	186	11	28	17	121	21	119	11	42	10	41
Tue, Mar 10 2015	46	269	13	43	24	118	36	206	14	44	38	450
Wed, Mar 11 2015	32	142	12	137	19	284	24	198	14	54	27	233
Thu, Mar 12 2015	27	92	10	41	12	42	21	74	25	181	12	47
Fri, Mar 13 2015	43	171	13	29	36	103	238	1003	21	267	161	1011
Sat, Mar 14 2015	22	64	14	50	22	87	39	161	14	40	35	160
Sun, Mar 15 2015	18	56	10	41	9	18	18	62	19	114	17	76
Mon, Mar 16 2015	60	204	12	38	21	106	82	655	24	74	20	103
Tue, Mar 17 2015	53	217	14	48	16	49	33	92	27	161	34	146
Wed, Mar 18 2015	64	281	18	57	22	97	34	79	20	58	31	133
Thu, Mar 19 2015	30	89	15	70	25	110	62	321	17	88	36	159
Fri, Mar 20 2015	30	165	12	54	6	15	68	1004	11	40	103	1012
Sat, Mar 21 2015	16	56	10	54	16	297	30	114	11	31	19	58
Sun, Mar 22 2015	24	61	15	44	17	43	26	75	17	47	21	75
Mon, Mar 23 2015	36	138	16	50	21	54	35	156	19	64	29	98
Tue, Mar 24 2015	45	192	17	49	20	62	34	100	26	87	78	1013
Wed, Mar 25 2015	29	100	13	57	30	177	29	156	13	69	23	131
Thu, Mar 26 2015	25	59	16	47	28	104	38	91	17	43	23	90
Fri, Mar 27 2015	40	136	26	68	37	116	39	90	23	53	37	120
Sat, Mar 28 2015	21	60	13	46	15	48	51	237	15	48	24	286
Sun, Mar 29 2015	22	129	9	34	11	37	22	172	10	37	11	64
Mon, Mar 30 2015	32	121	15	57	22	155	35	278	13	38	29	119
Tue, Mar 31 2015	37	153	9	51	12	52	19	187	12	50	19	86
Wed, Apr 1 2015	35	105	16	48	21	146	28	73	16	48	24	87
Thu, Apr 2 2015	40	98	19	48	25	65	33	77	20	51	29	96
Fri, Apr 3 2015	39	264	21	51	25	90	33	109	25	71	30	123
Sat, Apr 4 2015	24	54	15	47	19	53	44	498	26	183	25	96
Sun, Apr 5 2015	23	59	17	41	20	47	27	105	N/A	N/A	23	68
Mon, Apr 6 2015	27	71	27	176	54	244	54	181	N/A	N/A	53	204
Tue, Apr 7 2015	19	66	17	70	35	211	65	310	N/A	N/A	53	260
Wed, Apr 8 2015	23	60	26	90	57	321	190	1004	N/A	N/A	124	1012
Thu, Apr 9 2015	27	61	29	81	47	158	65	310	N/A	N/A	64	304
Fri, Apr 10 2015	34	92	21	74	32	87	45	296	N/A	N/A	46	345

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Apr 11 2015	24	79	15	40	19	41	38	103	N/A	N/A	25	85
Sun, Apr 12 2015	17	43	9	37	13	58	44	350	N/A	N/A	18	67
Mon, Apr 13 2015	57	600	24	96	42	140	69	412	N/A	N/A	55	240
Tue, Apr 14 2015	24	89	17	60	39	170	53	259	N/A	N/A	49	137
Wed, Apr 15 2015	26	66	20	73	49	239	45	144	N/A	N/A	54	221
Thu, Apr 16 2015	28	111	21	81	36	136	56	171	N/A	N/A	49	176
Fri, Apr 17 2015	29	98	22	77	38	152	62	330	N/A	N/A	69	382
Sat, Apr 18 2015	22	62	18	42	31	86	110	622	N/A	N/A	46	350
Sun, Apr 19 2015	65	1004	16	42	30	93	99	715	N/A	N/A	67	284
Mon, Apr 20 2015	44	326	30	95	58	208	143	1004	N/A	N/A	70	325
Tue, Apr 21 2015	23	63	22	72	30	106	54	413	N/A	N/A	34	162
Wed, Apr 22 2015	35	130	19	57	24	91	36	154	N/A	N/A	35	212
Thu, Apr 23 2015	59	179	23	59	26	59	52	211	N/A	N/A	32	89
Fri, Apr 24 2015	57	230	27	63	31	97	54	176	N/A	N/A	35	103
Sat, Apr 25 2015	27	71	21	45	23	49	48	140	N/A	N/A	27	74
Sun, Apr 26 2015	17	56	10	43	14	49	29	175	N/A	N/A	13	65
Mon, Apr 27 2015	30	90	19	69	65	356	76	286	N/A	N/A	63	327
Tue, Apr 28 2015	21	61	17	84	25	91	33	112	N/A	N/A	26	85
Wed, Apr 29 2015	29	89	22	66	48	158	54	251	N/A	N/A	54	328
Thu, Apr 30 2015	32	104	24	63	35	109	45	125	N/A	N/A	41	138
Fri, May 1 2015	27	91	19	60	30	111	44	202	N/A	N/A	22	170
Sat, May 2 2015	24	85	18	65	22	62	34	95	N/A	N/A	11	33
Sun, May 3 2015	24	109	17	43	16	17	40	160	N/A	N/A	11	29
Mon, May 4 2015	23	66	22	63	N/A	N/A	62	191	N/A	N/A	18	79
Tue, May 5 2015	28	78	32	118	27	273	50	141	N/A	N/A	28	124
Wed, May 6 2015	26	85	19	61	N/A	N/A	37	186	N/A	N/A	19	99
Thu, May 7 2015	27	107	21	131	N/A	N/A	54	194	N/A	N/A	32	152
Fri, May 8 2015	18	72	13	47	N/A	N/A	37	135	N/A	N/A	20	83
Sat, May 9 2015	24	79	21	58	N/A	N/A	68	965	N/A	N/A	32	154
Sun, May 10 2015	20	65	17	41	N/A	N/A	31	110	N/A	N/A	15	37
Mon, May 11 2015	27	94	26	112	N/A	N/A	51	167	N/A	N/A	33	125
Tue, May 12 2015	26	72	24	105	N/A	N/A	45	193	N/A	N/A	38	163
Wed, May 13 2015	30	77	26	80	N/A	N/A	69	273	N/A	N/A	37	155
Thu, May 14 2015	23	71	14	44	22	86	30	133	N/A	N/A	16	67
Fri, May 15 2015	35	153	16	53	27	76	45	196	N/A	N/A	33	350
Sat, May 16 2015	34	140	17	79	26	99	30	89	N/A	N/A	4	4
Sun, May 17 2015	27	71	14	49	17	47	28	199	N/A	N/A	N/A	N/A
Mon, May 18 2015	47	125	30	103	57	241	91	658	N/A	N/A	331	411
Tue, May 19 2015	39	187	24	53	30	62	98	710	N/A	N/A	N/A	N/A
Wed, May 20 2015	33	99	13	44	18	56	24	82	N/A	N/A	517	517
Thu, May 21 2015	79	335	14	49	20	84	30	96	N/A	N/A	N/A	N/A
Fri, May 22 2015	43	127	12	50	16	62	24	81	N/A	N/A	N/A	N/A
Sat, May 23 2015	23	93	18	45	29	83	43	189	N/A	N/A	N/A	N/A
Sun, May 24 2015	28	111	16	73	18	43	26	129	N/A	N/A	N/A	N/A
Mon, May 25 2015	25	71	12	37	14	45	22	75	N/A	N/A	N/A	N/A
Tue, May 26 2015	33	123	12	55	19	87	26	131	N/A	N/A	1013	1013
Wed, May 27 2015	57	202	10	43	14	81	54	291	N/A	N/A	86	1013
Thu, May 28 2015	44	126	8	53	14	57	65	701	N/A	N/A	28	167
Fri, May 29 2015	46	135	10	56	14	117	21	78	N/A	N/A	10	52
Sat, May 30 2015	21	81	9	36	12	42	21	94	N/A	N/A	17	104
Sun, May 31 2015	20	115	8	45	11	78	16	57	N/A	N/A	6	22
Mon, Jun 1 2015	21	75	20	77	30	103	30	96	N/A	N/A	24	86
Tue, Jun 2 2015	33	121	23	87	38	143	30	86	N/A	N/A	28	127
Wed, Jun 3 2015	36	148	18	82	31	126	26	105	N/A	N/A	18	63
Thu, Jun 4 2015	38	96	13	49	19	53	23	79	N/A	N/A	13	64
Fri, Jun 5 2015	41	139	14	43	17	80	25	79	N/A	N/A	11	40
Sat, Jun 6 2015	28	114	19	85	14	53	21	107	N/A	N/A	10	34
Sun, Jun 7 2015	19	47	25	72	18	65	21	101	N/A	N/A	15	43
Mon, Jun 8 2015	27	73	27	86	25	88	29	122	N/A	N/A	37	131
Tue, Jun 9 2015	27	102	26	91	35	113	148	833	N/A	N/A	63	204
Wed, Jun 10 2015	21	71	18	81	25	80	36	143	N/A	N/A	35	140
Thu, Jun 11 2015	28	107	11	52	13	47	25	80	N/A	N/A	20	71
Fri, Jun 12 2015	36	101	14	54	17	111	22	104	N/A	N/A	9	46

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Jun 13 2015	20	72	20	83	12	44	50	946	N/A	N/A	12	43
Sun, Jun 14 2015	19	104	18	64	10	35	18	63	N/A	N/A	15	60
Mon, Jun 15 2015	27	78	19	70	17	60	32	242	N/A	N/A	11	100
Tue, Jun 16 2015	25	61	25	80	23	83	36	129	N/A	N/A	30	130
Wed, Jun 17 2015	24	66	34	206	44	189	30	118	N/A	N/A	31	138
Thu, Jun 18 2015	26	57	23	73	34	140	34	166	N/A	N/A	36	155
Fri, Jun 19 2015	27	91	20	73	22	71	27	84	N/A	N/A	28	93
Sat, Jun 20 2015	17	60	13	40	15	50	18	67	N/A	N/A	19	65
Sun, Jun 21 2015	24	85	17	65	10	34	15	50	N/A	N/A	15	51
Mon, Jun 22 2015	30	107	22	85	28	120	30	101	N/A	N/A	31	105
Tue, Jun 23 2015	30	80	20	104	29	158	31	119	N/A	N/A	21	166
Wed, Jun 24 2015	34	247	13	70	23	100	29	149	N/A	N/A	12	56
Thu, Jun 25 2015	25	75	25	96	30	98	30	90	N/A	N/A	25	76
Fri, Jun 26 2015	22	63	17	73	28	103	32	128	N/A	N/A	23	85
Sat, Jun 27 2015	28	86	24	75	17	55	49	566	N/A	N/A	14	144
Sun, Jun 28 2015	21	59	39	136	16	55	50	233	N/A	N/A	14	61
Mon, Jun 29 2015	43	100	47	145	15	42	23	77	N/A	N/A	12	47
Tue, Jun 30 2015	44	147	80	259	19	70	33	95	N/A	N/A	15	45
Wed, Jul 1 2015	54	154	110	347	16	48	25	82	N/A	N/A	17	57
Thu, Jul 2 2015	59	166	71	186	19	51	24	84	N/A	N/A	25	88
Fri, Jul 3 2015	22	65	47	141	21	55	35	150	N/A	N/A	19	59
Sat, Jul 4 2015	22	68	44	154	18	66	39	344	N/A	N/A	12	39
Sun, Jul 5 2015	26	88	35	117	30	464	85	488	N/A	N/A	8	26
Mon, Jul 6 2015	29	111	41	181	106	740	115	587	N/A	N/A	80	301
Tue, Jul 7 2015	31	107	25	101	37	175	70	312	N/A	N/A	63	397
Wed, Jul 8 2015	28	79	22	72	31	114	31	129	N/A	N/A	27	105
Thu, Jul 9 2015	23	51	25	133	42	152	36	107	N/A	N/A	28	128
Fri, Jul 10 2015	18	56	12	56	31	247	24	85	N/A	N/A	15	52
Sat, Jul 11 2015	20	98	6	33	9	34	13	56	N/A	N/A	7	23
Sun, Jul 12 2015	19	66	8	41	9	39	15	71	N/A	N/A	7	22
Mon, Jul 13 2015	27	77	12	49	13	41	31	126	N/A	N/A	13	53
Tue, Jul 14 2015	27	72	16	73	29	166	32	133	N/A	N/A	25	145
Wed, Jul 15 2015	29	74	19	66	24	81	27	83	N/A	N/A	18	80
Thu, Jul 16 2015	32	99	14	51	17	59	26	130	N/A	N/A	11	45
Fri, Jul 17 2015	33	107	15	77	19	71	33	239	N/A	N/A	18	84
Sat, Jul 18 2015	21	71	11	32	15	40	22	69	N/A	N/A	9	26
Sun, Jul 19 2015	25	84	12	47	18	49	26	92	N/A	N/A	9	40
Mon, Jul 20 2015	28	89	16	61	25	93	61	440	N/A	N/A	12	48
Tue, Jul 21 2015	39	108	16	58	25	79	54	295	N/A	N/A	17	71
Wed, Jul 22 2015	34	97	14	60	16	75	21	71	N/A	N/A	12	42
Thu, Jul 23 2015	32	77	20	75	27	100	82	649	N/A	N/A	44	190
Fri, Jul 24 2015	38	99	19	75	27	96	112	824	N/A	N/A	34	169
Sat, Jul 25 2015	31	89	16	60	19	59	80	467	N/A	N/A	39	202
Sun, Jul 26 2015	28	93	13	46	17	55	14	56	N/A	N/A	13	27
Mon, Jul 27 2015	33	107	22	74	27	88	38	270	N/A	N/A	118	465
Tue, Jul 28 2015	46	153	29	86	48	449	29	97	N/A	N/A	39	103
Wed, Jul 29 2015	28	94	34	105	47	168	59	326	N/A	N/A	80	177
Thu, Jul 30 2015	27	77	30	116	52	352	112	995	N/A	N/A	67	125
Fri, Jul 31 2015	35	137	31	121	68	287	64	371	N/A	N/A	198	695
Sat, Aug 1 2015	31	111	26	98	59	220	176	1005	N/A	N/A	378	1013
Sun, Aug 2 2015	30	89	21	55	30	79	84	304	N/A	N/A	40	93
Mon, Aug 3 2015	45	153	25	57	31	76	98	335	N/A	N/A	57	121
Tue, Aug 4 2015	58	211	22	81	28	131	108	588	N/A	N/A	40	168
Wed, Aug 5 2015	28	66	17	64	30	110	70	485	4	4	53	140
Thu, Aug 6 2015	30	82	31	108	46	166	128	903	4	4	112	306
Fri, Aug 7 2015	45	130	21	49	24	49	41	113	N/A	N/A	13	53
Sat, Aug 8 2015	32	123	29	96	49	182	56	208	N/A	N/A	134	354
Sun, Aug 9 2015	29	169	10	39	13	40	21	63	N/A	N/A	20	53
Mon, Aug 10 2015	29	125	24	134	49	229	70	290	N/A	N/A	55	202
Tue, Aug 11 2015	29	76	22	108	35	176	36	197	N/A	N/A	39	130
Wed, Aug 12 2015	31	98	24	96	39	215	44	252	N/A	N/A	64	363
Thu, Aug 13 2015	26	63	20	79	47	197	111	826	N/A	N/A	66	145
Fri, Aug 14 2015	28	75	29	119	49	175	43	143	N/A	N/A	67	136

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Aug 15 2015	22	74	13	46	22	67	22	107	N/A	N/A	23	51
Sun, Aug 16 2015	29	129	13	44	21	84	31	229	N/A	N/A	44	106
Mon, Aug 17 2015	37	98	11	61	19	120	26	129	N/A	N/A	15	54
Tue, Aug 18 2015	47	151	13	51	29	91	23	87	N/A	N/A	24	57
Wed, Aug 19 2015	70	280	12	43	25	71	23	112	N/A	N/A	20	41
Thu, Aug 20 2015	66	222	13	53	19	68	19	81	N/A	N/A	21	63
Fri, Aug 21 2015	35	105	17	60	40	97	26	76	N/A	N/A	50	137
Sat, Aug 22 2015	31	104	18	52	31	101	54	340	N/A	N/A	38	108
Sun, Aug 23 2015	21	64	14	43	17	52	40	179	N/A	N/A	18	93
Mon, Aug 24 2015	36	476	8	28	9	26	23	108	N/A	N/A	7	27
Tue, Aug 25 2015	26	71	11	44	12	44	45	251	N/A	N/A	10	36
Wed, Aug 26 2015	27	80	9	57	11	45	29	208	N/A	N/A	8	19
Thu, Aug 27 2015	36	129	10	44	18	81	18	71	N/A	N/A	9	27
Fri, Aug 28 2015	37	178	12	49	38	125	21	80	N/A	N/A	18	105
Sat, Aug 29 2015	28	135	10	40	51	213	18	79	N/A	N/A	21	62
Sun, Aug 30 2015	23	88	10	36	28	120	21	60	N/A	N/A	26	59
Mon, Aug 31 2015	34	167	10	43	16	65	35	215	N/A	N/A	22	66
Tue, Sep 1 2015	25	84	12	36	31	83	31	74	N/A	N/A	32	86
Wed, Sep 2 2015	55	164	18	69	25	63	37	118	N/A	N/A	25	62
Thu, Sep 3 2015	27	75	9	45	11	42	28	103	N/A	N/A	5	14
Fri, Sep 4 2015	-	-	18	81	37	245	41	257	N/A	N/A	12	49
Sat, Sep 5 2015	-	-	15	52	36	145	31	92	N/A	N/A	14	56
Sun, Sep 6 2015	-	-	14	42	27	107	29	99	N/A	N/A	14	30
Mon, Sep 7 2015	-	-	16	85	21	77	35	139	N/A	N/A	14	40
Tue, Sep 8 2015	-	-	15	41	23	62	30	109	N/A	N/A	23	50
Wed, Sep 9 2015	-	-	12	48	17	53	28	115	N/A	N/A	16	48
Thu, Sep 10 2015	-	-	9	54	11	47	30	121	N/A	N/A	7	23
Fri, Sep 11 2015	-	-	11	37	12	39	34	139	N/A	N/A	5	15
Sat, Sep 12 2015	-	-	11	46	17	57	26	70	N/A	N/A	13	57
Sun, Sep 13 2015	-	-	11	53	18	250	31	215	N/A	N/A	6	19
Mon, Sep 14 2015	-	-	15	63	32	221	47	219	N/A	N/A	25	108
Tue, Sep 15 2015	-	-	10	46	21	126	25	135	N/A	N/A	22	80
Wed, Sep 16 2015	-	-	16	68	39	171	52	246	24	69	61	255
Thu, Sep 17 2015	-	-	14	58	36	182	51	371	18	134	45	107
Fri, Sep 18 2015	-	-	21	67	40	169	63	268	29	228	49	133
Sat, Sep 19 2015	-	-	17	45	25	90	36	125	35	180	37	83
Sun, Sep 20 2015	-	-	17	43	21	45	29	77	40	288	28	86
Mon, Sep 21 2015	-	-	24	140	33	127	46	178	31	269	69	209
Tue, Sep 22 2015	-	-	22	68	25	75	46	355	32	162	47	110
Wed, Sep 23 2015	-	-	14	56	21	118	55	476	20	94	59	192
Thu, Sep 24 2015	-	-	15	61	22	75	46	268	20	82	46	128
Fri, Sep 25 2015	-	-	25	204	33	183	66	267	30	141	104	312
Sat, Sep 26 2015	-	-	14	48	20	51	36	284	39	346	47	138
Sun, Sep 27 2015	-	-	8	28	11	31	20	175	24	138	10	36
Mon, Sep 28 2015	-	-	20	74	47	206	49	186	33	229	47	103
Tue, Sep 29 2015	-	-	25	98	30	136	70	280	48	322	79	192
Wed, Sep 30 2015	-	-	22	90	29	194	103	738	37	441	44	114
Thu, Oct 1 2015	-	-	14	47	22	94	70	278	21	182	85	228
Fri, Oct 2 2015	-	-	21	139	27	104	92	432	18	45	55	120
Sat, Oct 3 2015	-	-	14	44	18	48	53	268	26	181	34	75
Sun, Oct 4 2015	-	-	8	27	12	36	22	91	27	181	12	53
Mon, Oct 5 2015	-	-	7	30	18	120	36	226	15	82	39	281
Tue, Oct 6 2015	-	-	14	41	34	140	N/A	N/A	36	318	117	641
Wed, Oct 7 2015	-	-	15	41	35	204	N/A	N/A	28	193	87	331
Thu, Oct 8 2015	-	-	13	59	16	61	N/A	N/A	24	104	26	82
Fri, Oct 9 2015	-	-	17	57	25	85	-	-	26	53	44	125
Sat, Oct 10 2015	-	-	19	53	23	57	-	-	32	138	53	255
Sun, Oct 11 2015	-	-	12	45	15	48	-	-	22	115	35	93
Mon, Oct 12 2015	-	-	9	53	11	45	-	-	27	144	6	31
Tue, Oct 13 2015	-	-	8	30	15	61	-	-	14	54	19	41
Wed, Oct 14 2015	-	-	7	45	14	58	-	-	13	59	15	57
Thu, Oct 15 2015	-	-	7	33	14	94	-	-	16	82	15	54
Fri, Oct 16 2015	-	-	13	47	26	131	N/A	N/A	17	98	67	147

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Oct 17 2015	-	-	10	46	15	76	N/A	N/A	38	367	35	109
Sun, Oct 18 2015	-	-	-	-	-	-	N/A	N/A	24	219	36	76
Mon, Oct 19 2015	-	-	-	-	-	-	-	-	24	182	65	126
Tue, Oct 20 2015	-	-	-	-	-	-	-	-	25	148	42	330
Wed, Oct 21 2015	-	-	-	-	-	-	-	-	28	135	38	69
Thu, Oct 22 2015	-	-	-	-	-	-	-	-	25	154	63	156
Fri, Oct 23 2015	-	-	-	-	-	-	-	-	21	165	36	83
Sat, Oct 24 2015	-	-	-	-	-	-	-	-	19	155	39	86
Sun, Oct 25 2015	-	-	-	-	-	-	-	-	41	348	36	78
Mon, Oct 26 2015	-	-	-	-	-	-	-	-	52	294	28	71
Tue, Oct 27 2015	-	-	-	-	-	-	-	-	24	222	105	227
Wed, Oct 28 2015	-	-	-	-	-	-	-	-	44	233	144	302
Thu, Oct 29 2015	-	-	-	-	-	-	-	-	48	362	47	107
Fri, Oct 30 2015	-	-	-	-	-	-	-	-	43	216	40	84
Sat, Oct 31 2015	-	-	-	-	-	-	-	-	25	169	21	58
Sun, Nov 1 2015	-	-	6	7	-	-	-	-	27	120	27	89
Tue, Nov 3 2015	-	-	2	3	-	-	-	-	46	333	37	62
Wed, Nov 4 2015	-	-	11	14	-	-	-	-	70	455	46	105
Tue, Nov 10 2015	-	-	44	76	-	-	-	-	45	452	104	358
Sun, Nov 15 2015	-	-	17	18	-	-	-	-	38	256	50	209
Mon, Nov 16 2015	-	-	10	12	-	-	-	-	49	803	59	163
Tue, Nov 17 2015	-	-	1	2	-	-	-	-	30	169	17	65
Wed, Nov 18 2015	-	-	1	1	-	-	-	-	45	521	15	67
Thu, Nov 19 2015	-	-	12	16	-	-	-	-	54	526	33	77
Tue, Nov 10 2015	-	-	-	-	-	-	-	-	34	101	62	110
Wed, Nov 11 2015	-	-	-	-	-	-	-	-	48	401	95	657
Thu, Nov 12 2015	-	-	-	-	-	-	-	-	40	201	62	107
Fri, Nov 13 2015	-	-	-	-	-	-	-	-	50	383	28	98
Sat, Nov 14 2015	-	-	-	-	-	-	-	-	30	508	25	65
Sun, Nov 15 2015	-	-	-	-	-	-	-	-	37	199	19	40
Mon, Nov 16 2015	-	-	-	-	-	-	-	-	38	125	39	74
Tue, Nov 17 2015	-	-	-	-	-	-	-	-	47	399	63	140
Wed, Nov 18 2015	-	-	-	-	-	-	-	-	40	281	71	350
Thu, Nov 19 2015	-	-	-	-	-	-	-	-	73	695	22	58
Fri, Nov 20 2015	-	-	-	-	-	-	-	-	50	309	4	5
Sat, Nov 21 2015	-	-	-	-	-	-	-	-	57	285	5	6
Sun, Nov 22 2015	-	-	-	-	-	-	-	-	68	296	5	8
Mon, Nov 23 2015	-	-	-	-	-	-	-	-	37	244	5	7
Tue, Nov 24 2015	-	-	-	-	-	-	-	-	17	86	9	29
Wed, Nov 25 2015	-	-	-	-	-	-	-	-	17	63	13	41
Thu, Nov 26 2015	-	-	-	-	-	-	-	-	26	139	4	6
Fri, Nov 27 2015	-	-	-	-	-	-	-	-	36	198	12	47
Sat, Nov 28 2015	-	-	-	-	-	-	-	-	38	569	14	60
Sun, Nov 29 2015	-	-	-	-	-	-	-	-	35	201	7	15
Mon, Nov 30 2015	-	-	-	-	-	-	-	-	41	292	22	60
Tue, Dec 1 2015	-	-	-	-	-	-	-	-	38	295	41	102
Wed, Dec 2 2015	-	-	-	-	-	-	-	-	34	177	19	84
Thu, Dec 3 2015	-	-	-	-	-	-	-	-	27	261	37	144
Fri, Dec 4 2015	-	-	-	-	-	-	-	-	23	151	47	151
Sat, Dec 5 2015	-	-	-	-	-	-	-	-	30	152	27	93
Sun, Dec 6 2015	-	-	6	11	-	-	-	-	23	199	30	151
Mon, Dec 7 2015	-	-	N/A	N/A	-	-	-	-	29	99	30	104
Tue, Dec 8 2015	-	-	-	-	-	-	-	-	22	229	32	94
Wed, Dec 9 2015	-	-	-	-	-	-	-	-	21	281	67	115
Thu, Dec 10 2015	-	-	N/A	N/A	-	-	-	-	40	241	48	96
Fri, Dec 11 2015	-	-	N/A	N/A	-	-	-	-	43	238	28	60
Sat, Dec 12 2015	-	-	N/A	N/A	-	-	-	-	48	309	20	57
Sun, Dec 13 2015	-	-	N/A	N/A	-	-	-	-	45	287	21	55
Mon, Dec 14 2015	-	-	N/A	N/A	-	-	-	-	34	204	22	78
Tue, Dec 15 2015	-	-	N/A	N/A	-	-	-	-	44	394	45	102
Wed, Dec 16 2015	-	-	N/A	N/A	-	-	-	-	46	439	65	251
Thu, Dec 17 2015	-	-	N/A	N/A	-	-	-	-	40	274	22	121
Fri, Dec 18 2015	-	-	N/A	N/A	-	-	-	-	46	328	14	44

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Dec 19 2015	-	-	N/A	N/A	-	-	-	-	64	474	53	160
Sun, Dec 20 2015	-	-	-	-	-	-	-	-	59	782	277	1012
Mon, Dec 21 2015	-	-	-	-	-	-	-	-	48	699	38	96
Tue, Dec 22 2015	-	-	-	-	-	-	-	-	51	395	32	84
Wed, Dec 23 2015	-	-	N/A	N/A	-	-	-	-	41	250	31	67
Thu, Dec 24 2015	-	-	N/A	N/A	-	-	-	-	31	243	16	48
Fri, Dec 25 2015	-	-	N/A	N/A	-	-	-	-	27	179	15	46
Sat, Dec 26 2015	-	-	N/A	N/A	-	-	-	-	54	486	12	40
Sun, Dec 27 2015	-	-	N/A	N/A	-	-	-	-	39	341	11	27
Mon, Dec 28 2015	-	-	N/A	N/A	-	-	-	-	38	182	15	37
Tue, Dec 29 2015	-	-	N/A	N/A	-	-	-	-	50	273	N/A	N/A
Wed, Dec 30 2015	-	-	N/A	N/A	-	-	-	-	23	129	N/A	N/A
Thu, Dec 31 2015	-	-	N/A	N/A	-	-	-	-	42	279	N/A	N/A
Fri, Jan 1 2016	-	-	N/A	N/A	-	-	-	-	25	123	N/A	N/A
Sat, Jan 2 2016	-	-	-	-	-	-	-	-	22	80	N/A	N/A
Sun, Jan 3 2016	-	-	N/A	N/A	-	-	-	-	18	66	N/A	N/A
Mon, Jan 4 2016	-	-	N/A	N/A	-	-	-	-	13	43	N/A	N/A
Tue, Jan 5 2016	-	-	N/A	N/A	-	-	-	-	23	121	N/A	N/A
Wed, Jan 6 2016	-	-	N/A	N/A	-	-	-	-	37	370	N/A	N/A
Thu, Jan 7 2016	-	-	-	-	-	-	-	-	26	134	9	30
Fri, Jan 8 2016	-	-	12	27	-	-	-	-	32	128	58	149
Sat, Jan 9 2016	-	-	13	27	-	-	-	-	31	165	30	136
Sun, Jan 10 2016	-	-	16	35	-	-	-	-	30	163	21	55
Mon, Jan 11 2016	-	-	19	26	-	-	-	-	28	124	8	33
Tue, Jan 12 2016	-	-	18	26	-	-	-	-	30	121	N/A	N/A
Wed, Jan 13 2016	-	-	25	40	-	-	-	-	32	197	N/A	N/A
Thu, Jan 14 2016	-	-	-	-	-	-	-	-	38	123	N/A	N/A
Fri, Jan 15 2016	-	-	-	-	-	-	-	-	40	176	29	124
Sat, Jan 16 2016	-	-	19	28	-	-	-	-	40	142	40	250
Sun, Jan 17 2016	-	-	18	42	-	-	-	-	38	249	28	58
Mon, Jan 18 2016	-	-	15	47	-	-	-	-	34	228	32	67
Tue, Jan 19 2016	-	-	14	49	-	-	-	-	30	132	31	62
Wed, Jan 20 2016	-	-	10	59	-	-	-	-	33	123	21	75
Thu, Jan 21 2016	-	-	20	87	-	-	-	-	20	46	31	70
Fri, Jan 22 2016	-	-	12	46	-	-	-	-	23	101	43	104
Sat, Jan 23 2016	-	-	13	22	-	-	-	-	29	163	28	65
Sun, Jan 24 2016	-	-	14	30	-	-	-	-	35	154	44	170
Mon, Jan 25 2016	-	-	30	79	-	-	-	-	70	386	30	119
Tue, Jan 26 2016	-	-	9	32	-	-	-	-	49	386	34	76
Wed, Jan 27 2016	-	-	15	52	-	-	-	-	41	192	36	83
Thu, Jan 28 2016	-	-	22	53	-	-	-	-	29	103	28	72
Fri, Jan 29 2016	-	-	18	65	-	-	-	-	46	278	33	91
Sat, Jan 30 2016	-	-	19	43	-	-	-	-	27	120	30	91
Sun, Jan 31 2016	-	-	16	48	-	-	-	-	17	83	28	101
Mon, Feb 1 2016	-	-	4	34	-	-	-	-	25	101	35	129
Tue, Feb 2 2016	-	-	12	60	11	52	-	-	27	170	24	69
Wed, Feb 3 2016	-	-	10	40	14	55	-	-	20	92	11	38
Thu, Feb 4 2016	-	-	12	45	19	127	-	-	26	111	8	11
Fri, Feb 5 2016	-	-	11	39	16	101	-	-	26	125	23	49
Sat, Feb 6 2016	-	-	8	44	11	38	-	-	28	110	7	19
Sun, Feb 7 2016	-	-	15	47	20	70	-	-	20	99	29	59
Mon, Feb 8 2016	-	-	20	54	22	64	-	-	23	68	25	93
Tue, Feb 9 2016	-	-	17	49	21	85	-	-	23	64	25	54
Wed, Feb 10 2016	-	-	16	51	18	58	-	-	26	78	32	131
Thu, Feb 11 2016	-	-	19	84	21	80	-	-	23	160	30	195
Fri, Feb 12 2016	-	-	18	60	16	53	-	-	28	201	61	525
Sat, Feb 13 2016	-	-	13	55	15	43	-	-	27	102	19	43
Sun, Feb 14 2016	-	-	17	59	19	53	-	-	44	248	7	10
Mon, Feb 15 2016	-	-	25	89	29	75	-	-	40	726	N/A	N/A
Tue, Feb 16 2016	-	-	59	357	58	344	-	-	76	733	528	1012
Wed, Feb 17 2016	-	-	21	59	30	102	-	-	90	296	78	124
Thu, Feb 18 2016	-	-	19	61	27	88	-	-	29	324	37	102
Fri, Feb 19 2016	-	-	10	47	13	52	-	-	19	107	10	41

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Feb 20 2016	-	-	9	59	11	48	-	-	23	128	16	53
Sun, Feb 21 2016	-	-	13	37	15	65	-	-	41	252	18	48
Mon, Feb 22 2016	-	-	24	80	30	192	-	-	56	426	37	151
Tue, Feb 23 2016	-	-	18	51	19	48	-	-	38	172	32	100
Wed, Feb 24 2016	-	-	12	47	15	40	-	-	23	86	19	65
Thu, Feb 25 2016	-	-	20	67	33	144	-	-	25	105	58	200
Fri, Feb 26 2016	-	-	15	59	19	51	-	-	38	148	18	57
Sat, Feb 27 2016	-	-	14	47	15	39	-	-	26	103	22	68
Sun, Feb 28 2016	-	-	14	49	17	52	-	-	25	78	106	1015
Mon, Feb 29 2016	-	-	14	50	16	45			34	183	20	50
Tue, Mar 1 2016	-	-	19	58	22	54			46	191	23	55
Wed, Mar 2 2016	-	-	25	82	40	139			31	139	38	93
Thu, Mar 3 2016	-	-	25	63	27	83			51	279	45	189
Fri, Mar 4 2016	-	-	20	52	21	53			37	152	30	74
Sat, Mar 5 2016	-	-	12	44	13	42			24	102	28	58
Sun, Mar 6 2016	-	-	14	46	14	40			32	230	15	48
Mon, Mar 7 2016	-	-	18	56	23	74	42	109	42	269	16	49
Tue, Mar 8 2016	-	-	12	46	21	61	39	139	37	230	14	62
Wed, Mar 9 2016	-	-	47	187	90	262	187	704	57	275	424	1011
Thu, Mar 10 2016	-	-	68	234	74	401	87	438	25	80	225	861
Fri, Mar 11 2016	-	-	45	125	43	117	50	199	35	266	180	1012
Sat, Mar 12 2016	-	-	24	58	26	49	34	65	32	124	31	220
Sun, Mar 13 2016	-	-	16	43	18	34	26	79	27	121	9	22
Mon, Mar 14 2016	-	-	15	57	19	56	27	78	35	190	18	68
Tue, Mar 15 2016	-	-	12	41	15	44	21	67	32	180	28	81
Wed, Mar 16 2016	-	-	17	47	56	305	84	513	82	1005	190	988
Thu, Mar 17 2016	-	-	23	102	37	130	43	122	28	269	51	135
Fri, Mar 18 2016	-	-	17	63	27	94	49	328	34	570	39	131
Sat, Mar 19 2016	-	-	9	27	13	44	20	59	17	63	13	35
Sun, Mar 20 2016	-	-	13	50	16	75	21	65	24	59	14	39
Mon, Mar 21 2016	-	-	14	45	18	72	25	73	34	239	17	53
Tue, Mar 22 2016	-	-	17	53	18	54	42	213	57	434	17	63
Wed, Mar 23 2016	-	-	18	49	21	74	37	119	39	197	27	51
Thu, Mar 24 2016	-	-	20	51	21	50	39	84	47	257	18	55
Fri, Mar 25 2016	-	-	15	54	19	91	41	215	46	380	4	8
Sat, Mar 26 2016	-	-	12	48	13	43	26	63	30	106	27	77
Sun, Mar 27 2016	-	-	10	44	11	39	20	79	21	88	23	53
Mon, Mar 28 2016	-	-	9	52	12	52	26	108	26	168	12	33
Tue, Mar 29 2016	-	-	18	42	19	42	43	226	50	201	21	45
Wed, Mar 30 2016	-	-	29	73	29	77	50	116	79	515	17	31
Thu, Mar 31 2016	-	-	26	68	27	79	50	101	83	380	32	55
Fri, Apr 1 2016	-	-	27	69	27	68	43	118	54	248	31	78
Sat, Apr 2 2016	-	-	16	47	18	48	28	93	32	130	25	66
Sun, Apr 3 2016	-	-	16	52	16	41	32	127	31	157	24	64
Mon, Apr 4 2016	-	-	16	48	17	43	29	114	35	172	24	50
Tue, Apr 5 2016	-	-	12	41	23	85	38	121	41	199	26	68
Wed, Apr 6 2016	-	-	35	131	63	223	129	423	44	310	249	449
Thu, Apr 7 2016	-	-	39	207	37	135	51	145	27	84	52	124
Fri, Apr 8 2016	-	-	31	116	30	84	39	109	49	215	29	78
Sat, Apr 9 2016	-	-	11	42	12	46	21	92	21	101	9	33
Sun, Apr 10 2016	-	-	12	52	13	43	22	113	18	57	61	412
Mon, Apr 11 2016	-	-	26	137	34	170	57	361	28	217	81	238
Tue, Apr 12 2016	-	-	20	64	32	167	67	257	61	779	55	185
Wed, Apr 13 2016	-	-	23	69	37	125	72	279	58	630	41	109
Thu, Apr 14 2016	-	-	28	142	31	118	63	530	50	799	34	76
Fri, Apr 15 2016	-	-	28	115	34	171	43	136	32	174	27	63
Sat, Apr 16 2016	-	-	9	36	13	89	7	7	26	232	8	25
Sun, Apr 17 2016	-	-	5	39	7	32	N/A	N/A	29	175	4	11
Mon, Apr 18 2016	-	-	32	140	47	228	92	1003	19	61	71	213
Tue, Apr 19 2016	-	-	21	64	34	127	63	229	39	464	62	152
Wed, Apr 20 2016	-	-	24	88	47	220	66	233	20	69	81	230
Thu, Apr 21 2016	-	-	17	57	23	105	20	115	20	68	50	132
Fri, Apr 22 2016	-	-	25	131	31	110	42	193	32	140	64	183

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Apr 23 2016	-	-	15	65	18	65	38	157	50	404	15	51
Sun, Apr 24 2016	-	-	15	42	17	45	32	209	40	268	15	41
Mon, Apr 25 2016	-	-	28	97	33	94	31	140	37	184	73	219
Tue, Apr 26 2016	-	-	31	108	46	178	49	283	28	359	68	503
Wed, Apr 27 2016	-	-	27	114	35	129	32	138	34	436	32	109
Thu, Apr 28 2016	-	-	28	86	40	172	36	137	30	87	31	70
Fri, Apr 29 2016	-	-	25	77	34	142	40	127	48	196	7	28
Sat, Apr 30 2016	-	-	14	48	17	40	29	93	36	221	21	53
Sun, May 1 2016	-	-	12	49	17	83	32	240	37	538	15	38
Mon, May 2 2016	-	-	21	84	31	136	61	242	28	517	74	195
Tue, May 3 2016	-	-	16	86	25	140	39	137	28	204	28	87
Wed, May 4 2016	-	-	12	51	17	64	48	215	36	330	28	85
Thu, May 5 2016	-	-	19	55	18	50	52	322	77	796	22	46
Fri, May 6 2016	-	-	14	46	16	49	35	1004	35	275	22	46
Sat, May 7 2016	-	-	7	36	13	47	25	97	25	239	12	36
Sun, May 8 2016	-	-	10	32	15	34	25	84	19	49	14	39
Mon, May 9 2016	-	-	28	134	40	174	43	141	23	129	33	85
Tue, May 10 2016	-	-	27	139	39	162	47	133	26	199	39	97
Wed, May 11 2016	-	-	33	194	37	135	43	149	22	59	30	64
Thu, May 12 2016	-	-	19	74	21	82	28	94	21	73	14	44
Fri, May 13 2016	-	-	17	69	17	68	26	97	19	54	53	215
Sat, May 14 2016	-	-	9	37	10	38	23	83	26	220	19	62
Sun, May 15 2016	-	-	10	44	12	38	24	89	22	126	14	36
Mon, May 16 2016	-	-	34	136	44	159	139	992	21	71	5	5
Tue, May 17 2016	-	-	37	144	56	182	80	388	29	144	N/A	N/A
Wed, May 18 2016	-	-	19	119	32	138	36	153	31	193	N/A	N/A
Thu, May 19 2016	-	-	24	101	31	134	46	209	21	75	N/A	N/A
Fri, May 20 2016	-	-	41	200	62	321	90	354	29	139	N/A	N/A
Sat, May 21 2016	-	-	17	49	27	79	78	300	25	95	N/A	N/A
Sun, May 22 2016	-	-	14	43	19	56	36	103	29	94	N/A	N/A
Mon, May 23 2016	-	-	25	108	27	155	49	450	45	388	45	157
Tue, May 24 2016	-	-	22	88	40	187	50	186	23	110	41	122
Wed, May 25 2016	-	-	13	61	18	63	44	189	40	372	6	8
Thu, May 26 2016	-	-	11	56	13	48	31	195	36	337	16	69
Fri, May 27 2016	-	-	14	50	15	37	36	232	48	593	10	29
Sat, May 28 2016	-	-	12	42	13	44	49	299	73	527	8	23
Sun, May 29 2016	-	-	14	53	15	45	35	156	44	356	21	81
Mon, May 30 2016	-	-	6	36	9	29	20	84	28	198	5	17
Tue, May 31 2016	-	-	7	23	11	39	38	178	13	60	16	49
Wed, Jun 1 2016	-	-	12	52	19	59	44	185	21	70	40	154
Thu, Jun 2 2016	-	-	16	56	23	78	49	163	20	68	31	77
Fri, Jun 3 2016	-	-	13	43	18	68	32	224	26	190	23	48
Sat, Jun 4 2016	-	-	10	46	11	45	28	113	30	199	7	21
Sun, Jun 5 2016	-	-	8	34	9	30	19	93	22	281	7	10
Mon, Jun 6 2016	-	-	8	41	13	52	30	185	23	118	26	90
Tue, Jun 7 2016	-	-	25	85	46	143	59	200	20	57	31	135
Wed, Jun 8 2016	-	-	24	71	31	104	42	153	24	114	44	217
Thu, Jun 9 2016	-	-	12	47	17	55	39	162	45	402	22	90
Fri, Jun 10 2016	-	-	11	35	15	51	28	134	33	208	18	53
Sat, Jun 11 2016	-	-	9	34	11	40	26	151	27	145	16	66
Sun, Jun 12 2016	-	-	10	50	13	42	44	253	43	392	17	66
Mon, Jun 13 2016	-	-	34	125	81	369	97	403	39	352	61	202
Tue, Jun 14 2016	-	-	30	125	52	198	69	272	38	376	52	220
Wed, Jun 15 2016	-	-	22	60	49	161	80	266	37	315	68	254
Thu, Jun 16 2016	-	-	26	87	52	353	77	345	54	630	53	226
Fri, Jun 17 2016	-	-	18	66	22	79	89	525	47	358	37	141
Sat, Jun 18 2016	-	-	11	41	13	39	123	1004	20	126	20	87
Sun, Jun 19 2016	-	-	9	38	13	48	27	120	29	243	28	109
Mon, Jun 20 2016	-	-	20	101	26	164	33	165	26	249	29	138
Tue, Jun 21 2016	-	-	15	69	22	94	27	129	19	171	28	172
Wed, Jun 22 2016	-	-	18	65	30	112	54	216	27	206	74	814
Thu, Jun 23 2016	-	-	20	92	46	217	51	224	34	345	39	166
Fri, Jun 24 2016	-	-	14	46	29	126	95	336	53	480	46	196

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Jun 25 2016	-	-	10	30	12	34	22	179	45	610	15	52
Sun, Jun 26 2016	-	-	10	32	12	35	22	80	22	109	19	100
Mon, Jun 27 2016	-	-	18	75	26	100	34	127	16	46	33	135
Tue, Jun 28 2016	-	-	36	113	58	199	57	223	33	134	64	198
Wed, Jun 29 2016	-	-	29	99	42	129	42	153	34	170	36	125
Thu, Jun 30 2016	-	-	31	131	53	178	67	552	40	206	58	198
Fri, Jul 1 2016	-	-	43	146	66	291	104	576	45	150	107	1012
Sat, Jul 2 2016	-	-	29	83	50	187	67	310	31	116	136	1012
Sun, Jul 3 2016	-	-	14	44	15	38	41	284	54	404	20	68
Mon, Jul 4 2016	-	-	13	41	16	37	32	146	41	332	18	63
Tue, Jul 5 2016	-	-	10	38	17	63	36	171	33	159	18	80
Wed, Jul 6 2016	-	-	12	40	20	73	55	172	34	314	31	152
Thu, Jul 7 2016	-	-	29	120	53	241	83	451	27	194	66	280
Fri, Jul 8 2016	-	-	29	114	33	152	64	299	24	422	36	168
Sat, Jul 9 2016	-	-	14	37	19	48	42	579	60	985	23	68
Sun, Jul 10 2016	-	-	12	38	14	38	34	126	26	138	18	61
Mon, Jul 11 2016	-	-	16	53	22	155	40	374	28	129	31	206
Tue, Jul 12 2016	-	-	24	98	37	122	39	142	30	147	37	136
Wed, Jul 13 2016	-	-	15	71	27	119	35	171	27	206	36	144
Thu, Jul 14 2016	51	242	15	63	23	232	38	298	24	163	26	138
Fri, Jul 15 2016	43	154	13	46	20	90	40	147	36	176	24	98
Sat, Jul 16 2016	40	183	9	36	11	36	25	108	23	110	15	60
Sun, Jul 17 2016	23	113	9	37	10	39	30	155	37	306	16	58
Mon, Jul 18 2016	27	172	15	105	15	57	51	216	64	435	19	93
Tue, Jul 19 2016	66	195	15	84	16	41	45	274	38	237	22	66
Wed, Jul 20 2016	N/A	N/A	24	104	33	180	45	427	46	465	35	162
Thu, Jul 21 2016	69	70	22	85	36	160	39	134	18	64	40	143
Fri, Jul 22 2016	N/A	N/A	28	93	38	157	48	192	21	62	56	205
Sat, Jul 23 2016	N/A	N/A	10	35	12	30	50	450	38	382	17	46
Sun, Jul 24 2016	N/A	N/A	12	31	15	70	68	372	106	539	17	52
Mon, Jul 25 2016	59	277	15	38	15	37	56	555	64	790	21	52
Tue, Jul 26 2016	45	151	13	64	25	97	34	114	56	59	30	106
Wed, Jul 27 2016	28	167	28	93	38	120	52	153	N/A	N/A	62	215
Thu, Jul 28 2016	29	107	28	92	39	121	57	172	N/A	N/A	57	193
Fri, Jul 29 2016	5	27	21	117	31	133	73	324	N/A	N/A	79	392
Sat, Jul 30 2016	N/A	N/A	9	27	12	33	22	80	N/A	N/A	21	71
Sun, Jul 31 2016	-	-	7	37	9	30	32	257	N/A	N/A	14	57
Mon, Aug 1 2016	-	-	12	64	18	74	33	192	N/A	N/A	48	225
Tue, Aug 2 2016	28	29	14	71	21	89	47	201	23	686	29	132
Wed, Aug 3 2016	59	240	25	80	40	157	73	348	69	646	54	157
Thu, Aug 4 2016	30	153	19	79	40	144	44	159	N/A	N/A	44	135
Fri, Aug 5 2016	27	128	19	102	47	223	43	172	N/A	N/A	40	152
Sat, Aug 6 2016	17	120	7	31	8	30	29	189	N/A	N/A	18	136
Sun, Aug 7 2016	22	108	10	36	11	28	29	148	N/A	N/A	14	53
Mon, Aug 8 2016	30	123	19	79	32	164	45	159	N/A	N/A	43	189
Tue, Aug 9 2016	22	127	14	52	20	64	36	143	N/A	N/A	32	140
Wed, Aug 10 2016	27	120	19	83	47	192	59	205	N/A	N/A	52	256
Thu, Aug 11 2016	22	99	22	100	31	151	63	298	26	1004	44	220
Fri, Aug 12 2016	23	123	20	76	23	64	39	137	41	572	30	86
Sat, Aug 13 2016	26	116	11	37	13	30	24	75	26	172	20	95
Sun, Aug 14 2016	25	121	8	31	13	35	25	108	26	172	21	91
Mon, Aug 15 2016	40	222	19	68	25	114	33	117	24	104	28	111
Tue, Aug 16 2016	29	185	19	80	29	137	33	133	24	218	38	190
Wed, Aug 17 2016	31	258	20	95	31	131	40	149	20	137	65	516
Thu, Aug 18 2016	24	139	24	109	20	66	47	174	25	140	43	157
Fri, Aug 19 2016	37	180	17	65	25	81	41	192	30	276	29	125
Sat, Aug 20 2016	31	150	10	36	13	41	32	216	37	313	20	72
Sun, Aug 21 2016	24	113	8	31	10	33	26	200	25	167	16	64
Mon, Aug 22 2016	35	191	10	58	16	70	30	143	30	160	17	80
Tue, Aug 23 2016	31	132	14	58	28	117	51	138	46	304	26	105
Wed, Aug 24 2016	37	152	12	43	18	91	44	193	56	334	17	74
Thu, Aug 25 2016	36	128	16	81	20	55	27	94	24	150	24	83
Fri, Aug 26 2016	39	164	13	49	22	79	46	266	34	204	27	119

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Aug 27 2016	57	419	9	36	11	34	29	365	30	316	18	91
Sun, Aug 28 2016	76	351	9	31	13	38	26	215	32	189	15	51
Mon, Aug 29 2016	46	246	19	78	29	107	50	167	25	107	36	135
Tue, Aug 30 2016	54	301	16	57	24	79	56	303	75	1003	33	132
Wed, Aug 31 2016	32	132	22	65	35	85	50	176	27	116	35	86
Thu, Sep 1 2016	53	301	35	121	73	329	101	321	54	908	139	552
Fri, Sep 2 2016	33	150	24	74	50	197	72	458	58	424	42	140
Sat, Sep 3 2016	50	376	15	45	21	63	52	313	50	424	24	97
Sun, Sep 4 2016	41	223	15	56	17	46	44	309	50	665	26	98
Mon, Sep 5 2016	26	102	12	41	15	39	26	89	27	134	22	89
Tue, Sep 6 2016	30	190	14	79	19	98	37	158	39	181	26	146
Wed, Sep 7 2016	38	186	15	68	25	111	47	208	34	262	24	88
Thu, Sep 8 2016	31	176	20	64	38	156	51	294	25	136	31	120
Fri, Sep 9 2016	36	217	14	53	24	112	50	197	33	328	39	142
Sat, Sep 10 2016	32	99	7	33	11	35	18	60	25	260	17	69
Sun, Sep 11 2016	26	147	9	41	10	31	34	321	38	335	17	77
Mon, Sep 12 2016	24	140	8	40	12	56	34	208	26	337	21	131
Tue, Sep 13 2016	15	81	8	36	11	47	35	264	39	296	14	56
Wed, Sep 14 2016	20	97	10	45	11	32	24	153	41	262	15	50
Thu, Sep 15 2016	29	106	11	32	14	33	29	102	31	145	21	79
Fri, Sep 16 2016	24	89	12	35	17	36	51	529	50	366	23	62
Sat, Sep 17 2016	20	133	9	36	12	30	23	137	32	272	16	68
Sun, Sep 18 2016	27	135	13	36	16	38	25	60	34	236	20	66
Mon, Sep 19 2016	21	97	15	77	20	60	27	91	30	252	23	75
Tue, Sep 20 2016	26	113	18	80	23	78	33	193	40	315	23	69
Wed, Sep 21 2016	26	117	19	69	24	98	35	138	25	216	27	97
Thu, Sep 22 2016	25	133	16	59	26	117	38	150	31	202	36	227
Fri, Sep 23 2016	37	133	25	124	34	115	40	121	33	214	36	133
Sat, Sep 24 2016	54	110	12	42	15	41	29	97	32	177	24	83
Sun, Sep 25 2016	N/A	N/A	11	56	22	273	28	212	34	518	25	89
Mon, Sep 26 2016	N/A	N/A	15	47	28	144	36	141	21	153	29	89
Tue, Sep 27 2016	N/A	N/A	23	83	35	131	74	305	32	212	81	411
Wed, Sep 28 2016	N/A	N/A	17	62	28	95	69	374	51	420	81	319
Thu, Sep 29 2016	55	55	18	67	24	82	36	153	26	208	31	175
Fri, Sep 30 2016	N/A	N/A	26	131	35	108	61	347	22	130	59	594
Sat, Oct 1 2016	N/A	N/A	13	47	19	73	37	200	42	214	22	89
Sun, Oct 2 2016	N/A	N/A	14	40	18	51	53	389	62	390	24	67
Mon, Oct 3 2016	54	229	42	131	42	159	72	275	58	295	52	201
Tue, Oct 4 2016	44	232	35	131	46	155	54	145	52	249	41	146
Wed, Oct 5 2016	36	162	37	140	83	478	72	276	46	325	46	217
Thu, Oct 6 2016	37	213	32	137	40	120	48	167	34	327	39	136
Fri, Oct 7 2016	29	157	31	148	78	449	48	155	27	196	73	481
Sat, Oct 8 2016	36	204	12	49	17	76	23	90	18	54	46	431
Sun, Oct 9 2016	35	193	12	39	13	54	22	81	17	84	127	751
Mon, Oct 10 2016	28	196	18	97	30	127	38	201	13	50	183	1013
Tue, Oct 11 2016	34	148	31	118	46	176	70	276	26	78	171	1014
Wed, Oct 12 2016	25	236	29	119	40	148	61	217	36	290	66	336
Thu, Oct 13 2016	33	178	23	94	32	116	54	219	23	65	124	1012
Fri, Oct 14 2016	27	159	35	1013	46	368	47	299	25	186	145	1011
Sat, Oct 15 2016	27	145	13	47	16	43	24	77	27	97	45	373
Sun, Oct 16 2016	26	115	9	34	12	33	21	75	22	115	136	972
Mon, Oct 17 2016	36	182	17	81	47	814	42	171	26	189	45	432
Tue, Oct 18 2016	37	226	25	116	31	140	41	156	26	121	33	116
Wed, Oct 19 2016	30	162	31	131	103	504	52	371	40	660	42	215
Thu, Oct 20 2016	25	116	23	95	39	154	43	245	40	420	38	179
Fri, Oct 21 2016	24	101	19	78	23	104	36	192	32	274	22	103
Sat, Oct 22 2016	28	130	16	51	27	102	42	198	44	537	64	721
Sun, Oct 23 2016	28	133	15	37	21	45	62	731	63	693	24	68
Mon, Oct 24 2016	27	159	20	90	29	134	41	506	32	515	28	104
Tue, Oct 25 2016	35	155	18	70	32	158	42	187	18	58	44	168
Wed, Oct 26 2016	26	123	12	49	22	93	42	181	36	395	31	132
Thu, Oct 27 2016	28	151	21	71	29	87	61	351	44	709	32	131
Fri, Oct 28 2016	31	193	28	94	38	167	51	145	37	516	42	172

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Oct 29 2016	24	117	12	74	13	43	44	478	48	358	16	62
Sun, Oct 30 2016	25	165	16	86	23	94	44	260	48	581	25	83
Mon, Oct 31 2016	28	112	35	137	56	237	66	205	33	75	60	251
Tue, Nov 1 2016	27	156	28	124	61	281	60	272	24	52	56	290
Wed, Nov 2 2016	27	158	24	82	49	189	42	184	21	57	36	155
Thu, Nov 3 2016	31	153	24	93	29	122	38	160	21	67	33	159
Fri, Nov 4 2016	35	203	30	127	52	205	53	327	41	548	40	163
Sat, Nov 5 2016	24	120	11	39	15	49	24	74	24	109	19	90
Sun, Nov 6 2016	30	160	14	49	16	46	29	94	37	317	24	98
Mon, Nov 7 2016	23	134	13	72	32	131	44	159	23	121	35	125
Tue, Nov 8 2016	54	216	20	55	23	60	41	120	58	269	74	581
Wed, Nov 9 2016	50	258	14	53	17	54	36	105	42	256	60	460
Thu, Nov 10 2016	52	264	15	75	20	83	40	203	35	130	46	350
Fri, Nov 11 2016	39	204	14	52	13	38	28	96	35	223	29	273
Sat, Nov 12 2016	37	223	15	53	17	49	30	102	37	136	46	342
Sun, Nov 13 2016	2	2	13	55	16	54	20	71	21	92	24	156
Mon, Nov 14 2016	32	181	48	218	60	282	55	275	19	58	140	1012
Tue, Nov 15 2016	37	181	36	140	68	545	77	268	67	488	61	282
Wed, Nov 16 2016	33	143	24	69	27	66	48	202	25	104	43	195
Thu, Nov 17 2016	29	137	31	119	49	218	53	214	31	130	66	396
Fri, Nov 18 2016	27	116	21	90	25	110	55	267	20	158	56	589
Sat, Nov 19 2016	17	78	7	26	9	40	42	218	49	262	12	44
Sun, Nov 20 2016	28	130	16	46	20	51	30	78	28	102	24	70
Mon, Nov 21 2016	15	109	9	27	13	46	51	320	50	319	16	62
Tue, Nov 22 2016	36	178	26	78	41	148	51	141	31	154	42	191
Wed, Nov 23 2016	29	147	28	109	55	237	59	444	58	631	44	168
Thu, Nov 24 2016	22	150	13	43	17	54	44	287	42	339	31	862
Fri, Nov 25 2016	23	120	18	56	22	53	37	174	32	195	26	73
Sat, Nov 26 2016	30	117	23	56	28	60	36	84	33	161	64	508
Sun, Nov 27 2016	25	111	16	46	19	40	51	540	32	203	22	67
Mon, Nov 28 2016	36	154	30	88	34	102	60	136	53	200	36	98
Tue, Nov 29 2016	28	116	25	87	28	92	59	563	70	929	26	71
Wed, Nov 30 2016	26	126	17	59	24	90	57	501	47	794	27	111
Thu, Dec 1 2016	25	94	22	71	27	115	52	649	59	909	23	78
Fri, Dec 2 2016	87	316	20	51	24	68	31	69	23	65	29	99
Sat, Dec 3 2016	29	198	13	60	17	100	33	119	48	225	22	106
Sun, Dec 4 2016	17	84	9	35	12	29	36	116	50	220	13	40
Mon, Dec 5 2016	25	181	9	52	11	63	18	94	31	252	16	85
Tue, Dec 6 2016	37	215	10	56	17	210	359	538	28	338	17	71
Wed, Dec 7 2016	36	175	10	46	12	43	N/A	N/A	27	187	18	73
Thu, Dec 8 2016	13	46	13	30	14	32	38	148	58	323	17	48
Fri, Dec 9 2016	29	133	14	52	14	42	35	182	43	447	17	61
Sat, Dec 10 2016	19	109	9	36	11	35	37	98	39	203	14	56
Sun, Dec 11 2016	25	116	7	44	11	76	25	95	37	226	16	78
Mon, Dec 12 2016	53	342	11	59	14	51	22	92	36	282	19	94
Tue, Dec 13 2016	27	124	9	41	17	75	29	130	20	193	22	108
Wed, Dec 14 2016	34	175	17	64	22	73	25	86	26	99	22	111
Thu, Dec 15 2016	29	127	16	61	21	99	40	230	43	211	25	108
Fri, Dec 16 2016	34	161	15	44	18	46	68	888	89	1005	23	82
Sat, Dec 17 2016	23	97	13	42	13	36	62	483	72	790	19	67
Sun, Dec 18 2016	19	75	11	40	14	30	46	202	58	423	15	42
Mon, Dec 19 2016	37	189	16	65	19	55	27	136	27	136	23	75
Tue, Dec 20 2016	30	140	18	64	22	66	30	107	37	278	22	76
Wed, Dec 21 2016	34	163	12	44	19	99	54	199	51	383	24	125
Thu, Dec 22 2016	26	129	13	41	83	712	39	245	44	224	24	104
Fri, Dec 23 2016	35	176	11	45	29	412	36	180	38	354	25	138
Sat, Dec 24 2016	24	92	10	38	15	50	20	107	26	157	16	90
Sun, Dec 25 2016	25	112	15	44	22	147	29	94	25	80	55	625
Mon, Dec 26 2016	25	175	14	48	35	467	31	135	31	154	21	70
Tue, Dec 27 2016	44	208	29	86	39	139	68	211	24	68	71	247
Wed, Dec 28 2016	39	237	22	116	32	138	67	439	39	305	65	511
Thu, Dec 29 2016	29	165	16	68	19	93	46	299	51	220	26	115
Fri, Dec 30 2016	17	87	9	49	12	41	32	232	25	219	23	63

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Dec 31 2016	22	97	7	29	8	35	18	64	17	62	13	48
Sun, Jan 1 2017	27	121	8	35	9	30	15	48	15	49	18	62
Mon, Jan 2 2017	33	193	11	51	10	44	14	55	20	125	53	513
Tue, Jan 3 2017	45	219	10	47	13	54	18	89	18	80	30	118
Wed, Jan 4 2017	49	263	11	50	14	60	15	58	33	161	44	634
Thu, Jan 5 2017	30	175	9	59	11	53	24	100	18	93	29	269
Fri, Jan 6 2017	42	203	11	51	15	61	31	121	19	108	58	345
Sat, Jan 7 2017	24	101	9	34	10	37	23	97	21	82	128	1011
Sun, Jan 8 2017	34	196	9	49	9	32	27	83	12	60	170	1013
Mon, Jan 9 2017	52	280	16	83	19	109	46	179	46	355	64	476
Tue, Jan 10 2017	46	197	18	51	23	71	36	105	35	290	33	120
Wed, Jan 11 2017	64	304	21	64	21	48	48	106	64	316	32	142
Thu, Jan 12 2017	61	294	21	66	24	88	60	360	57	329	35	200
Fri, Jan 13 2017	101	354	17	48	17	43	52	176	60	246	29	91
Sat, Jan 14 2017	51	172	18	72	21	104	34	98	35	178	26	93
Sun, Jan 15 2017	34	206	18	56	18	45	37	113	54	290	31	113
Mon, Jan 16 2017	31	170	12	47	12	42	26	97	36	173	22	98
Tue, Jan 17 2017	41	177	14	53	14	54	29	130	24	65	33	119
Wed, Jan 18 2017	45	213	17	61	15	48	25	78	30	126	25	83
Thu, Jan 19 2017	52	241	18	60	19	60	40	182	48	290	100	653
Fri, Jan 20 2017	29	165	11	45	15	59	27	105	29	276	48	519
Sat, Jan 21 2017	12	71	11	51	12	42	43	295	47	242	27	180
Sun, Jan 22 2017	-	-	30	89	-	-	52	191	-	-	-	-
Mon, Jan 23 2017	-	-	21	52	-	-	65	172	-	-	-	-
Tue, Jan 24 2017	-	-	9	49	-	-	34	224	-	-	-	-
Wed, Jan 25 2017	-	-	10	31	-	-	27	95	-	-	-	-
Thu, Jan 26 2017	-	-	15	51	-	-	30	107	-	-	-	-
Fri, Jan 27 2017	-	-	13	55	-	-	28	101	-	-	-	-
Sat, Jan 28 2017	-	-	9	51	-	-	34	199	-	-	-	-
Sun, Jan 29 2017	-	-	19	61	-	-	67	362	-	-	-	-
Mon, Jan 30 2017	-	-	30	89	-	-	76	282	-	-	-	-
Tue, Jan 31 2017	-	-	28	73	-	-	51	147	-	-	-	-
Wed, Feb 1 2017	-	-	31	83	-	-	47	116	-	-	-	-
Thu, Feb 2 2017	247	290	28	59	28	48	47	110	52	92	43	96
Fri, Feb 3 2017	54	278	24	75	28	65	49	133	65	405	33	109
Sat, Feb 4 2017	27	85	23	48	28	62	51	167	54	255	30	65
Sun, Feb 5 2017	47	230	17	52	19	44	64	567	64	584	149	1013
Mon, Feb 6 2017	15	93	10	37	24	1001	53	321	73	588	14	38
Tue, Feb 7 2017	32	131	19	49	21	45	41	156	71	964	26	77
Wed, Feb 8 2017	29	132	16	51	24	82	45	158	60	964	31	106
Thu, Feb 9 2017	41	225	12	49	15	55	22	83	21	105	23	107
Fri, Feb 10 2017	66	370	14	45	16	43	39	152	51	278	42	242
Sat, Feb 11 2017	12	41	8	25	16	31	63	303	97	605	12	32
Sun, Feb 12 2017	31	132	16	38	N/A	N/A	42	299	64	484	24	91
Mon, Feb 13 2017	33	128	15	43	N/A	N/A	57	248	59	414	27	124
Tue, Feb 14 2017	26	126	13	40	2	2	67	292	61	421	18	62
Wed, Feb 15 2017	26	110	9	49	N/A	N/A	42	291	77	440	16	44
Thu, Feb 16 2017	34	142	10	39	N/A	N/A	21	147	63	1005	N/A	N/A
Fri, Feb 17 2017	48	235	11	43	N/A	N/A	31	145	42	326	17	115
Sat, Feb 18 2017	1	2	12	54	N/A	N/A	36	218	53	325	24	93
Sun, Feb 19 2017	30	128	24	49	N/A	N/A	53	111	40	117	43	117
Mon, Feb 20 2017	33	129	24	49	N/A	N/A	44	97	44	142	33	122
Tue, Feb 21 2017	26	98	25	103	N/A	N/A	55	703	58	935	33	147
Wed, Feb 22 2017	36	178	30	96	N/A	N/A	48	280	28	98	38	181
Thu, Feb 23 2017	30	135	18	54	N/A	N/A	49	288	19	58	45	218
Fri, Feb 24 2017	29	158	19	75	N/A	N/A	40	164	20	110	62	252
Sat, Feb 25 2017	32	136	13	41	N/A	N/A	25	65	29	125	21	62
Sun, Feb 26 2017	30	178	11	47	N/A	N/A	22	83	36	216	77	851
Mon, Feb 27 2017	38	189	18	77	N/A	N/A	48	319	53	388	110	1011
Tue, Feb 28 2017	26	155	20	77	N/A	N/A	56	468	80	941	21	64
Wed, Mar 1 2017	17	102	11	34	N/A	N/A	67	378	135	738	16	76
Thu, Mar 2 2017	39	227	14	41	N/A	N/A	69	501	99	1004	21	70
Fri, Mar 3 2017	33	156	13	38	N/A	N/A	54	290	72	517	18	56

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Mar 4 2017	19	102	14	43	N/A	N/A	79	418	97	428	N/A	N/A
Sun, Mar 5 2017	26	158	11	41	N/A	N/A	31	118	48	340	N/A	N/A
Mon, Mar 6 2017	44	210	19	50	N/A	N/A	38	139	66	581	7	33
Tue, Mar 7 2017	46	232	14	51	N/A	N/A	24	87	42	346	42	212
Wed, Mar 8 2017	34	199	13	55	N/A	N/A	28	97	37	230	31	114
Thu, Mar 9 2017	59	304	16	51	N/A	N/A	30	78	45	277	40	190
Fri, Mar 10 2017	55	211	22	57	N/A	N/A	43	102	48	193	36	132
Sat, Mar 11 2017	37	145	17	43	N/A	N/A	58	233	71	146	27	75
Sun, Mar 12 2017	N/A	N/A	16	48	N/A	N/A	47	228	57	353	29	181
Mon, Mar 13 2017	N/A	N/A	23	61	N/A	N/A	57	277	68	251	32	95
Tue, Mar 14 2017	1	2	14	56	N/A	N/A	30	100	41	436	35	166
Wed, Mar 15 2017	39	179	13	48	N/A	N/A	26	93	37	283	27	175
Thu, Mar 16 2017	47	241	13	70	N/A	N/A	26	89	41	317	31	269
Fri, Mar 17 2017	37	140	19	61	N/A	N/A	48	147	38	138	49	165
Sat, Mar 18 2017	46	267	15	47	N/A	N/A	24	68	32	255	46	526
Sun, Mar 19 2017	45	182	12	54	N/A	N/A	26	211	27	169	82	521
Mon, Mar 20 2017	39	179	21	76	N/A	N/A	35	132	28	118	58	232
Tue, Mar 21 2017	48	161	21	63	N/A	N/A	35	109	50	419	161	1012
Wed, Mar 22 2017	57	209	22	69	N/A	N/A	35	118	44	209	85	739
Thu, Mar 23 2017	N/A	N/A	21	56	N/A	N/A	41	183	67	227	47	164
Fri, Mar 24 2017	1	2	15	55	N/A	N/A	35	127	54	495	59	587
Sat, Mar 25 2017	39	183	18	48	N/A	N/A	34	116	48	318	36	131
Sun, Mar 26 2017	36	149	19	49	N/A	N/A	35	72	47	206	120	1012
Mon, Mar 27 2017	41	186	29	118	N/A	N/A	43	178	77	745	56	517
Tue, Mar 28 2017	1	2	19	65	N/A	N/A	33	93	36	249	40	282
Wed, Mar 29 2017	53	230	20	76	N/A	N/A	34	92	49	395	190	1012
Thu, Mar 30 2017	N/A	N/A	23	77	N/A	N/A	31	82	37	183	49	290
Fri, Mar 31 2017	116	195	23	85	N/A	N/A	33	103	42	218	80	875
Sat, Apr 1 2017	101	204	24	64	N/A	N/A	40	126	39	159	64	407
Sun, Apr 2 2017	87	145	22	71	N/A	N/A	42	145	63	343	188	1013
Mon, Apr 3 2017	105	192	28	78	N/A	N/A	44	150	36	149	37	120
Tue, Apr 4 2017	110	196	26	106	N/A	N/A	35	125	28	67	N/A	N/A
Wed, Apr 5 2017	93	173	25	91	N/A	N/A	34	111	40	194	94	1013
Thu, Apr 6 2017	56	227	26	111	N/A	N/A	36	167	34	159	37	183
Fri, Apr 7 2017	41	181	18	70	N/A	N/A	29	81	26	93	65	337
Sat, Apr 8 2017	31	127	14	52	N/A	N/A	25	80	27	119	92	813
Sun, Apr 9 2017	41	186	16	64	N/A	N/A	36	166	74	543	101	1013
Mon, Apr 10 2017	44	211	17	64	N/A	N/A	32	127	29	149	31	126
Tue, Apr 11 2017	26	157	19	69	N/A	N/A	28	109	49	308	25	121
Wed, Apr 12 2017	42	203	14	47	N/A	N/A	30	95	36	149	30	141
Thu, Apr 13 2017	37	188	14	49	N/A	N/A	30	130	41	417	27	137
Fri, Apr 14 2017	28	182	10	52	N/A	N/A	29	185	53	605	18	90
Sat, Apr 15 2017	30	145	11	42	N/A	N/A	22	74	28	133	27	163
Sun, Apr 16 2017	8	86	4	42	N/A	N/A	17	129	43	348	9	61
Mon, Apr 17 2017	22	111	13	42	N/A	N/A	27	76	18	71	22	112
Tue, Apr 18 2017	40	135	24	64	N/A	N/A	41	96	40	196	42	278
Wed, Apr 19 2017	33	161	14	36	N/A	N/A	47	202	75	395	27	114
Thu, Apr 20 2017	17	87	9	46	N/A	N/A	53	260	72	408	14	50
Fri, Apr 21 2017	25	117	14	49	N/A	N/A	50	429	73	540	20	80
Sat, Apr 22 2017	20	89	10	35	N/A	N/A	28	116	42	309	19	146
Sun, Apr 23 2017	27	128	15	43	N/A	N/A	41	271	56	286	26	118
Mon, Apr 24 2017	39	133	20	58	N/A	N/A	40	129	36	178	32	93
Tue, Apr 25 2017	28	120	18	72	N/A	N/A	36	184	44	404	69	933
Wed, Apr 26 2017	25	125	26	106	N/A	N/A	37	230	41	386	26	91
Thu, Apr 27 2017	39	246	15	72	N/A	N/A	40	177	68	660	42	401
Fri, Apr 28 2017	23	129	10	64	N/A	N/A	23	136	38	239	19	138
Sat, Apr 29 2017	14	66	9	46	N/A	N/A	22	156	39	313	18	149
Sun, Apr 30 2017	11	59	6	25	N/A	N/A	38	315	53	362	9	75
Mon, May 1 2017	41	133	15	40	N/A	N/A	32	97	33	241	31	151
Tue, May 2 2017	40	159	18	56	N/A	N/A	34	80	60	269	53	273
Wed, May 3 2017	33	158	16	51	N/A	N/A	30	88	45	293	47	337
Thu, May 4 2017	24	109	N/A	N/A	N/A	N/A	31	99	44	218	30	96
Fri, May 5 2017	35	126	N/A	N/A	N/A	N/A	44	138	26	151	52	244

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, May 6 2017	28	117	N/A	N/A	N/A	N/A	32	76	37	258	56	235
Sun, May 7 2017	30	144	N/A	N/A	N/A	N/A	33	80	51	297	33	130
Mon, May 8 2017	36	195	N/A	N/A	N/A	N/A	44	264	70	670	29	150
Tue, May 9 2017	35	155	1	1	N/A	N/A	40	137	44	311	32	170
Wed, May 10 2017	28	96	N/A	N/A	N/A	N/A	53	156	35	132	42	148
Thu, May 11 2017	35	121	N/A	N/A	N/A	N/A	45	163	42	205	48	189
Fri, May 12 2017	29	116	N/A	N/A	N/A	N/A	52	147	32	248	59	285
Sat, May 13 2017	22	98	N/A	N/A	N/A	N/A	40	124	64	543	42	146
Sun, May 14 2017	23	104	N/A	N/A	N/A	N/A	42	127	36	518	123	932
Mon, May 15 2017	32	125	N/A	N/A	N/A	N/A	60	168	59	552	86	307
Tue, May 16 2017	37	105	N/A	N/A	N/A	N/A	69	176	28	167	256	1012
Wed, May 17 2017	30	112	N/A	N/A	N/A	N/A	50	130	32	89	159	943
Thu, May 18 2017	36	173	N/A	N/A	N/A	N/A	40	152	70	526	61	778
Fri, May 19 2017	46	242	N/A	N/A	N/A	N/A	26	86	40	498	19	71
Sat, May 20 2017	25	121	N/A	N/A	N/A	N/A	22	112	40	428	17	89
Sun, May 21 2017	24	106	N/A	N/A	N/A	N/A	18	56	29	242	36	435
Mon, May 22 2017	29	139	N/A	N/A	N/A	N/A	51	199	32	476	67	240
Tue, May 23 2017	24	107	N/A	N/A	N/A	N/A	71	392	82	716	41	189
Wed, May 24 2017	28	128	N/A	N/A	N/A	N/A	38	203	50	452	28	99
Thu, May 25 2017	29	138	N/A	N/A	N/A	N/A	30	163	33	250	35	476
Fri, May 26 2017	33	168	N/A	N/A	N/A	N/A	28	131	37	173	30	124
Sat, May 27 2017	28	145	N/A	N/A	N/A	N/A	22	79	66	90	18	73
Sun, May 28 2017	28	145	N/A	N/A	N/A	N/A	22	82	31	113	19	126
Mon, May 29 2017	30	156	N/A	N/A	N/A	N/A	24	78	27	104	24	97
Tue, May 30 2017	40	179	N/A	N/A	N/A	N/A	36	102	43	365	73	482
Wed, May 31 2017	35	126	N/A	N/A	N/A	N/A	48	151	25	77	47	143
Thu, Jun 1 2017	37	174	N/A	N/A	N/A	N/A	61	162	50	421	136	910
Fri, Jun 2 2017	36	142	N/A	N/A	N/A	N/A	75	308	44	846	92	358
Sat, Jun 3 2017	21	84	N/A	N/A	N/A	N/A	44	465	42	792	43	715
Sun, Jun 4 2017	23	93	N/A	N/A	N/A	N/A	32	266	44	486	21	112
Mon, Jun 5 2017	30	123	N/A	N/A	N/A	N/A	42	161	21	148	44	238
Tue, Jun 6 2017	34	153	N/A	N/A	N/A	N/A	52	168	22	71	52	206
Wed, Jun 7 2017	38	171	N/A	N/A	N/A	N/A	36	131	24	83	78	523
Thu, Jun 8 2017	31	171	N/A	N/A	N/A	N/A	22	101	18	64	37	358
Fri, Jun 9 2017	48	208	N/A	N/A	N/A	N/A	29	284	29	342	36	204
Sat, Jun 10 2017	18	86	N/A	N/A	N/A	N/A	24	299	27	260	18	119
Sun, Jun 11 2017	24	105	N/A	N/A	N/A	N/A	24	98	33	358	25	110
Mon, Jun 12 2017	18	117	N/A	N/A	N/A	N/A	17	59	17	75	N/A	N/A
Tue, Jun 13 2017	32	151	N/A	N/A	N/A	N/A	36	164	33	197	N/A	N/A
Wed, Jun 14 2017	25	131	N/A	N/A	N/A	N/A	49	421	47	448	N/A	N/A
Thu, Jun 15 2017	25	147	N/A	N/A	N/A	N/A	28	115	33	170	N/A	N/A
Fri, Jun 16 2017	37	155	N/A	N/A	N/A	N/A	29	96	30	132	N/A	N/A
Sat, Jun 17 2017	22	115	N/A	N/A	N/A	N/A	19	64	29	256	N/A	N/A
Sun, Jun 18 2017	19	87	N/A	N/A	N/A	N/A	14	59	26	95	N/A	N/A
Mon, Jun 19 2017	34	169	N/A	N/A	N/A	N/A	34	132	24	185	N/A	N/A
Tue, Jun 20 2017	32	177	N/A	N/A	N/A	N/A	31	93	29	163	N/A	N/A
Wed, Jun 21 2017	34	143	N/A	N/A	N/A	N/A	62	371	46	254	N/A	N/A
Thu, Jun 22 2017	32	126	N/A	N/A	N/A	N/A	34	113	25	118	N/A	N/A
Fri, Jun 23 2017	34	148	N/A	N/A	N/A	N/A	43	167	32	259	75	374
Sat, Jun 24 2017	25	143	N/A	N/A	N/A	N/A	25	149	21	83	N/A	N/A
Sun, Jun 25 2017	25	146	N/A	N/A	N/A	N/A	19	69	30	122	N/A	N/A
Mon, Jun 26 2017	32	165	N/A	N/A	N/A	N/A	42	151	36	157	N/A	N/A
Tue, Jun 27 2017	33	166	N/A	N/A	N/A	N/A	32	111	26	121	N/A	N/A
Wed, Jun 28 2017	41	183	N/A	N/A	N/A	N/A	66	277	30	83	N/A	N/A
Thu, Jun 29 2017	32	158	N/A	N/A	N/A	N/A	35	111	27	267	N/A	N/A
Fri, Jun 30 2017	20	123	N/A	N/A	N/A	N/A	44	526	46	452	-	-
Sat, Jul 1 2017	24	109	N/A	N/A	N/A	N/A	31	140	55	397	-	-
Sun, Jul 2 2017	27	126	N/A	N/A	N/A	N/A	19	62	22	70	-	-
Mon, Jul 3 2017	27	141	N/A	N/A	N/A	N/A	37	369	41	426	-	-
Tue, Jul 4 2017	27	127	N/A	N/A	N/A	N/A	31	72	32	111	-	-
Wed, Jul 5 2017	40	152	N/A	N/A	N/A	N/A	44	120	28	94	-	-
Thu, Jul 6 2017	36	295	N/A	N/A	N/A	N/A	34	161	25	206	-	-
Fri, Jul 7 2017	37	151	N/A	N/A	N/A	N/A	32	111	26	212	-	-

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Jul 8 2017	25	104	N/A	N/A	N/A	N/A	18	138	23	343	-	-
Sun, Jul 9 2017	24	108	N/A	N/A	N/A	N/A	18	66	17	47	-	-
Mon, Jul 10 2017	47	212	N/A	N/A	N/A	N/A	37	152	25	122	-	-
Tue, Jul 11 2017	48	228	4	27	52	127	24	119	34	162	-	-
Wed, Jul 12 2017	49	181	17	97	74	265	32	197	40	393	-	-
Thu, Jul 13 2017	45	197	22	75	N/A	N/A	34	115	24	116	-	-
Fri, Jul 14 2017	49	180	20	65	N/A	N/A	49	142	27	109	-	-
Sat, Jul 15 2017	22	105	11	36	N/A	N/A	23	80	17	57	-	-
Sun, Jul 16 2017	24	119	11	43	N/A	N/A	26	238	28	334	-	-
Mon, Jul 17 2017	32	138	18	81	N/A	N/A	53	237	52	589	-	-
Tue, Jul 18 2017	34	147	18	56	N/A	N/A	41	149	22	121	-	-
Wed, Jul 19 2017	29	150	17	64	N/A	N/A	51	443	48	687	-	-
Thu, Jul 20 2017	30	116	26	70	N/A	N/A	54	393	33	281	-	-
Fri, Jul 21 2017	33	123	21	67	N/A	N/A	42	125	34	185	-	-
Sat, Jul 22 2017	25	108	13	41	N/A	N/A	26	92	41	289	-	-
Sun, Jul 23 2017	27	125	11	35	N/A	N/A	33	258	47	631	-	-
Mon, Jul 24 2017	52	396	9	36	N/A	N/A	22	95	27	148	-	-
Tue, Jul 25 2017	28	116	18	73	N/A	N/A	58	229	32	251	-	-
Wed, Jul 26 2017	32	137	22	78	N/A	N/A	61	209	32	413	-	-
Thu, Jul 27 2017	33	130	26	88	N/A	N/A	67	200	27	137	-	-
Fri, Jul 28 2017	31	140	14	49	N/A	N/A	43	133	31	275	-	-
Sat, Jul 29 2017	28	106	15	48	N/A	N/A	29	83	34	122	-	-
Sun, Jul 30 2017	26	100	9	33	N/A	N/A	21	60	20	92	-	-
Mon, Jul 31 2017	37	158	19	75	N/A	N/A	47	175	18	67	-	-
Tue, Aug 1 2017	34	147	13	45	N/A	N/A	33	145	31	172	-	-
Wed, Aug 2 2017	37	195	13	70	N/A	N/A	25	113	28	96	-	-
Thu, Aug 3 2017	46	273	12	54	N/A	N/A	30	180	22	96	-	-
Fri, Aug 4 2017	35	172	22	97	N/A	N/A	46	186	24	108	-	-
Sat, Aug 5 2017	29	116	18	58	N/A	N/A	37	158	26	109	-	-
Sun, Aug 6 2017	30	128	13	43	N/A	N/A	29	92	20	57	-	-
Mon, Aug 7 2017	58	238	22	81	N/A	N/A	62	187	20	60	-	-
Tue, Aug 8 2017	41	206	17	71	N/A	N/A	46	170	16	69	-	-
Wed, Aug 9 2017	44	180	17	66	N/A	N/A	33	113	18	63	-	-
Thu, Aug 10 2017	41	152	26	96	N/A	N/A	54	184	21	53	-	-
Fri, Aug 11 2017	42	158	56	264	N/A	N/A	113	633	21	55	-	-
Sat, Aug 12 2017	25	110	15	52	N/A	N/A	34	138	20	54	-	-
Sun, Aug 13 2017	27	121	11	42	N/A	N/A	24	74	24	133	-	-
Mon, Aug 14 2017	24	123	12	47	N/A	N/A	37	280	37	420	-	-
Tue, Aug 15 2017	N/A	N/A	19	79	N/A	N/A	60	202	33	319	-	-
Wed, Aug 16 2017	N/A	N/A	15	53	N/A	N/A	40	131	33	314	-	-
Thu, Aug 17 2017	N/A	N/A	15	56	N/A	N/A	30	94	25	300	-	-
Fri, Aug 18 2017	N/A	N/A	14	53	N/A	N/A	30	124	22	140	-	-
Sat, Aug 19 2017	N/A	N/A	8	38	N/A	N/A	22	93	18	49	-	-
Sun, Aug 20 2017	N/A	N/A	11	41	N/A	N/A	20	90	32	180	-	-
Mon, Aug 21 2017	N/A	N/A	12	56	N/A	N/A	35	141	32	170	-	-
Tue, Aug 22 2017	N/A	N/A	19	108	N/A	N/A	35	138	22	105	-	-
Wed, Aug 23 2017	N/A	N/A	29	114	N/A	N/A	58	194	30	108	-	-
Thu, Aug 24 2017	N/A	N/A	36	143	N/A	N/A	44	152	44	372	-	-
Fri, Aug 25 2017	77	553	32	96	N/A	N/A	49	197	21	55	-	-
Sat, Aug 26 2017	32	149	14	47	N/A	N/A	31	89	21	58	-	-
Sun, Aug 27 2017	43	266	14	42	N/A	N/A	29	181	24	61	-	-
Mon, Aug 28 2017	35	200	14	49	N/A	N/A	24	98	28	101	-	-
Tue, Aug 29 2017	35	184	18	95	N/A	N/A	41	325	53	386	-	-
Wed, Aug 30 2017	38	161	18	61	N/A	N/A	33	105	24	99	-	-
Thu, Aug 31 2017	40	178	24	95	N/A	N/A	31	96	27	124	-	-
Fri, Sep 1 2017	38	234	14	62	N/A	N/A	23	93	20	66	-	-
Sat, Sep 2 2017	28	149	12	74	N/A	N/A	22	150	21	78	-	-
Sun, Sep 3 2017	30	149	10	44	N/A	N/A	20	88	27	132	-	-
Mon, Sep 4 2017	61	1009	10	45	N/A	N/A	29	122	48	295	-	-
Tue, Sep 5 2017	75	422	18	81	N/A	N/A	28	118	28	126	-	-
Wed, Sep 6 2017	46	194	15	72	N/A	N/A	23	94	16	98	-	-
Thu, Sep 7 2017	38	180	28	84	N/A	N/A	39	170	26	138	-	-
Fri, Sep 8 2017	37	165	22	78	N/A	N/A	42	145	27	72	-	-

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Sep 9 2017	27	122	13	47	N/A	N/A	34	361	48	268	-	-
Sun, Sep 10 2017	28	194	11	60	N/A	N/A	28	164	41	257	-	-
Mon, Sep 11 2017	48	294	13	50	N/A	N/A	29	89	34	230	-	-
Tue, Sep 12 2017	64	312	13	68	N/A	N/A	27	99	34	229	-	-
Wed, Sep 13 2017	62	310	12	47	N/A	N/A	18	99	22	80	-	-
Thu, Sep 14 2017	49	242	14	60	N/A	N/A	16	81	34	225	-	-
Fri, Sep 15 2017	35	149	13	56	N/A	N/A	22	94	20	70	-	-
Sat, Sep 16 2017	22	116	13	62	N/A	N/A	30	109	28	147	-	-
Sun, Sep 17 2017	32	163	20	78	N/A	N/A	50	251	23	69	-	-
Mon, Sep 18 2017	31	120	36	135	N/A	N/A	49	179	28	66	-	-
Tue, Sep 19 2017	33	137	25	102	N/A	N/A	51	254	38	355	-	-
Wed, Sep 20 2017	36	155	23	94	N/A	N/A	39	136	30	101	-	-
Thu, Sep 21 2017	32	133	25	97	N/A	N/A	68	268	21	58	-	-
Fri, Sep 22 2017	33	134	25	98	N/A	N/A	75	404	19	54	-	-
Sat, Sep 23 2017	34	174	11	41	N/A	N/A	34	234	17	60	-	-
Sun, Sep 24 2017	29	134	10	39	N/A	N/A	24	143	18	60	-	-
Mon, Sep 25 2017	45	234	13	59	N/A	N/A	32	271	19	89	-	-
Tue, Sep 26 2017	39	185	20	94	N/A	N/A	22	127	17	80	-	-
Wed, Sep 27 2017	39	157	15	66	N/A	N/A	34	138	22	73	-	-
Thu, Sep 28 2017	37	163	22	81	N/A	N/A	45	177	35	350	-	-
Fri, Sep 29 2017	33	173	13	46	N/A	N/A	28	121	18	84	-	-
Sat, Sep 30 2017	37	240	14	52	N/A	N/A	32	84	41	279	-	-
Sun, Oct 1 2017	33	180	21	67	N/A	N/A	39	104	55	272	-	-
Mon, Oct 2 2017	106	434	16	66	N/A	N/A	40	125	54	224	-	-
Tue, Oct 3 2017	45	219	15	76	N/A	N/A	29	132	35	189	-	-
Wed, Oct 4 2017	32	184	19	81	N/A	N/A	54	188	30	177	-	-
Thu, Oct 5 2017	43	197	32	104	N/A	N/A	68	330	47	326	-	-
Fri, Oct 6 2017	29	126	22	73	N/A	N/A	37	94	36	211	-	-
Sat, Oct 7 2017	25	161	15	55	N/A	N/A	37	329	48	664	-	-
Sun, Oct 8 2017	29	139	12	46	N/A	N/A	33	109	55	483	-	-
Mon, Oct 9 2017	33	226	9	50	N/A	N/A	23	99	16	120	-	-
Tue, Oct 10 2017	37	163	10	55	N/A	N/A	26	82	31	204	-	-
Wed, Oct 11 2017	45	271	16	63	N/A	N/A	35	181	30	302	-	-
Thu, Oct 12 2017	57	270	12	49	N/A	N/A	26	111	36	285	-	-
Fri, Oct 13 2017	38	156	16	62	N/A	N/A	28	94	31	210	-	-
Sat, Oct 14 2017	37	223	13	52	N/A	N/A	30	83	45	316	-	-
Sun, Oct 15 2017	22	104	15	59	N/A	N/A	64	508	75	594	-	-
Mon, Oct 16 2017	33	159	28	103	N/A	N/A	75	824	52	480	-	-
Tue, Oct 17 2017	33	186	32	152	N/A	N/A	44	138	35	286	-	-
Wed, Oct 18 2017	21	107	17	74	N/A	N/A	67	513	90	621	-	-
Thu, Oct 19 2017	24	100	16	69	N/A	N/A	35	210	45	470	-	-
Fri, Oct 20 2017	22	113	19	67	N/A	N/A	50	302	58	493	-	-
Sat, Oct 21 2017	28	116	15	48	N/A	N/A	30	76	31	99	-	-
Sun, Oct 22 2017	31	163	16	45	N/A	N/A	36	157	52	309	-	-
Mon, Oct 23 2017	13	114	11	38	N/A	N/A	86	414	129	557	-	-
Tue, Oct 24 2017	21	115	14	54	N/A	N/A	23	87	52	460	-	-
Wed, Oct 25 2017	30	185	17	54	N/A	N/A	29	118	50	474	-	-
Thu, Oct 26 2017	24	104	17	61	N/A	N/A	32	103	40	305	-	-
Fri, Oct 27 2017	30	139	14	55	N/A	N/A	23	86	56	557	-	-
Sat, Oct 28 2017	20	168	9	60	N/A	N/A	22	87	37	386	-	-
Sun, Oct 29 2017	25	151	8	56	N/A	N/A	15	75	25	198	-	-
Mon, Oct 30 2017	42	193	15	53	N/A	N/A	28	69	43	219	-	-
Tue, Oct 31 2017	34	170	8	39	N/A	N/A	37	190	49	371	-	-
Wed, Nov 1 2017	51	249	17	57	N/A	N/A	50	206	71	406	-	-
Thu, Nov 2 2017	47	207	26	86	N/A	N/A	38	91	47	318	-	-
Fri, Nov 3 2017	30	150	17	62	N/A	N/A	33	123	36	141	-	-
Sat, Nov 4 2017	17	96	11	38	N/A	N/A	21	83	24	142	-	-
Sun, Nov 5 2017	20	105	11	39	N/A	N/A	39	366	58	478	-	-
Mon, Nov 6 2017	43	195	28	90	N/A	N/A	38	106	40	235	-	-
Tue, Nov 7 2017	23	172	15	69	N/A	N/A	31	232	48	681	-	-
Wed, Nov 8 2017	30	134	12	73	N/A	N/A	36	277	34	180	-	-
Thu, Nov 9 2017	26	135	12	44	N/A	N/A	29	130	27	197	-	-
Fri, Nov 10 2017	23	142	8	41	N/A	N/A	26	180	36	166	-	-

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Nov 11 2017	12	54	6	27	N/A	N/A	51	394	70	403	-	-
Sun, Nov 12 2017	20	89	9	48	N/A	N/A	21	254	40	858	-	-
Mon, Nov 13 2017	28	149	12	61	N/A	N/A	23	79	17	57	-	-
Tue, Nov 14 2017	26	113	15	56	N/A	N/A	50	161	42	215	-	-
Wed, Nov 15 2017	26	118	23	70	N/A	N/A	71	501	55	462	-	-
Thu, Nov 16 2017	28	108	19	68	N/A	N/A	49	141	20	67	-	-
Fri, Nov 17 2017	38	255	12	40	N/A	N/A	21	74	23	108	-	-
Sat, Nov 18 2017	17	107	10	41	N/A	N/A	16	47	33	240	-	-
Sun, Nov 19 2017	32	424	11	37	N/A	N/A	24	93	52	535	-	-
Mon, Nov 20 2017	26	137	20	72	N/A	N/A	32	106	51	360	-	-
Tue, Nov 21 2017	53	1009	28	216	N/A	N/A	40	235	41	623	-	-
Wed, Nov 22 2017	36	148	28	88	N/A	N/A	71	332	49	396	-	-
Thu, Nov 23 2017	25	118	21	86	N/A	N/A	51	447	39	264	-	-
Fri, Nov 24 2017	19	120	27	269	46	46	76	842	68	818	-	-
Sat, Nov 25 2017	17	80	8	35	28	118	20	116	30	191	-	-
Sun, Nov 26 2017	21	89	15	41	36	135	39	244	45	434	-	-
Mon, Nov 27 2017	16	72	17	54	N/A	N/A	39	235	47	230	-	-
Tue, Nov 28 2017	26	128	17	48	N/A	N/A	33	82	54	270	-	-
Wed, Nov 29 2017	32	139	19	72	N/A	N/A	57	232	50	388	-	-
Thu, Nov 30 2017	46	913	20	59	N/A	N/A	33	218	36	244	-	-
Fri, Dec 1 2017	13	74	11	32	N/A	N/A	28	112	29	322	-	-
Sat, Dec 2 2017	10	76	11	36	N/A	N/A	59	343	71	494	-	-
Sun, Dec 3 2017	27	102	20	44	N/A	N/A	34	106	24	104	-	-
Mon, Dec 4 2017	30	130	22	67	N/A	N/A	40	104	48	426	-	-
Tue, Dec 5 2017	29	116	28	91	5	6	72	250	41	259	-	-
Wed, Dec 6 2017	51	223	27	57	58	168	44	99	48	455	-	-
Thu, Dec 7 2017	44	209	18	54	52	211	40	167	59	371	-	-
Fri, Dec 8 2017	50	238	16	141	N/A	N/A	37	109	61	357	-	-
Sat, Dec 9 2017	23	127	12	74	N/A	N/A	31	172	48	375	-	-
Sun, Dec 10 2017	24	142	10	50	N/A	N/A	28	93	43	255	-	-
Mon, Dec 11 2017	39	240	11	46	N/A	N/A	32	153	48	515	-	-
Tue, Dec 12 2017	21	155	12	57	N/A	N/A	35	216	49	610	-	-
Wed, Dec 13 2017	25	96	20	65	2	2	46	139	58	458	-	-
Thu, Dec 14 2017	35	300	24	101	67	279	58	483	28	920	-	-
Fri, Dec 15 2017	21	127	15	55	48	285	51	444	110	1002	-	-
Sat, Dec 16 2017	54	321	11	41	42	204	44	215	73	653	-	-
Sun, Dec 17 2017	17	106	8	39	28	123	35	234	45	193	-	-
Mon, Dec 18 2017	44	203	12	37	40	164	25	70	41	216	-	-
Tue, Dec 19 2017	7	49	7	30	7	7	32	126	28	133	-	-
Wed, Dec 20 2017	5	46	4	22	16	99	18	166	22	348	-	-
Thu, Dec 21 2017	20	92	9	41	35	145	26	81	25	138	-	-
Fri, Dec 22 2017	17	71	10	41	39	160	34	277	32	322	-	-
Sat, Dec 23 2017	28	105	11	41	33	125	23	80	36	345	-	-
Sun, Dec 24 2017	19	96	9	39	30	133	18	54	27	124	-	-
Mon, Dec 25 2017	20	101	8	30	26	101	17	69	37	159	-	-
Tue, Dec 26 2017	10	66	8	32	33	232	59	285	100	423	-	-
Wed, Dec 27 2017	23	118	9	59	27	119	23	195	54	627	-	-
Thu, Dec 28 2017	24	194	9	57	30	155	23	77	34	299	-	-
Fri, Dec 29 2017	23	97	10	43	33	120	20	65	24	214	-	-
Sat, Dec 30 2017	17	73	7	26	24	131	17	102	13	51	-	-
Sun, Dec 31 2017	25	100	12	41	32	154	24	65	21	79	-	-
Mon, Jan 1 2018	22	121	11	43	26	113	25	198	26	436	-	-
Tue, Jan 2 2018	28	118	21	66	46	156	38	131	47	674	-	-
Wed, Jan 3 2018	31	125	25	71	46	160	40	164	22	102	-	-
Thu, Jan 4 2018	27	116	18	67	49	242	36	123	24	103	-	-
Fri, Jan 5 2018	30	127	28	83	95	307	45	140	28	101	-	-
Sat, Jan 6 2018	24	133	13	34	30	115	27	84	39	330	-	-
Sun, Jan 7 2018	19	89	13	38	27	106	32	153	39	586	-	-
Mon, Jan 8 2018	28	120	21	86	51	246	43	416	41	280	-	-
Tue, Jan 9 2018	32	172	18	68	49	196	39	138	61	523	-	-
Wed, Jan 10 2018	38	201	20	92	50	200	51	190	41	316	-	-
Thu, Jan 11 2018	47	216	18	59	45	158	34	89	56	370	-	-
Fri, Jan 12 2018	47	235	14	59	N/A	N/A	44	116	54	246	-	-

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Jan 13 2018	33	156	14	49	N/A	N/A	36	111	51	301	-	-
Sun, Jan 14 2018	27	144	15	48	N/A	N/A	32	149	83	1004	-	-
Mon, Jan 15 2018	26	144	12	49	N/A	N/A	23	80	97	895	-	-
Tue, Jan 16 2018	31	143	17	84	2	3	38	124	100	815	-	-
Wed, Jan 17 2018	42	157	27	156	94	561	56	171	100	414	-	-
Thu, Jan 18 2018	143	1009	50	220	114	521	129	850	49	864	-	-
Fri, Jan 19 2018	30	136	17	49	N/A	N/A	40	168	72	593	-	-
Sat, Jan 20 2018	21	143	10	64	N/A	N/A	53	302	109	736	-	-
Sun, Jan 21 2018	21	106	10	38	N/A	N/A	14	66	62	591	-	-
Mon, Jan 22 2018	25	119	13	53	N/A	N/A	33	105	73	610	-	-
Tue, Jan 23 2018	27	143	20	93	N/A	N/A	37	128	72	519	-	-
Wed, Jan 24 2018	29	144	21	69	N/A	N/A	33	84	53	751	-	-
Thu, Jan 25 2018	41	152	20	47	N/A	N/A	42	96	91	912	-	-
Fri, Jan 26 2018	47	282	15	52	N/A	N/A	33	147	76	717	-	-
Sat, Jan 27 2018	25	153	15	43	N/A	N/A	30	90	80	721	-	-
Sun, Jan 28 2018	19	94	9	32	N/A	N/A	17	55	74	835	-	-
Mon, Jan 29 2018	41	288	11	51	N/A	N/A	24	78	45	198	-	-
Tue, Jan 30 2018	44	261	9	39	N/A	N/A	27	175	41	262	-	-
Wed, Jan 31 2018	46	182	17	46	N/A	N/A	45	134	79	633	-	-
Thu, Feb 1 2018	29	133	12	48	N/A	N/A	73	261	85	437	-	-
Fri, Feb 2 2018	22	127	15	56	N/A	N/A	88	469	137	764	-	-
Sat, Feb 3 2018	20	88	16	39	N/A	N/A	67	414	78	542	-	-
Sun, Feb 4 2018	17	55	13	35	N/A	N/A	87	521	120	795	-	-
Mon, Feb 5 2018	20	62	9	46	N/A	N/A	29	243	50	422	-	-
Tue, Feb 6 2018	35	178	10	42	N/A	N/A	23	60	48	608	-	-
Wed, Feb 7 2018	34	151	11	47	N/A	N/A	33	295	39	214	-	-
Thu, Feb 8 2018	32	404	15	56	N/A	N/A	47	220	29	329	-	-
Fri, Feb 9 2018	30	99	24	79	N/A	N/A	55	175	72	799	-	-
Sat, Feb 10 2018	28	107	22	58	N/A	N/A	44	149	38	165	-	-
Sun, Feb 11 2018	21	151	9	47	N/A	N/A	17	96	47	417	-	-
Mon, Feb 12 2018	40	180	11	41	N/A	N/A	24	88	38	325	-	-
Tue, Feb 13 2018	25	170	17	37	N/A	N/A	66	262	97	707	-	-
Wed, Feb 14 2018	10	80	7	27	N/A	N/A	69	949	90	450	-	-
Thu, Feb 15 2018	22	103	-	-	N/A	N/A	27	114	39	215	-	-
Fri, Feb 16 2018	31	155	-	-	N/A	N/A	29	120	39	261	-	-
Sat, Feb 17 2018	29	123	-	-	N/A	N/A	15	53	22	122	-	-
Sun, Feb 18 2018	8	64	-	-	N/A	N/A	29	372	N/A	N/A	-	-
Mon, Feb 19 2018	26	117	-	-	N/A	N/A	31	92	N/A	N/A	-	-
Tue, Feb 20 2018	36	157	-	-	N/A	N/A	35	171	N/A	N/A	-	-
Wed, Feb 21 2018	32	149	-	-	N/A	N/A	26	78	N/A	N/A	-	-
Thu, Feb 22 2018	13	63	-	-	N/A	N/A	47	258	N/A	N/A	-	-
Fri, Feb 23 2018	27	113	-	-	N/A	N/A	35	97	N/A	N/A	-	-
Sat, Feb 24 2018	24	79	-	-	N/A	N/A	51	378	N/A	N/A	-	-
Sun, Feb 25 2018	22	140	-	-	N/A	N/A	82	398	N/A	N/A	-	-
Mon, Feb 26 2018	19	77	-	-	N/A	N/A	54	280	N/A	N/A	-	-
Tue, Feb 27 2018	43	123	-	-	N/A	N/A	54	158	N/A	N/A	-	-
Wed, Feb 28 2018	30	125	-	-	N/A	N/A	58	184	N/A	N/A	-	-
Thu, Mar 1 2018	32	189	-	-	N/A	N/A	86	798	N/A	N/A	-	-
Fri, Mar 2 2018	23	112	16	66	N/A	N/A	52	313	N/A	N/A	-	-
Sat, Mar 3 2018	19	81	12	31	N/A	N/A	37	186	N/A	N/A	-	-
Sun, Mar 4 2018	24	150	15	43	N/A	N/A	30	67	N/A	N/A	-	-
Mon, Mar 5 2018	24	98	18	54	N/A	N/A	36	95	N/A	N/A	-	-
Tue, Mar 6 2018	22	89	17	50	N/A	N/A	36	187	N/A	N/A	-	-
Wed, Mar 7 2018	24	122	18	72	N/A	N/A	40	219	N/A	N/A	-	-
Thu, Mar 8 2018	23	97	24	99	N/A	N/A	39	169	N/A	N/A	-	-
Fri, Mar 9 2018	27	99	22	76	N/A	N/A	35	95	N/A	N/A	-	-
Sat, Mar 10 2018	24	93	13	39	N/A	N/A	26	60	N/A	N/A	-	-
Sun, Mar 11 2018	20	110	16	47	N/A	N/A	24	56	N/A	N/A	-	-
Mon, Mar 12 2018	19	73	23	92	N/A	N/A	28	157	N/A	N/A	-	-
Tue, Mar 13 2018	20	79	14	59	N/A	N/A	44	242	N/A	N/A	-	-
Wed, Mar 14 2018	30	119	18	61	N/A	N/A	54	260	N/A	N/A	-	-
Thu, Mar 15 2018	36	148	15	41	N/A	N/A	53	267	N/A	N/A	-	-
Fri, Mar 16 2018	43	241	13	56	N/A	N/A	40	249	N/A	N/A	-	-

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, Mar 17 2018	31	141	11	50	N/A	N/A	26	129	N/A	N/A	-	-
Sun, Mar 18 2018	10	66	4	26	N/A	N/A	14	70	N/A	N/A	-	-
Mon, Mar 19 2018	22	104	20	75	N/A	N/A	38	95	N/A	N/A	-	-
Tue, Mar 20 2018	22	107	19	59	N/A	N/A	33	83	N/A	N/A	-	-
Wed, Mar 21 2018	30	176	18	63	N/A	N/A	34	82	N/A	N/A	-	-
Thu, Mar 22 2018	17	97	16	50	N/A	N/A	60	285	N/A	N/A	-	-
Fri, Mar 23 2018	31	166	16	46	N/A	N/A	70	336	N/A	N/A	-	-
Sat, Mar 24 2018	15	105	6	30	N/A	N/A	43	332	N/A	N/A	-	-
Sun, Mar 25 2018	27	112	11	42	N/A	N/A	45	525	N/A	N/A	-	-
Mon, Mar 26 2018	25	113	8	42	N/A	N/A	43	796	N/A	N/A	-	-
Tue, Mar 27 2018	29	127	8	33	N/A	N/A	18	56	N/A	N/A	-	-
Wed, Mar 28 2018	45	231	12	77	N/A	N/A	24	241	N/A	N/A	-	-
Thu, Mar 29 2018	51	203	11	35	N/A	N/A	23	70	N/A	N/A	-	-
Fri, Mar 30 2018	36	179	13	48	N/A	N/A	40	226	N/A	N/A	-	-
Sat, Mar 31 2018	18	89	11	43	N/A	N/A	66	611	N/A	N/A	-	-
Sun, Apr 1 2018	31	134	15	49	N/A	N/A	39	187	N/A	N/A	-	-
Mon, Apr 2 2018	10	42	8	26	N/A	N/A	83	517	N/A	N/A	-	-
Tue, Apr 3 2018	27	119	9	33	N/A	N/A	32	186	N/A	N/A	-	-
Wed, Apr 4 2018	16	69	11	35	N/A	N/A	91	354	N/A	N/A	-	-
Thu, Apr 5 2018	23	107	8	31	N/A	N/A	40	176	N/A	N/A	-	-
Fri, Apr 6 2018	25	112	15	69	N/A	N/A	30	84	N/A	N/A	-	-
Sat, Apr 7 2018	19	80	8	29	N/A	N/A	31	146	N/A	N/A	-	-
Sun, Apr 8 2018	15	82	5	31	N/A	N/A	15	86	N/A	N/A	-	-
Mon, Apr 9 2018	26	112	18	80	N/A	N/A	28	83	N/A	N/A	-	-
Tue, Apr 10 2018	38	174	24	75	N/A	N/A	32	83	N/A	N/A	-	-
Wed, Apr 11 2018	28	165	26	111	N/A	N/A	41	108	N/A	N/A	-	-
Thu, Apr 12 2018	24	86	14	65	N/A	N/A	32	340	N/A	N/A	-	-
Fri, Apr 13 2018	35	128	24	75	N/A	N/A	53	353	N/A	N/A	-	-
Sat, Apr 14 2018	18	98	12	59	N/A	N/A	62	559	N/A	N/A	-	-
Sun, Apr 15 2018	23	112	14	49	N/A	N/A	42	233	N/A	N/A	-	-
Mon, Apr 16 2018	35	291	27	92	N/A	N/A	41	183	N/A	N/A	-	-
Tue, Apr 17 2018	23	96	30	94	N/A	N/A	49	330	N/A	N/A	-	-
Wed, Apr 18 2018	34	146	23	77	N/A	N/A	51	311	N/A	N/A	-	-
Thu, Apr 19 2018	23	124	16	47	N/A	N/A	29	140	N/A	N/A	-	-
Fri, Apr 20 2018	30	111	30	139	N/A	N/A	36	133	N/A	N/A	-	-
Sat, Apr 21 2018	26	96	14	56	N/A	N/A	53	357	N/A	N/A	-	-
Sun, Apr 22 2018	23	137	14	46	N/A	N/A	20	59	N/A	N/A	-	-
Mon, Apr 23 2018	27	109	27	109	N/A	N/A	45	214	N/A	N/A	-	-
Tue, Apr 24 2018	34	95	17	52	N/A	N/A	31	125	N/A	N/A	-	-
Wed, Apr 25 2018	34	126	26	87	N/A	N/A	38	103	N/A	N/A	-	-
Thu, Apr 26 2018	28	151	11	47	N/A	N/A	25	139	N/A	N/A	-	-
Fri, Apr 27 2018	28	117	8	27	N/A	N/A	43	174	N/A	N/A	-	-
Sat, Apr 28 2018	18	87	12	50	N/A	N/A	18	69	N/A	N/A	-	-
Sun, Apr 29 2018	32	117	14	44	N/A	N/A	29	82	N/A	N/A	-	-
Mon, Apr 30 2018	38	169	11	36	N/A	N/A	24	54	N/A	N/A	-	-
Tue, May 1 2018	43	273	10	48	N/A	N/A	26	109	N/A	N/A	-	-
Wed, May 2 2018	21	171	9	41	N/A	N/A	28	174	N/A	N/A	-	-
Thu, May 3 2018	28	159	9	40	N/A	N/A	27	103	N/A	N/A	-	-
Fri, May 4 2018	43	162	11	45	N/A	N/A	25	84	N/A	N/A	-	-
Sat, May 5 2018	18	84	7	37	N/A	N/A	15	56	N/A	N/A	-	-
Sun, May 6 2018	23	104	8	36	N/A	N/A	17	42	N/A	N/A	-	-
Mon, May 7 2018	30	155	20	75	N/A	N/A	68	259	N/A	N/A	-	-
Tue, May 8 2018	28	141	20	71	N/A	N/A	31	90	N/A	N/A	-	-
Wed, May 9 2018	37	152	20	64	N/A	N/A	40	130	N/A	N/A	-	-
Thu, May 10 2018	52	307	16	58	N/A	N/A	37	140	N/A	N/A	-	-
Fri, May 11 2018	50	245	17	47	N/A	N/A	40	148	N/A	N/A	-	-
Sat, May 12 2018	22	120	13	41	N/A	N/A	21	79	N/A	N/A	-	-
Sun, May 13 2018	20	90	13	52	N/A	N/A	20	54	N/A	N/A	-	-
Mon, May 14 2018	25	131	19	89	N/A	N/A	28	75	N/A	N/A	-	-
Tue, May 15 2018	31	138	20	112	N/A	N/A	21	63	N/A	N/A	-	-
Wed, May 16 2018	44	218	13	45	N/A	N/A	24	85	N/A	N/A	-	-
Thu, May 17 2018	36	189	22	107	N/A	N/A	33	111	N/A	N/A	-	-
Fri, May 18 2018	33	144	31	117	N/A	N/A	37	110	N/A	N/A	-	-

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2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Sat, May 19 2018	33	121	34	101	N/A	N/A	46	240	N/A	N/A	-	-
Sun, May 20 2018	37	219	24	54	N/A	N/A	45	214	N/A	N/A	-	-
Mon, May 21 2018	26	102	21	81	N/A	N/A	52	166	N/A	N/A	-	-
Tue, May 22 2018	30	126	30	137	N/A	N/A	33	85	N/A	N/A	-	-
Wed, May 23 2018	24	147	24	105	N/A	N/A	37	182	N/A	N/A	-	-
Thu, May 24 2018	30	140	34	157	N/A	N/A	39	128	N/A	N/A	-	-
Fri, May 25 2018	31	132	22	86	N/A	N/A	42	127	N/A	N/A	-	-
Sat, May 26 2018	21	119	13	37	N/A	N/A	22	66	N/A	N/A	-	-
Sun, May 27 2018	20	84	9	34	N/A	N/A	17	64	N/A	N/A	-	-
Mon, May 28 2018	20	106	10	44	N/A	N/A	31	418	N/A	N/A	-	-
Tue, May 29 2018	2	11	9	20	N/A	N/A	20	103	N/A	N/A	-	-
Tue, Jul 24 2018	-	-	-	-	N/A	N/A	27	76	-	-	-	-
Wed, Jul 25 2018	-	-	-	-	N/A	N/A	32	149	-	-	-	-
Thu, Jul 26 2018	-	-	5	26	N/A	N/A	24	80	N/A	N/A	-	-
Fri, Jul 27 2018	-	-	26	85	N/A	N/A	34	89	N/A	N/A	-	-
Sat, Jul 28 2018	-	-	16	59	N/A	N/A	26	77	N/A	N/A	-	-
Sun, Jul 29 2018	-	-	14	38	N/A	N/A	28	80	N/A	N/A	-	-
Mon, Jul 30 2018	-	-	16	47	N/A	N/A	34	83	N/A	N/A	-	-
Tue, Jul 31 2018	-	-	21	61	N/A	N/A	38	121	N/A	N/A	-	-
Wed, Aug 1 2018	36	199	55	260	N/A	N/A	78	765	N/A	N/A	-	-
Thu, Aug 2 2018	28	106	38	140	N/A	N/A	52	151	N/A	N/A	-	-
Fri, Aug 3 2018	25	115	26	108	N/A	N/A	54	179	N/A	N/A	-	-
Sat, Aug 4 2018	21	99	15	41	N/A	N/A	46	262	N/A	N/A	-	-
Sun, Aug 5 2018	20	93	10	29	N/A	N/A	29	268	N/A	N/A	-	-
Mon, Aug 6 2018	28	111	13	41	N/A	N/A	29	97	N/A	N/A	-	-
Tue, Aug 7 2018	28	123	14	46	N/A	N/A	36	143	N/A	N/A	-	-
Wed, Aug 8 2018	27	121	32	123	N/A	N/A	44	126	N/A	N/A	-	-
Thu, Aug 9 2018	29	129	12	41	N/A	N/A	20	72	N/A	N/A	-	-
Fri, Aug 10 2018	24	102	15	74	N/A	N/A	33	193	N/A	N/A	-	-
Sat, Aug 11 2018	24	109	9	35	N/A	N/A	22	149	N/A	N/A	-	-
Sun, Aug 12 2018	28	121	15	41	N/A	N/A	28	82	N/A	N/A	-	-
Mon, Aug 13 2018	34	174	19	62	N/A	N/A	33	117	N/A	N/A	-	-
Tue, Aug 14 2018	34	151	12	44	N/A	N/A	24	101	N/A	N/A	-	-
Wed, Aug 15 2018	35	161	17	75	N/A	N/A	26	109	N/A	N/A	-	-
Thu, Aug 16 2018	45	211	16	54	N/A	N/A	25	104	N/A	N/A	-	-
Fri, Aug 17 2018	42	185	16	70	N/A	N/A	18	85	N/A	N/A	-	-
Sat, Aug 18 2018	23	108	11	50	N/A	N/A	29	295	N/A	N/A	-	-
Sun, Aug 19 2018	26	167	12	49	N/A	N/A	26	103	N/A	N/A	-	-
Mon, Aug 20 2018	27	116	18	80	N/A	N/A	36	106	N/A	N/A	-	-
Tue, Aug 21 2018	33	152	42	171	N/A	N/A	69	447	N/A	N/A	-	-
Wed, Aug 22 2018	30	114	17	52	N/A	N/A	43	165	N/A	N/A	-	-
Thu, Aug 23 2018	10	44	11	53	N/A	N/A	32	181	N/A	N/A	-	-
Fri, Aug 24 2018	23	277	15	43	N/A	N/A	69	526	N/A	N/A	-	-
Sat, Aug 25 2018	17	73	10	31	N/A	N/A	50	288	N/A	N/A	-	-
Sun, Aug 26 2018	17	81	9	32	N/A	N/A	43	402	N/A	N/A	-	-
Mon, Aug 27 2018	21	84	11	40	N/A	N/A	53	324	N/A	N/A	-	-
Tue, Aug 28 2018	26	145	14	53	N/A	N/A	38	172	N/A	N/A	-	-
Wed, Aug 29 2018	31	119	22	65	N/A	N/A	29	69	N/A	N/A	-	-
Thu, Aug 30 2018	27	111	28	156	N/A	N/A	44	159	N/A	N/A	-	-
Fri, Aug 31 2018	30	111	20	84	N/A	N/A	35	160	N/A	N/A	-	-
Sat, Sep 1 2018	23	116	13	40	N/A	N/A	38	395	N/A	N/A	-	-
Sun, Sep 2 2018	25	114	9	34	N/A	N/A	47	345	N/A	N/A	-	-
Mon, Sep 3 2018	28	176	8	31	N/A	N/A	33	215	N/A	N/A	-	-
Tue, Sep 4 2018	28	113	16	71	N/A	N/A	32	170	N/A	N/A	-	-
Wed, Sep 5 2018	30	119	31	160	N/A	N/A	53	303	N/A	N/A	-	-
Thu, Sep 6 2018	31	151	30	108	N/A	N/A	60	181	N/A	N/A	-	-
Fri, Sep 7 2018	32	138	20	78	N/A	N/A	33	115	N/A	N/A	-	-
Sat, Sep 8 2018	27	136	13	43	N/A	N/A	26	101	N/A	N/A	-	-
Sun, Sep 9 2018	25	108	10	47	N/A	N/A	19	69	N/A	N/A	-	-
Mon, Sep 10 2018	42	237	12	39	N/A	N/A	24	115	N/A	N/A	-	-
Tue, Sep 11 2018	43	119	29	83	N/A	N/A	32	87	N/A	N/A	-	-
Wed, Sep 12 2018	7	49	8	45	N/A	N/A	91	328	N/A	N/A	-	-
Thu, Sep 13 2018	20	86	12	35	N/A	N/A	42	252	N/A	N/A	-	-

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Fri, Sep 14 2018	30	115	24	95	N/A	N/A	39	106	N/A	N/A	-	-
Sat, Sep 15 2018	21	100	12	37	N/A	N/A	38	278	N/A	N/A	-	-
Sun, Sep 16 2018	22	113	11	34	N/A	N/A	22	60	N/A	N/A	-	-
Mon, Sep 17 2018	24	100	10	34	N/A	N/A	29	109	N/A	N/A	-	-
Tue, Sep 18 2018	34	138	17	59	N/A	N/A	33	116	N/A	N/A	-	-
Wed, Sep 19 2018	54	221	18	73	N/A	N/A	33	212	N/A	N/A	-	-
Thu, Sep 20 2018	55	358	17	67	N/A	N/A	31	438	N/A	N/A	-	-
Fri, Sep 21 2018	39	176	20	75	N/A	N/A	33	107	N/A	N/A	-	-
Sat, Sep 22 2018	25	123	14	44	N/A	N/A	25	79	N/A	N/A	-	-
Sun, Sep 23 2018	30	161	12	46	N/A	N/A	24	82	N/A	N/A	-	-
Mon, Sep 24 2018	45	208	13	58	N/A	N/A	27	81	N/A	N/A	-	-
Tue, Sep 25 2018	33	183	13	47	N/A	N/A	42	115	N/A	N/A	-	-
Wed, Sep 26 2018	43	220	10	39	N/A	N/A	61	189	N/A	N/A	-	-
Thu, Sep 27 2018	24	157	13	219	N/A	N/A	32	547	N/A	N/A	-	-
Fri, Sep 28 2018	13	92	9	50	N/A	N/A	35	457	N/A	N/A	-	-
Sat, Sep 29 2018	28	133	8	32	N/A	N/A	12	54	N/A	N/A	-	-
Sun, Sep 30 2018	20	99	6	25	N/A	N/A	17	56	N/A	N/A	-	-
Mon, Oct 1 2018	44	181	9	38	N/A	N/A	16	79	N/A	N/A	-	-
Tue, Oct 2 2018	47	198	12	41	N/A	N/A	18	71	N/A	N/A	-	-
Wed, Oct 3 2018	33	166	11	47	N/A	N/A	20	74	N/A	N/A	-	-
Thu, Oct 4 2018	45	175	12	43	N/A	N/A	18	76	N/A	N/A	-	-
Fri, Oct 5 2018	45	193	14	52	N/A	N/A	26	90	N/A	N/A	-	-
Sat, Oct 6 2018	22	128	8	37	N/A	N/A	19	77	N/A	N/A	-	-
Sun, Oct 7 2018	19	101	9	42	N/A	N/A	25	107	N/A	N/A	-	-
Mon, Oct 8 2018	33	139	16	64	N/A	N/A	29	96	N/A	N/A	-	-
Tue, Oct 9 2018	31	131	11	40	N/A	N/A	30	171	N/A	N/A	-	-
Wed, Oct 10 2018	28	143	11	50	N/A	N/A	29	160	N/A	N/A	-	-
Thu, Oct 11 2018	40	184	10	71	N/A	N/A	21	144	N/A	N/A	-	-
Fri, Oct 12 2018	37	187	9	40	N/A	N/A	35	203	N/A	N/A	-	-
Sat, Oct 13 2018	20	147	9	48	N/A	N/A	16	83	N/A	N/A	-	-
Sun, Oct 14 2018	27	142	8	67	N/A	N/A	20	72	N/A	N/A	-	-
Mon, Oct 15 2018	22	110	12	49	N/A	N/A	31	226	N/A	N/A	-	-
Tue, Oct 16 2018	28	143	15	58	N/A	N/A	31	130	N/A	N/A	-	-
Wed, Oct 17 2018	32	148	19	64	N/A	N/A	28	85	N/A	N/A	-	-
Thu, Oct 18 2018	38	158	14	53	N/A	N/A	19	73	N/A	N/A	-	-
Fri, Oct 19 2018	42	215	12	56	N/A	N/A	21	76	N/A	N/A	-	-
Sat, Oct 20 2018	23	108	6	31	N/A	N/A	18	100	N/A	N/A	-	-
Sun, Oct 21 2018	27	149	8	36	N/A	N/A	18	71	N/A	N/A	-	-
Mon, Oct 22 2018	32	159	14	64	N/A	N/A	42	239	N/A	N/A	-	-
Tue, Oct 23 2018	31	155	18	77	N/A	N/A	41	284	N/A	N/A	-	-
Wed, Oct 24 2018	27	122	15	58	N/A	N/A	40	140	N/A	N/A	-	-
Thu, Oct 25 2018	28	157	21	72	N/A	N/A	46	272	N/A	N/A	-	-
Fri, Oct 26 2018	26	121	12	55	N/A	N/A	56	330	N/A	N/A	-	-
Sat, Oct 27 2018	30	132	12	42	N/A	N/A	29	131	N/A	N/A	-	-
Sun, Oct 28 2018	24	117	13	45	N/A	N/A	29	161	N/A	N/A	-	-
Mon, Oct 29 2018	60	236	19	41	N/A	N/A	33	70	N/A	N/A	-	-
Tue, Oct 30 2018	11	77	-	-	N/A	N/A	87	672	N/A	N/A	-	-
Wed, Oct 31 2018	30	146	-	-	N/A	N/A	23	68	N/A	N/A	-	-
Thu, Nov 1 2018	25	128	-	-	N/A	N/A	33	181	N/A	N/A	-	-
Fri, Nov 2 2018	24	119	-	-	N/A	N/A	29	176	N/A	N/A	-	-
Sat, Nov 3 2018	23	117	-	-	N/A	N/A	23	63	N/A	N/A	-	-
Sun, Nov 4 2018	21	108	-	-	N/A	N/A	24	78	N/A	N/A	-	-
Mon, Nov 5 2018	24	121	-	-	N/A	N/A	48	338	N/A	N/A	-	-
Tue, Nov 6 2018	28	130	-	-	N/A	N/A	22	78	N/A	N/A	-	-
Wed, Nov 7 2018	30	192	-	-	N/A	N/A	23	72	N/A	N/A	-	-
Thu, Nov 8 2018	41	196	-	-	N/A	N/A	23	92	N/A	N/A	-	-
Fri, Nov 9 2018	34	144	-	-	N/A	N/A	30	145	N/A	N/A	-	-
Sat, Nov 10 2018	17	132	-	-	N/A	N/A	21	127	N/A	N/A	-	-
Sun, Nov 11 2018	26	114	-	-	N/A	N/A	19	59	N/A	N/A	-	-
Mon, Nov 12 2018	50	574	-	-	N/A	N/A	29	75	N/A	N/A	-	-
Tue, Nov 13 2018	32	167	-	-	N/A	N/A	27	122	N/A	N/A	-	-
Wed, Nov 14 2018	34	150	-	-	N/A	N/A	24	88	N/A	N/A	-	-
Thu, Nov 15 2018	24	104	-	-	N/A	N/A	26	123	N/A	N/A	-	-

Appendix A
Dust Monitoring Data
2013 - 2018 Dataset

	Station 1		Station 2		Station 3		Station 4		Station 5		Station 7	
Date	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)	Dust (24h ave)	Dust (Max)
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Fri, Nov 16 2018	17	108	-	-	N/A	N/A	54	318	N/A	N/A	-	-
Sat, Nov 17 2018	20	113	-	-	N/A	N/A	28	154	N/A	N/A	-	-
Sun, Nov 18 2018	24	125	-	-	N/A	N/A	19	56	N/A	N/A	-	-
Mon, Nov 19 2018	26	116	-	-	N/A	N/A	54	323	N/A	N/A	-	-
Tue, Nov 20 2018	22	125	-	-	N/A	N/A	48	289	N/A	N/A	-	-
Wed, Nov 21 2018	28	125	-	-	N/A	N/A	37	209	N/A	N/A	-	-
Thu, Nov 22 2018	24	133	-	-	N/A	N/A	29	79	N/A	N/A	-	-
Fri, Nov 23 2018	27	127	-	-	N/A	N/A	35	140	N/A	N/A	-	-
Sat, Nov 24 2018	31	149	-	-	N/A	N/A	42	174	N/A	N/A	-	-
Sun, Nov 25 2018	31	144	-	-	N/A	N/A	35	99	N/A	N/A	-	-
Mon, Nov 26 2018	42	211	-	-	N/A	N/A	29	92	N/A	N/A	-	-
Tue, Nov 27 2018	24	125	-	-	N/A	N/A	46	311	N/A	N/A	-	-
Wed, Nov 28 2018	36	151	-	-	N/A	N/A	35	237	N/A	N/A	-	-
Thu, Nov 29 2018	43	192	-	-	N/A	N/A	27	77	N/A	N/A	-	-
Fri, Nov 30 2018	32	129	-	-	N/A	N/A	53	407	N/A	N/A	-	-
Sat, Dec 1 2018	18	89	-	-	N/A	N/A	18	58	N/A	N/A	-	-
Sun, Dec 2 2018	20	107	-	-	N/A	N/A	15	59	N/A	N/A	-	-
Mon, Dec 3 2018	25	118	-	-	N/A	N/A	33	101	N/A	N/A	-	-
Tue, Dec 4 2018	33	154	-	-	N/A	N/A	39	141	N/A	N/A	-	-
Wed, Dec 5 2018	35	130	-	-	N/A	N/A	42	109	N/A	N/A	-	-
Thu, Dec 6 2018	33	159	-	-	N/A	N/A	49	153	N/A	N/A	-	-
Fri, Dec 7 2018	26	135	-	-	N/A	N/A	38	285	N/A	N/A	-	-
Sat, Dec 8 2018	20	152	-	-	N/A	N/A	47	281	N/A	N/A	-	-
Sun, Dec 9 2018	26	116	-	-	N/A	N/A	60	450	N/A	N/A	-	-
Mon, Dec 10 2018	23	126	-	-	N/A	N/A	76	357	N/A	N/A	-	-
Tue, Dec 11 2018	21	92	-	-	N/A	N/A	30	144	N/A	N/A	-	-
Wed, Dec 12 2018	25	120	-	-	N/A	N/A	66	453	N/A	N/A	-	-
Thu, Dec 13 2018	24	100	-	-	N/A	N/A	33	136	N/A	N/A	-	-
Fri, Dec 14 2018	26	97	-	-	N/A	N/A	36	135	N/A	N/A	-	-
Sat, Dec 15 2018	23	116	-	-	N/A	N/A	23	66	N/A	N/A	-	-
Sun, Dec 16 2018	26	107	-	-	N/A	N/A	25	66	N/A	N/A	-	-
Mon, Dec 17 2018	29	134	-	-	N/A	N/A	29	143	N/A	N/A	-	-
Tue, Dec 18 2018	34	378	-	-	N/A	N/A	45	306	N/A	N/A	-	-
Wed, Dec 19 2018	23	85	-	-	N/A	N/A	60	272	N/A	N/A	-	-
Thu, Dec 20 2018	26	123	-	-	N/A	N/A	28	85	N/A	N/A	-	-
Fri, Dec 21 2018	25	150	-	-	N/A	N/A	33	137	N/A	N/A	-	-
Sat, Dec 22 2018	26	124	-	-	N/A	N/A	45	445	N/A	N/A	-	-
Sun, Dec 23 2018	21	107	-	-	N/A	N/A	22	101	N/A	N/A	-	-
Mon, Dec 24 2018	20	113	-	-	N/A	N/A	42	292	N/A	N/A	-	-
Tue, Dec 25 2018	19	120	-	-	N/A	N/A	25	179	N/A	N/A	-	-
Wed, Dec 26 2018	40	250	-	-	N/A	N/A	28	98	N/A	N/A	-	-
Thu, Dec 27 2018	44	227	-	-	N/A	N/A	43	106	N/A	N/A	-	-
Fri, Dec 28 2018	14	84	-	-	N/A	N/A	32	174	N/A	N/A	-	-
Sat, Dec 29 2018	23	103	-	-	N/A	N/A	26	73	N/A	N/A	-	-
Sun, Dec 30 2018	19	74	-	-	N/A	N/A	33	195	N/A	N/A	-	-
Mon, Dec 31 2018	21	96	-	-	N/A	N/A	40	503	N/A	N/A	-	-

Average	29	127	16	62	21	88	39	206	29	193	36	164
PM10 standard (annua	50		50		50		50		50		50	
Max 24-hr	247	1013	110	1013	106	740	356	1005	150	1007	1013	1017
2nd Highest 24-hr	143		80		77		266		137		528	
PM10 standard (24 hr)	150		150		150		150		150		150	
No. of Exceedances	1		0		0		19		0		22	
No. of Days	1577		1754		913		849		1562		1493	

Appendix **B**
Air Dispersion Modeling

Current Operations

```
                                                                         07/21/22
                                                                         14:43:25
 ***  SCREEN3 MODEL RUN  ***
 *** VERSION DATED 13043 ***

Current Emission Rate

SIMPLE TERRAIN INPUTS:
   SOURCE TYPE                  =         AREA
   EMISSION RATE (G/(S-M**2))  =     1.000000
   SOURCE HEIGHT (M)            =       0.1000
   LENGTH OF LARGER SIDE (M)   =      45.0000
   LENGTH OF SMALLER SIDE (M)  =      45.0000
   RECEPTOR HEIGHT (M)          =       1.8000
   URBAN/RURAL OPTION           =        RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

   MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION


BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

*** STABILITY CLASS  4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF   7.07 M/S ONLY ***

*********************************
*** SCREEN DISCRETE DISTANCES ***
*********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

  DIST     CONC              U10M   USTK  MIX HT   PLUME  MAX DIR
   (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   (DEG)
-------  ----------  ----  -----  -----  ------  ------  -------
   150.   0.7445E+06    4     7.1    7.1  2262.4    0.10     45.

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------  ---------   -------
SIMPLE TERRAIN      0.7445E+06      150.        0.


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

07/21/22
14:47:57

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 13043 ***

Current Operations

SIMPLE TERRAIN INPUTS:

```
   SOURCE TYPE                   =         AREA
   EMISSION RATE (G/(S-M**2))    =     0.167898E-03
   SOURCE HEIGHT (M)             =       0.1000
   LENGTH OF LARGER SIDE (M)     =      45.0000
   LENGTH OF SMALLER SIDE (M)    =      45.0000
   RECEPTOR HEIGHT (M)           =       1.8000
   URBAN/RURAL OPTION            =        RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

   MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION


BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

*** STABILITY CLASS  4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF   7.07 M/S ONLY ***

**********************************
*** SCREEN AUTOMATED DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***
```

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
1.	90.95	4	7.1	7.1	2262.4	0.10	45.
100.	196.1	4	7.1	7.1	2262.4	0.10	45.
200.	86.35	4	7.1	7.1	2262.4	0.10	45.
300.	47.98	4	7.1	7.1	2262.4	0.10	45.
400.	30.91	4	7.1	7.1	2262.4	0.10	44.
500.	21.67	4	7.1	7.1	2262.4	0.10	39.
600.	16.10	4	7.1	7.1	2262.4	0.10	35.
700.	12.48	4	7.1	7.1	2262.4	0.10	41.
800.	9.993	4	7.1	7.1	2262.4	0.10	30.
900.	8.199	4	7.1	7.1	2262.4	0.10	26.
1000.	6.872	4	7.1	7.1	2262.4	0.10	41.
1100.	5.936	4	7.1	7.1	2262.4	0.10	35.
1200.	5.196	4	7.1	7.1	2262.4	0.10	31.
1300.	4.597	4	7.1	7.1	2262.4	0.10	15.
1400.	4.103	4	7.1	7.1	2262.4	0.10	38.

1500.	3.691	4	7.1	7.1	2262.4	0.10	9.
1600.	3.343	4	7.1	7.1	2262.4	0.10	7.
1700.	3.046	4	7.1	7.1	2262.4	0.10	7.
1800.	2.790	4	7.1	7.1	2262.4	0.10	7.
1900.	2.567	4	7.1	7.1	2262.4	0.10	7.
2000.	2.371	4	7.1	7.1	2262.4	0.10	9.
2100.	2.199	4	7.1	7.1	2262.4	0.10	20.
2200.	2.047	4	7.1	7.1	2262.4	0.10	23.
2300.	1.911	4	7.1	7.1	2262.4	0.10	23.
2400.	1.790	4	7.1	7.1	2262.4	0.10	26.
2500.	1.680	4	7.1	7.1	2262.4	0.10	34.
2600.	1.582	4	7.1	7.1	2262.4	0.10	31.
2700.	1.492	4	7.1	7.1	2262.4	0.10	31.
2800.	1.411	4	7.1	7.1	2262.4	0.10	27.
2900.	1.336	4	7.1	7.1	2262.4	0.10	26.
3000.	1.268	4	7.1	7.1	2262.4	0.10	17.
3500.	1.006	4	7.1	7.1	2262.4	0.10	7.
4000.	0.8232	4	7.1	7.1	2262.4	0.10	7.
4500.	0.6896	4	7.1	7.1	2262.4	0.10	8.
5000.	0.5886	4	7.1	7.1	2262.4	0.10	8.
5500.	0.5101	4	7.1	7.1	2262.4	0.10	8.
6000.	0.4476	4	7.1	7.1	2262.4	0.10	8.
6500.	0.3970	4	7.1	7.1	2262.4	0.10	8.
7000.	0.3552	4	7.1	7.1	2262.4	0.10	8.
7500.	0.3203	4	7.1	7.1	2262.4	0.10	8.
8000.	0.2908	4	7.1	7.1	2262.4	0.10	8.

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 1. M:

48.	321.8	4	7.1	7.1	2262.4	0.10	45.

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
402.	30.67	4	7.1	7.1	2262.4	0.10	43.

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	321.8	48.	0.

```
***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

Current Operations – 1-hour maximum

09/06/22
02:58:30

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 13043 ***

1-hour max

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	AREA
EMISSION RATE (G/(S-M**2))	=	0.135000E-02
SOURCE HEIGHT (M)	=	0.1000
LENGTH OF LARGER SIDE (M)	=	45.0000
LENGTH OF SMALLER SIDE (M)	=	45.0000
RECEPTOR HEIGHT (M)	=	1.8000
URBAN/RURAL OPTION	=	RURAL

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION

BUOY. FLUX = 0.000 M**4/S**3; MOM. FLUX = 0.000 M**4/S**2.

*** STABILITY CLASS 4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF 7.07 M/S ONLY ***

****
*** SCREEN AUTOMATED DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
1.	731.3	4	7.1	7.1	2262.4	0.10	45.
100.	1577.	4	7.1	7.1	2262.4	0.10	45.
200.	694.3	4	7.1	7.1	2262.4	0.10	45.
300.	385.8	4	7.1	7.1	2262.4	0.10	45.
400.	248.5	4	7.1	7.1	2262.4	0.10	44.
500.	174.3	4	7.1	7.1	2262.4	0.10	39.
600.	129.5	4	7.1	7.1	2262.4	0.10	35.
700.	100.4	4	7.1	7.1	2262.4	0.10	41.
800.	80.35	4	7.1	7.1	2262.4	0.10	30.
900.	65.92	4	7.1	7.1	2262.4	0.10	26.
1000.	55.25	4	7.1	7.1	2262.4	0.10	41.
1100.	47.73	4	7.1	7.1	2262.4	0.10	35.
1200.	41.78	4	7.1	7.1	2262.4	0.10	31.
1300.	36.96	4	7.1	7.1	2262.4	0.10	15.
1400.	32.99	4	7.1	7.1	2262.4	0.10	38.

```
  1500.    29.68         4     7.1    7.1  2262.4    0.10      9.
  1600.    26.88         4     7.1    7.1  2262.4    0.10      7.
  1700.    24.49         4     7.1    7.1  2262.4    0.10      7.
  1800.    22.43         4     7.1    7.1  2262.4    0.10      7.
  1900.    20.64         4     7.1    7.1  2262.4    0.10      7.
  2000.    19.06         4     7.1    7.1  2262.4    0.10      9.
  2100.    17.68         4     7.1    7.1  2262.4    0.10     20.
  2200.    16.46         4     7.1    7.1  2262.4    0.10     23.
  2300.    15.37         4     7.1    7.1  2262.4    0.10     23.
  2400.    14.39         4     7.1    7.1  2262.4    0.10     26.
  2500.    13.51         4     7.1    7.1  2262.4    0.10     34.
  2600.    12.72         4     7.1    7.1  2262.4    0.10     31.
  2700.    12.00         4     7.1    7.1  2262.4    0.10     31.
  2800.    11.34         4     7.1    7.1  2262.4    0.10     27.
  2900.    10.74         4     7.1    7.1  2262.4    0.10     26.
  3000.    10.20         4     7.1    7.1  2262.4    0.10     17.
  3500.    8.090         4     7.1    7.1  2262.4    0.10      7.
  4000.    6.619         4     7.1    7.1  2262.4    0.10      7.
  4500.    5.545         4     7.1    7.1  2262.4    0.10      8.
  5000.    4.733         4     7.1    7.1  2262.4    0.10      8.
  5500.    4.102         4     7.1    7.1  2262.4    0.10      8.
  6000.    3.599         4     7.1    7.1  2262.4    0.10      8.
  6500.    3.192         4     7.1    7.1  2262.4    0.10      8.
  7000.    2.856         4     7.1    7.1  2262.4    0.10      8.
  7500.    2.576         4     7.1    7.1  2262.4    0.10      8.
  8000.    2.338         4     7.1    7.1  2262.4    0.10      8.

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND     1. M:
    48.    2587.         4     7.1    7.1  2262.4    0.10     45.

*********************************
*** SCREEN DISCRETE DISTANCES ***
*********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

   DIST     CONC             U10M   USTK  MIX HT   PLUME  MAX DIR
    (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   (DEG)
-------  ----------  ----  -----  -----  ------  ------  -------
   402.    246.6         4     7.1    7.1  2262.4    0.10     43.

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------   ---------   -------
SIMPLE TERRAIN       2587.          48.        0.
```

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***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

HMA Plant

```
                                                                  07/21/22
                                                                  16:36:49
 ***  SCREEN3 MODEL RUN  ***
 *** VERSION DATED 13043 ***

HMA Emissions

SIMPLE TERRAIN INPUTS:
   SOURCE TYPE                 =         AREA
   EMISSION RATE (G/(S-M**2))  =     1.000000
   SOURCE HEIGHT (M)           =       0.1000
   LENGTH OF LARGER SIDE (M)   =      45.0000
   LENGTH OF SMALLER SIDE (M)  =      45.0000
   RECEPTOR HEIGHT (M)         =       1.8000
   URBAN/RURAL OPTION          =        RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

   MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION


BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

*** STABILITY CLASS  4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF   8.87 M/S ONLY ***

*********************************
*** SCREEN DISCRETE DISTANCES ***
*********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

  DIST     CONC             U10M   USTK  MIX HT   PLUME  MAX DIR
   (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   (DEG)
-------  ----------  ----  -----  -----  ------  ------  -------
   150.   0.5934E+06    4     8.9    8.9  2838.4    0.10     45.

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------  ---------   -------
SIMPLE TERRAIN      0.5934E+06      150.        0.


***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

07/25/22
10:02:14

*** SCREEN3 MODEL RUN ***
*** VERSION DATED 13043 ***

HMA

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	AREA
EMISSION RATE (G/(S-M**2))	=	0.170711E-02
SOURCE HEIGHT (M)	=	0.1000
LENGTH OF LARGER SIDE (M)	=	45.0000
LENGTH OF SMALLER SIDE (M)	=	45.0000
RECEPTOR HEIGHT (M)	=	1.8000
URBAN/RURAL OPTION	=	RURAL

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION

BUOY. FLUX = 0.000 M**4/S**3; MOM. FLUX = 0.000 M**4/S**2.

*** STABILITY CLASS 4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF 8.87 M/S ONLY ***

****
*** SCREEN AUTOMATED DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
1.	737.1	4	8.9	8.9	2838.4	0.10	45.
100.	1589.	4	8.9	8.9	2838.4	0.10	45.
200.	699.8	4	8.9	8.9	2838.4	0.10	45.
300.	388.9	4	8.9	8.9	2838.4	0.10	45.
400.	250.5	4	8.9	8.9	2838.4	0.10	44.
500.	175.6	4	8.9	8.9	2838.4	0.10	39.
600.	130.5	4	8.9	8.9	2838.4	0.10	35.
700.	101.2	4	8.9	8.9	2838.4	0.10	41.
800.	80.98	4	8.9	8.9	2838.4	0.10	30.
900.	66.44	4	8.9	8.9	2838.4	0.10	26.
1000.	55.69	4	8.9	8.9	2838.4	0.10	41.
1100.	48.10	4	8.9	8.9	2838.4	0.10	35.
1200.	42.11	4	8.9	8.9	2838.4	0.10	31.
1300.	37.26	4	8.9	8.9	2838.4	0.10	15.
1400.	33.25	4	8.9	8.9	2838.4	0.10	38.

```
  1500.    29.91        4     8.9    8.9  2838.4    0.10      9.
  1600.    27.09        4     8.9    8.9  2838.4    0.10      7.
  1700.    24.69        4     8.9    8.9  2838.4    0.10      7.
  1800.    22.61        4     8.9    8.9  2838.4    0.10      7.
  1900.    20.80        4     8.9    8.9  2838.4    0.10      7.
  2000.    19.22        4     8.9    8.9  2838.4    0.10      9.
  2100.    17.82        4     8.9    8.9  2838.4    0.10     20.
  2200.    16.59        4     8.9    8.9  2838.4    0.10     23.
  2300.    15.49        4     8.9    8.9  2838.4    0.10     23.
  2400.    14.50        4     8.9    8.9  2838.4    0.10     26.
  2500.    13.62        4     8.9    8.9  2838.4    0.10     34.
  2600.    12.82        4     8.9    8.9  2838.4    0.10     31.
  2700.    12.09        4     8.9    8.9  2838.4    0.10     31.
  2800.    11.43        4     8.9    8.9  2838.4    0.10     27.
  2900.    10.83        4     8.9    8.9  2838.4    0.10     26.
  3000.    10.28        4     8.9    8.9  2838.4    0.10     17.
  3500.    8.154        4     8.9    8.9  2838.4    0.10      7.
  4000.    6.672        4     8.9    8.9  2838.4    0.10      7.
  4500.    5.589        4     8.9    8.9  2838.4    0.10      8.
  5000.    4.770        4     8.9    8.9  2838.4    0.10      8.
  5500.    4.134        4     8.9    8.9  2838.4    0.10      8.
  6000.    3.628        4     8.9    8.9  2838.4    0.10      8.
  6500.    3.217        4     8.9    8.9  2838.4    0.10      8.
  7000.    2.879        4     8.9    8.9  2838.4    0.10      8.
  7500.    2.596        4     8.9    8.9  2838.4    0.10      8.
  8000.    2.357        4     8.9    8.9  2838.4    0.10      8.

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND     1. M:
    48.    2608.        4     8.9    8.9  2838.4    0.10     45.

*********************************
*** SCREEN DISCRETE DISTANCES ***
*********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

   DIST     CONC             U10M   USTK  MIX HT   PLUME  MAX DIR
    (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   (DEG)
-------  ----------  ----  -----  -----  ------  ------  -------
   402.    248.6        4     8.9    8.9  2838.4    0.10     43.

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

 CALCULATION        MAX CONC    DIST TO   TERRAIN
  PROCEDURE        (UG/M**3)    MAX (M)    HT (M)
--------------    -----------   ---------   -------
SIMPLE TERRAIN       2608.          48.        0.
```

****
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
****

Concrete Plant

07/22/22
14:34:33

```
 ***  SCREEN3 MODEL RUN  ***
 *** VERSION DATED 13043 ***

Concrete Plant

SIMPLE TERRAIN INPUTS:
   SOURCE TYPE                  =         AREA
   EMISSION RATE (G/(S-M**2))  =     0.648975E-03
   SOURCE HEIGHT (M)           =       0.1000
   LENGTH OF LARGER SIDE (M)   =      35.0000
   LENGTH OF SMALLER SIDE (M)  =      35.0000
   RECEPTOR HEIGHT (M)         =       1.8000
   URBAN/RURAL OPTION          =        RURAL
THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

   MODEL ESTIMATES DIRECTION TO MAX CONCENTRATION


BUOY. FLUX =    0.000 M**4/S**3;  MOM. FLUX =    0.000 M**4/S**2.

*** STABILITY CLASS  4 ONLY ***
*** ANEMOMETER HEIGHT WIND SPEED OF   8.72 M/S ONLY ***

**********************************
*** SCREEN AUTOMATED DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***
```

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
1.	157.6	4	8.7	8.7	2790.4	0.10	45.
100.	438.7	4	8.7	8.7	2790.4	0.10	45.
200.	179.5	4	8.7	8.7	2790.4	0.10	42.
300.	95.87	4	8.7	8.7	2790.4	0.10	45.
400.	60.60	4	8.7	8.7	2790.4	0.10	37.
500.	42.06	4	8.7	8.7	2790.4	0.10	40.
600.	31.06	4	8.7	8.7	2790.4	0.10	31.
700.	23.97	4	8.7	8.7	2790.4	0.10	27.
800.	19.14	4	8.7	8.7	2790.4	0.10	38.
900.	15.67	4	8.7	8.7	2790.4	0.10	32.
1000.	13.11	4	8.7	8.7	2790.4	0.10	15.
1100.	11.32	4	8.7	8.7	2790.4	0.10	11.
1200.	9.903	4	8.7	8.7	2790.4	0.10	7.
1300.	8.757	4	8.7	8.7	2790.4	0.10	7.
1400.	7.812	4	8.7	8.7	2790.4	0.10	7.

1500.	7.022	4	8.7	8.7	2790.4	0.10	8.
1600.	6.355	4	8.7	8.7	2790.4	0.10	20.
1700.	5.787	4	8.7	8.7	2790.4	0.10	23.
1800.	5.298	4	8.7	8.7	2790.4	0.10	26.
1900.	4.873	4	8.7	8.7	2790.4	0.10	33.
2000.	4.502	4	8.7	8.7	2790.4	0.10	31.
2100.	4.174	4	8.7	8.7	2790.4	0.10	28.
2200.	3.885	4	8.7	8.7	2790.4	0.10	18.
2300.	3.627	4	8.7	8.7	2790.4	0.10	13.
2400.	3.397	4	8.7	8.7	2790.4	0.10	10.
2500.	3.189	4	8.7	8.7	2790.4	0.10	8.
2600.	3.002	4	8.7	8.7	2790.4	0.10	8.
2700.	2.832	4	8.7	8.7	2790.4	0.10	7.
2800.	2.678	4	8.7	8.7	2790.4	0.10	7.
2900.	2.536	4	8.7	8.7	2790.4	0.10	7.
3000.	2.407	4	8.7	8.7	2790.4	0.10	7.
3500.	1.908	4	8.7	8.7	2790.4	0.10	13.
4000.	1.561	4	8.7	8.7	2790.4	0.10	11.
4500.	1.307	4	8.7	8.7	2790.4	0.10	11.
5000.	1.116	4	8.7	8.7	2790.4	0.10	11.
5500.	0.9671	4	8.7	8.7	2790.4	0.10	11.
6000.	0.8486	4	8.7	8.7	2790.4	0.10	11.
6500.	0.7526	4	8.7	8.7	2790.4	0.10	11.
7000.	0.6735	4	8.7	8.7	2790.4	0.10	11.
7500.	0.6073	4	8.7	8.7	2790.4	0.10	11.
8000.	0.5513	4	8.7	8.7	2790.4	0.10	41.

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 1. M:

42.	804.6	4	8.7	8.7	2790.4	0.10	45.

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	MAX DIR (DEG)
402.	60.11	4	8.7	8.7	2790.4	0.10	37.

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)
SIMPLE TERRAIN	804.6	42.	0.

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***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
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Vibration Monitoring Summary

Project name: Makakilo Quarry
Submitted to: Jodie Cordero and Jon Archambeau – Grace Pacific LLC
Description of work: Vibration Monitoring Summary Period 2016-2023
Date of report: June 13, 2023

In advance of the proposed quarry boundary adjustments at the Makakilo quarry in Kapolei, HI, Detecht was asked to review blasting vibration data to date, update previously established attenuation models, and evaluate vibrations at structures closest to the quarry. This report reviews vibration measurements from January 2016 to May 2023 and compares results to a site attenuation study performed by Aimone-Martin Associates in 2010. Seismographs used during the eight-year period were Mini-Seis, Mini Seis III, and Mini Seis III Pro models, manufactured by White Industrial Seismology of Joplin, MO.

Currently, three semi-permanent vibration and pressure monitoring locations are deployed northwest of the quarry near structures closest to blasting operations. Prior to September 2018 there were seven monitoring locations north and west of the quarry. Seismograph locations relative to the quarry's current and revised boundaries are shown at the end of the report in Figures 1 and 2 for the monitoring periods after and before September 2018, respectively.

Figures 3 and 4 are maps showing distances of the closest residential structures relative to the quarry's current and revised boundaries, respectively. Currently, the closest house to the quarry boundary is to the north approximately 606 ft. The closet home to the revised boundary will be 908 ft. Table 1 summarizes distances to the closest residential structures based on current and proposed new boundaries for neighborhoods near the quarry. The revised boundary is farther from the residential structures to the north and southwest and closer to the west, compared to current boundaries. The revised and current boundaries are similar distance to the south residences.

Table 1 Summary of changes in distance to closest residential structures by cardinal direction

Cardinal Direction	Distance to Closest Residences (ft)	
	Current Boundary	Revised Boundary
North	606	908
West	1,138	990
South	1,011	1,011
Southwest	1,699	1,775

Ground vibrations at structures closest to blasting

Figure 5 is a plot of peak particle velocity (PPV) in the ground versus peak frequency associated with this motion as measured near structures closest to the blast during 2016-2023. The frequency-based safe vibration criteria, as recommended by the U.S. Bureau of Mines (USBM) is shown in this figure as a black line, established by the USBM as the 100% confidence limit to safe vibrations during rock blasting (Siskind et al., 1980). This line is the lowest possible combination of PPV and frequency that may cause threshold cracking in structures, represented by hairline cracking in gypsum drywall. This line was

Exhibit "X"

established based on over 40 years of research that included crack observations within structures subjected to ground vibrations from blasting. Since the establishment of the safe criteria, there have been no scientific studies showing that threshold cracking can occur below this black line.

Other construction materials such as mortar materials including stucco, grout, and mortar used in masonry walls/facades can begin to crack at a higher PPV threshold of 3.0 in/s (Stagg, 1984, Brown et al., 2004), shown in Figure 5 as the upper blue line. The threshold at which concrete can begin to crack (upper red line in Figure 5) is 8.0 in/s which represents a conservative limit based on 12 in/s recommended by Oriard (2002) with a 1.5 factor of safety.

Vibration attenuation model

The 2010 study performed by Aimone-Martin Associates included blast monitoring using linear arrays of seismographs to record vibrations at different distances from the blast. Ground motion attenuation specific to the quarry site is plotted in Figure 6 in terms of peak particle velocity (PPV) and scaled distance (SD). The graph includes a best-fit (or 50-percentile) regression line for the 2010 data with an equation given as

$$PPV = 14.27\, SD^{-1.18}$$

and a correlation coefficient, R^2, of 0.98.

In Figure 6, measurements collected during the 2010 study are plotted in red and data collected between 2016 and 2023 are plotted in black. The recent data generally follows the established attenuation trend. An upper bound or "worst-case" line below which all 2010 and recent data fall is defined with the equation

$$PPV = 84.95\, SD^{-1.18}$$

Application of site attenuation model for future blasting

The attenuation model for ground vibration is useful to the blaster as a guide for blast design. Knowing the distance to the closest structure, D, the charge weight, W, may be adjusted so that the predicted ground vibration (PPV) remains well below safe amplitudes.

The blue line in Figure 6 represents the USBM safe vibration criteria of 0.75 in/s, applicable for average frequencies at the Makakilo quarry. The scaled distance at which the upper bound line crosses the blue line, 55 ft/lb$^{1/2}$, can be used as the minimum design SD to keep vibrations below 0.75 in/s.

Table 2 shows the maximum allowable charge weight per 8 millisecond delay when blasting occurs at the revised boundary line, e.g., when blasting is the closest to residential structures in each direction. Planned blasts at greater distances could have higher allowable charge weights, providing the minimum scaled distance of 55 ft/lb$^{1/2}$ is maintained.

Quarry blasting operations during the 2016-2023 period used an average of 297 lb per delay. The highest charge weight blast on December 21, 2018 involved 780 lb per delay and was located more than 2300 ft from closest houses. These values are well below the maximum allowable charge weight at the given distance for the protection of nearby homes, as described above. During the same time period the highest PPV recorded at the quarry's permanent monitoring locations was 0.33 in/s and the average

PPV was 0.07 in/s from a database comprising 1781 data points. Figure 7 shows PPV data collected during 2016-2023 relative to scaled distance, separated by year.

Table 2 Maximum allowable charge weight per delay for blasting at the revised quarry boundary line

Maximum charge weight per 8ms delay for: PPV_{max} = 0.75 in/s SD_{min} = 55 ft/lb$^{1/2}$		
Cardinal Direction	**Distance (ft)**	**Max W (lb)**
North	908	272
West	990	323
South	1,011	337
Southwest	1,775	1,039

Findings

On-going blast vibration monitoring data recorded at the Makakilo quarry from January 2016 to May 2023 follow the previously established site attenuation model from a study conducted in 2010. A new upper bound or "worst-case" attenuation equation based on all data to date can inform future blasting design to protect structures comprising drywall, mortar materials, and concrete. To keep vibration amplitudes below 0.75 in/s and protect the weakest building materials, it is recommended to maintain a minimum scaled distance of 55 ft/lb$^{1/2}$, which corresponds to allowable maximum charge weights per delay given in Table 2 when blasting occurs at or near the revised quarry boundary line.

Blasting can be safely achieved within the new proposed quarry boundary with minor adjustments to design charge weights when planned blasting is closest to nearby residential structures. Maintaining a minimum scaled distance of 55 ft/lb$^{1/2}$ to the closest building will ensure that cracking or damage is not possible in any off-site structure.

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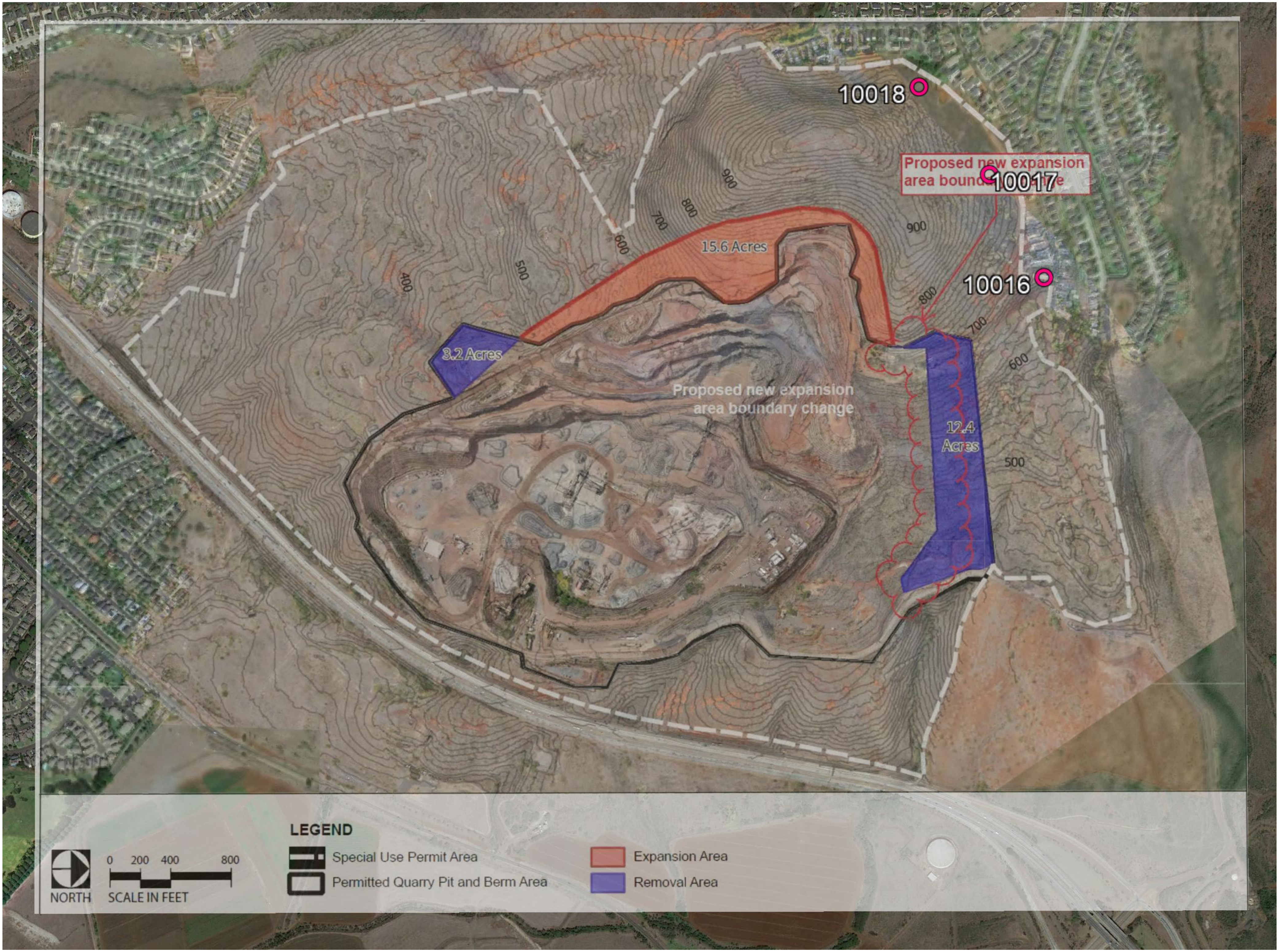

Figure 1. Makakilo quarry current seismograph locations (pink circles): after September 2018

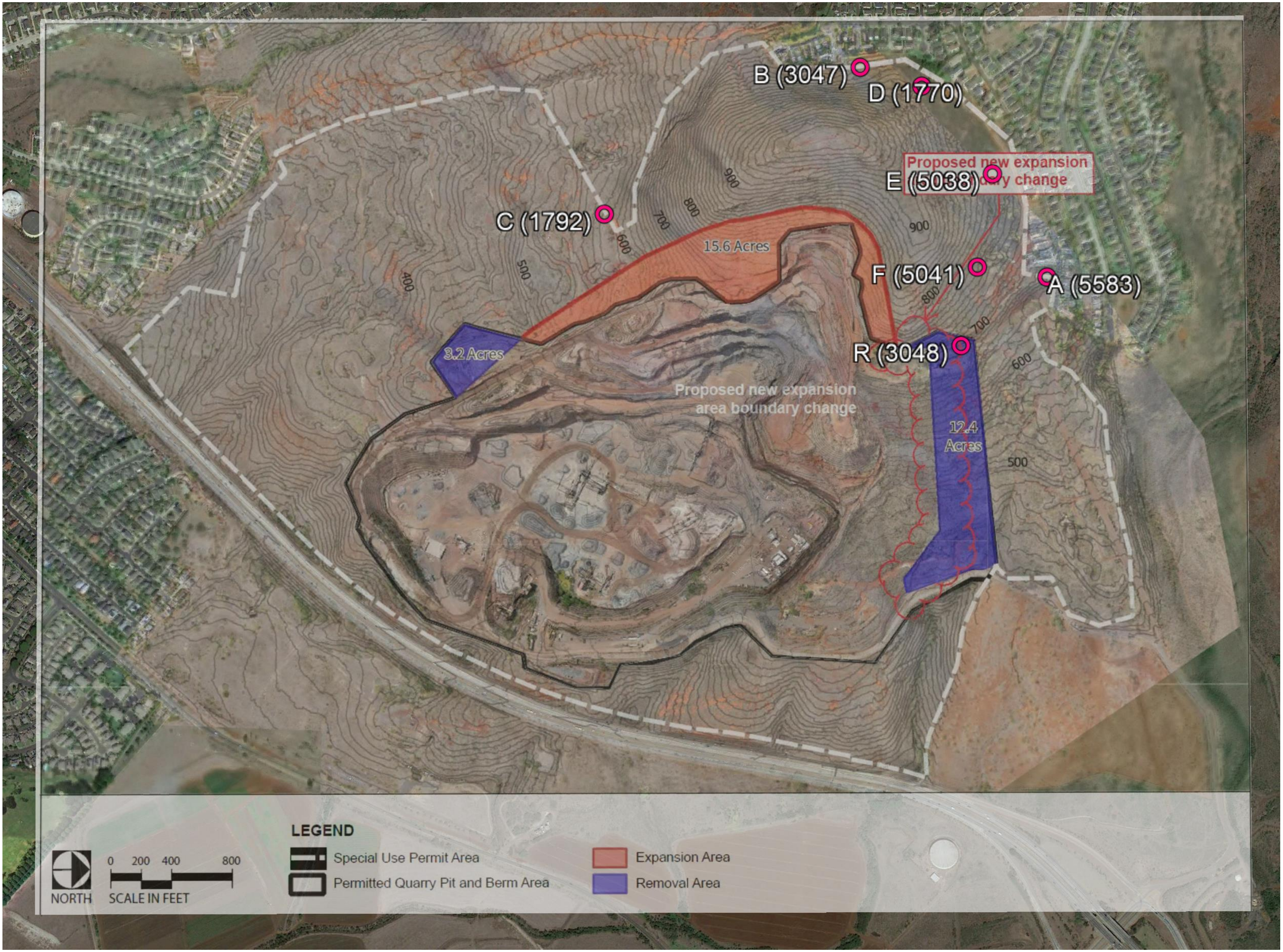

Figure 2. Makakilo quarry seismograph locations (pink circles): prior to September 2018

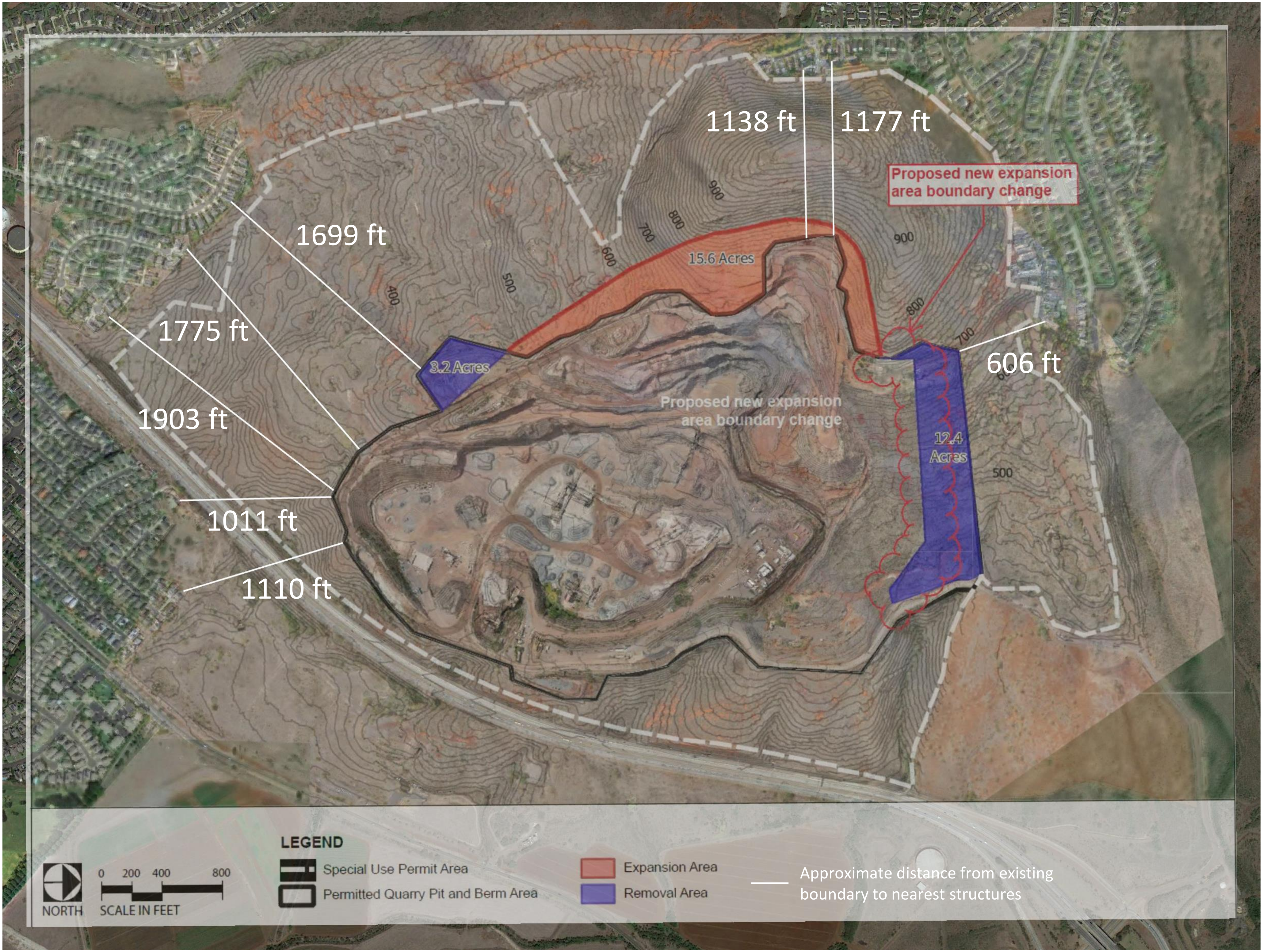

Figure 3. Makakilo quarry existing boundary (black) – approximate distances to nearby structures

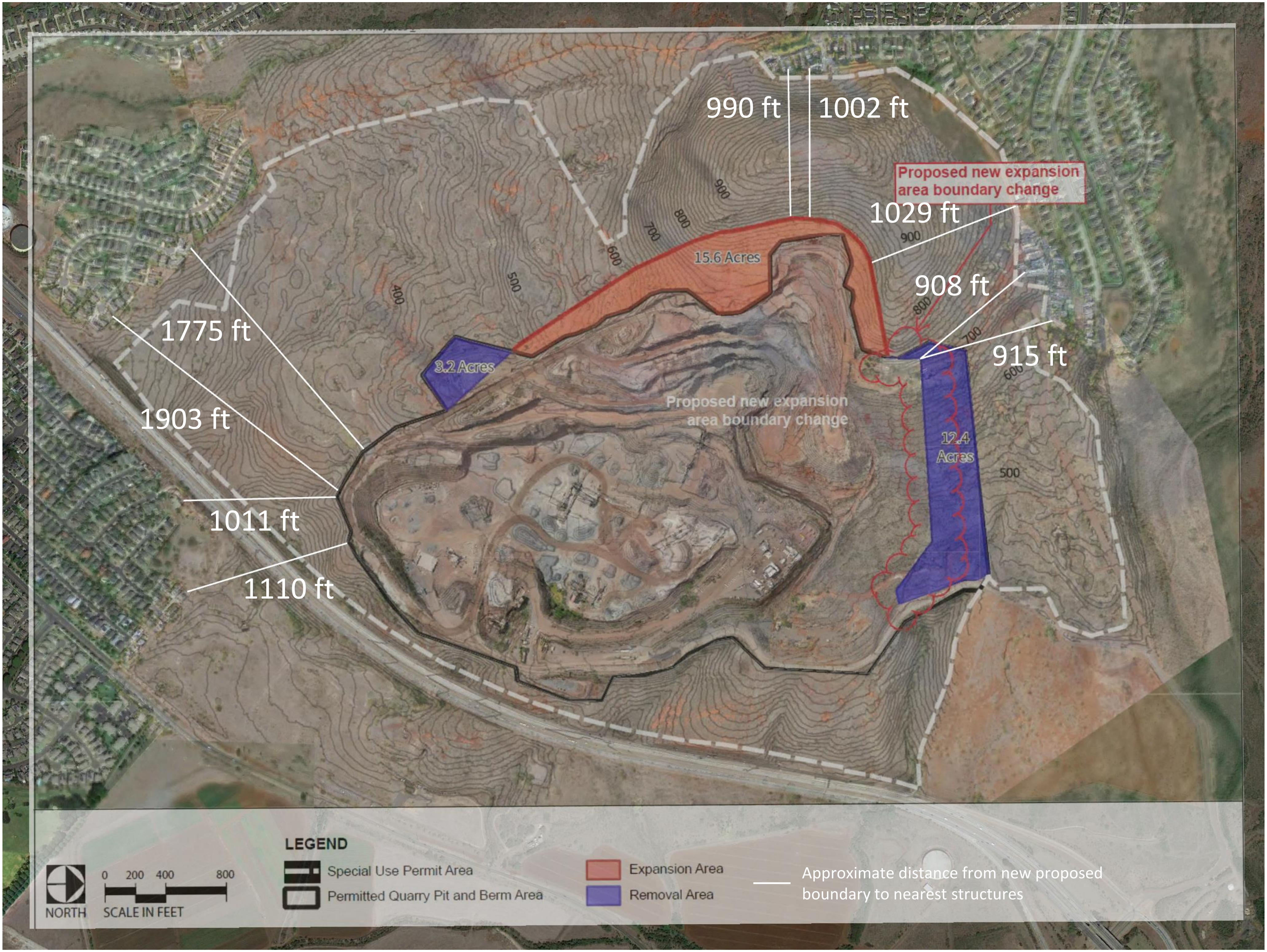

Figure 4. Makakilo quarry proposed boundary (red/blue) – approximate distances to nearby structures

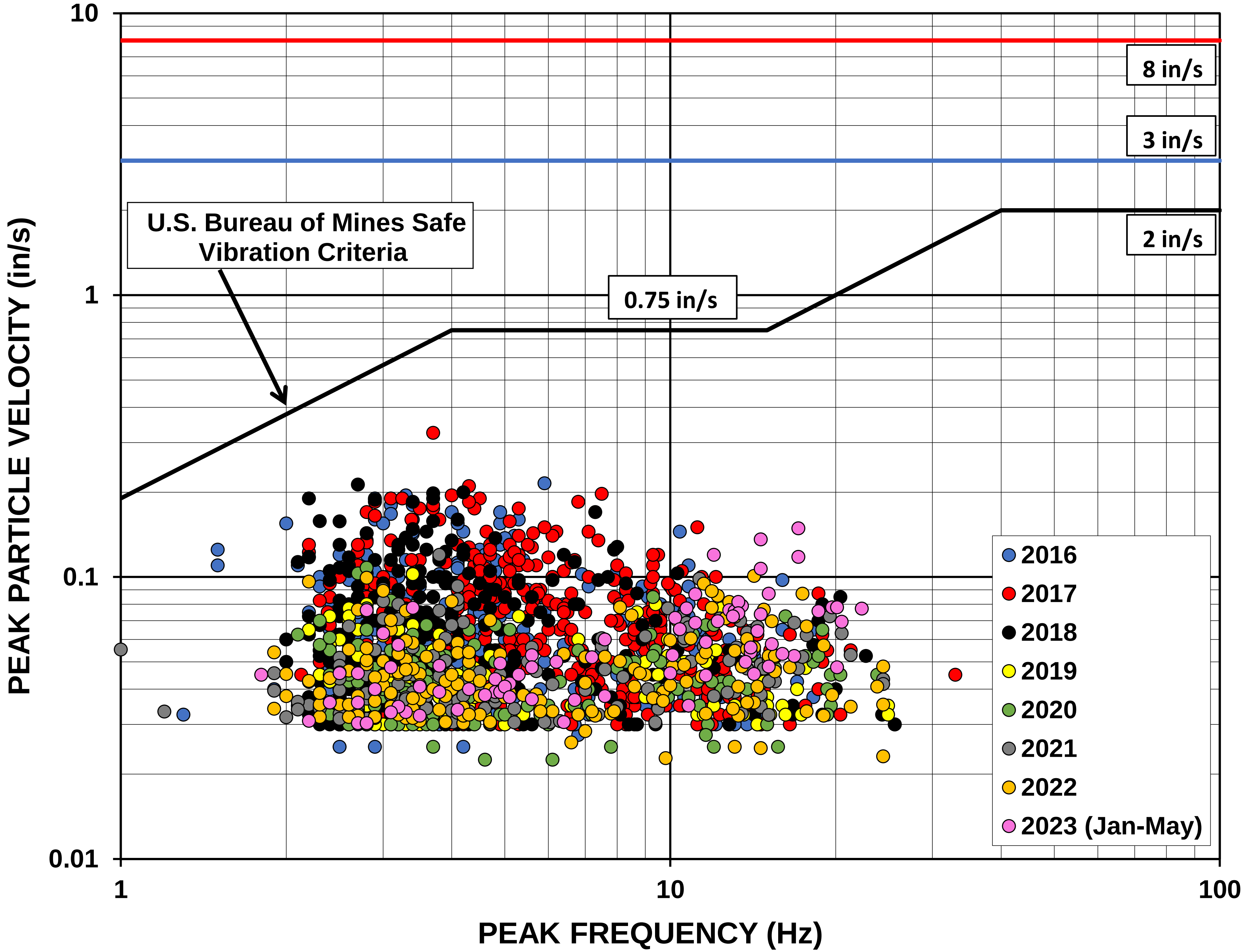

Figure 5. Peak particle velocity versus frequency and USBM safe vibration criteria at Makakilo quarry for period 2016 - 2023

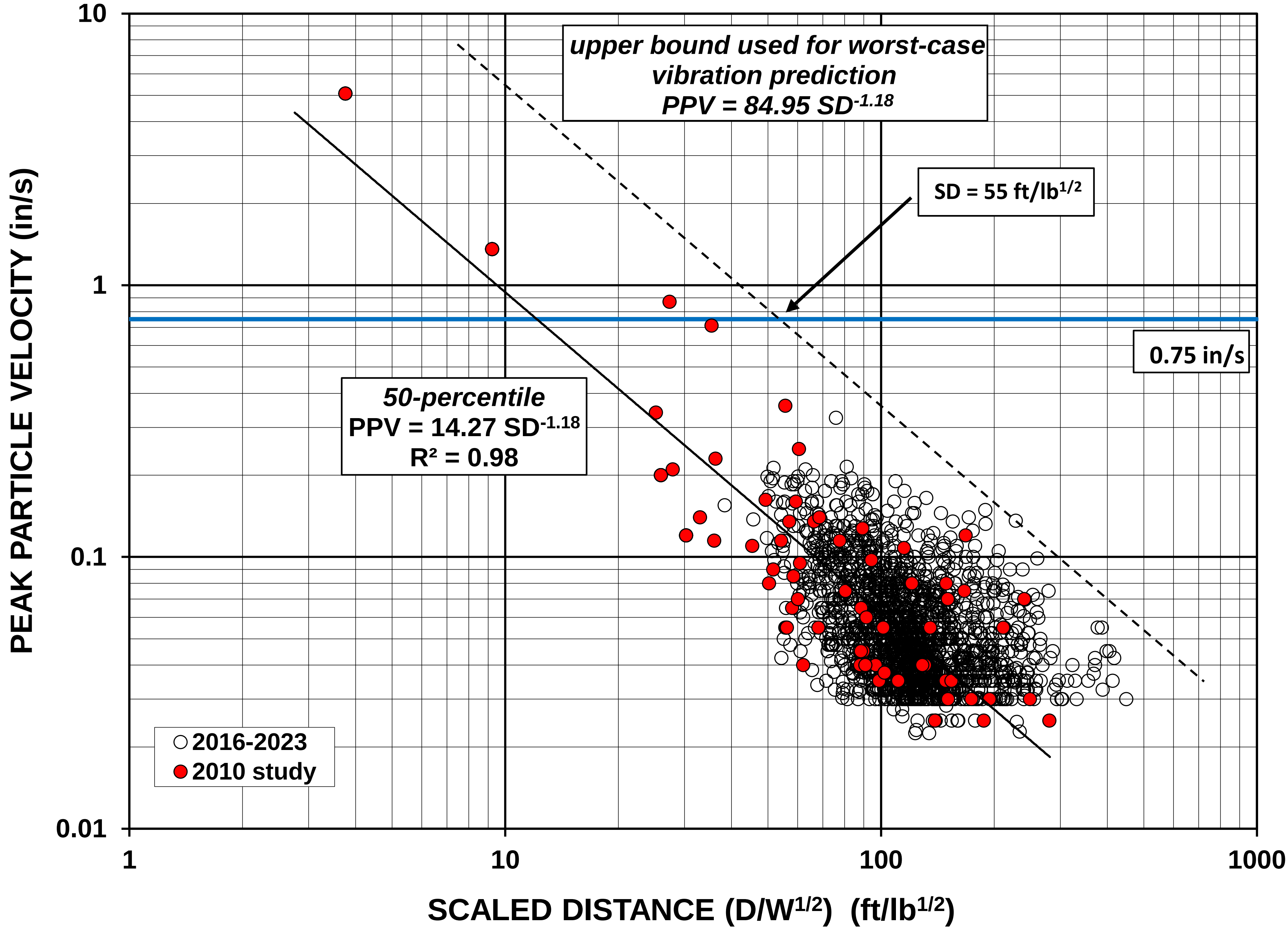

Figure 6. Peak particle velocity (PPV) versus scaled distance (SD) attenuation plot at Makakilo quarry

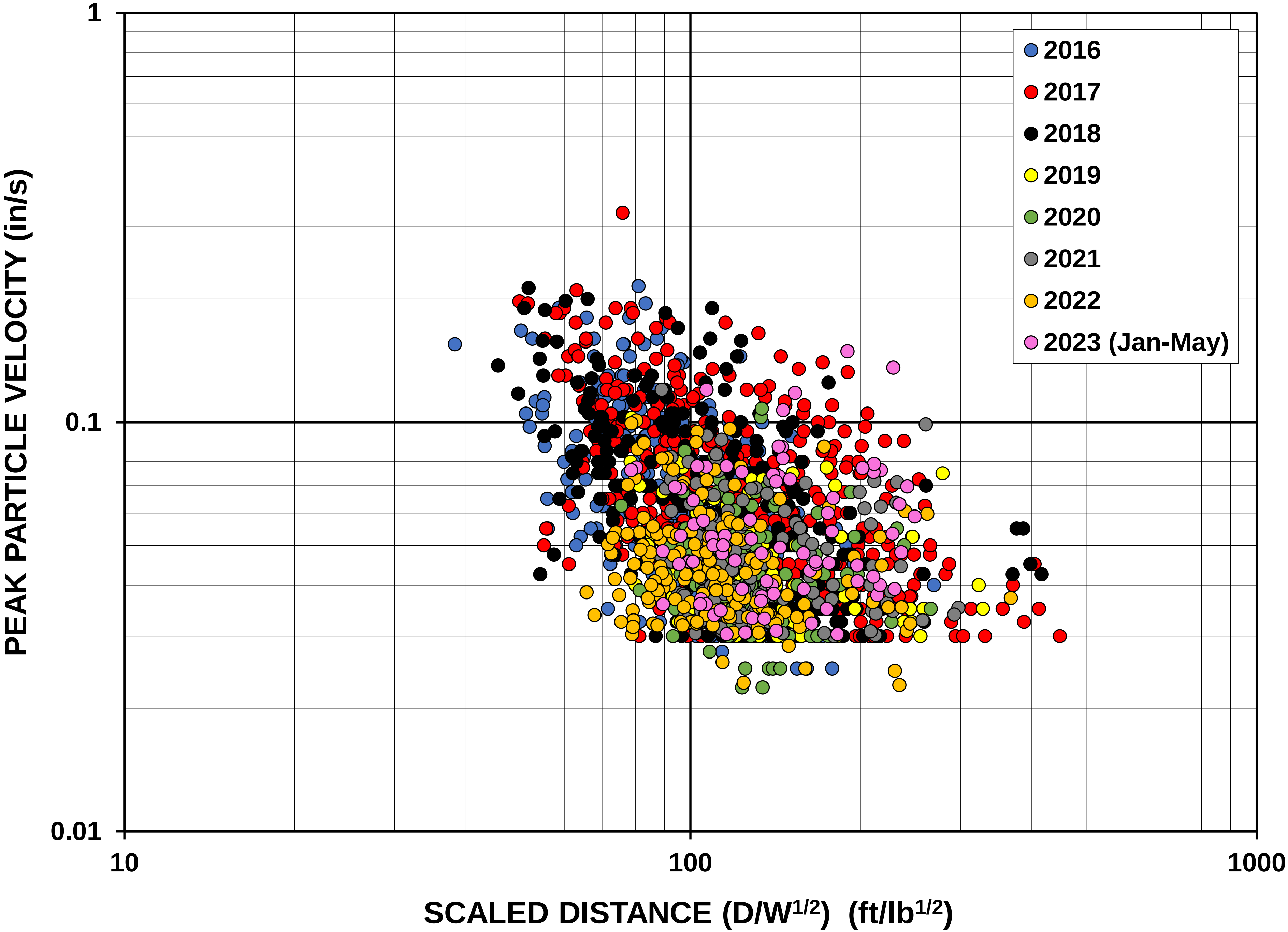

Figure 7. Peak particle velocity versus scaled distance measurements at Makakilo quarry for period 2016 - 2023

Makakilo Quarry Socio-Economic Impact Assessment

Prepared for:

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October 2022
Revised June 2023

Exhibit "Y"

Table of Contents

1 INTRODUCTION

A socio-economic impact assessment (SEIA) is a useful tool to help understand potential impacts a proposed action may have on the social and economic conditions within the subject area. It is important to determine not only the full range of impacts, such as changes to levels of income and employment, access to services, quality of life, but also the implications of each change. Understanding any potential impacts a proposed action may have can help design mitigation strategies to maximize positive impacts and minimize negative impacts.

While social impact assessments and economic impact assessments are often separate disciplines and employ different methods, they are complementary and sometimes overlap. For example, both types of assessments may examine demographic change; however, an economic assessment may place emphasis on workforce information while a social assessment may also discuss population change or household data. An integrated approach can provide a comprehensive and cost-effective outcome, providing information on potential economic impacts as well as important social values attached to the activity which inform likely attitudes and responses to the proposed change.

1.1 ABOUT GRACE PACIFIC

Grace Pacific is Hawaiʻi's largest asphalt paving contractor with operations on Oʻahu, Hawaiʻi, Maui and Kauaʻi. Since the 1930s, Grace Pacific used their expertise to enhance airport runways and taxiways, harbor wharves and container yards, interstate freeways, highways, bridges, roadways, bike paths, tennis courts, driveways, and parking lots throughout our state. Grace Pacific is one of the very few paving contractors that can do state highway jobs with their rigorous requirements and large scope of work.

Over the decades, Grace Pacific has expanded its services to become Hawaiʻi's leader on paving. They have quarries where they mine the aggregate and plants where they mix the asphalt. Additionally, Grace Pacific performs major repair and maintenance projects such as renovating bridges, installing guardrails and signs along highways, and applying protective coating to the asphalt to extend the useable life.

1.2 CONTRIBUTIONS TO THE COMMUNITY

The quarry provides 500 jobs on Hawaiʻi, Maui, Lānaʻi, Molokaʻi, Oʻahu and Kauaʻi, generating one million tons of rock materials each year. Grace Pacific has recycled more than 112,000 tons of concrete and asphalt each year since 2003, ensuring that our islands' precious resources are not wasted. The company also gives back to the community, actively supporting 20 public schools in Hawaiʻi. For the last 25 years, Grace Pacific has sponsored local fifth-graders with the Outstanding Keiki scholarship program. The company also supports more than 25 local nonprofits in an effort to be a good neighbor in Makakilo.

1.3 MAKAKILO QUARRY

Makakilo Quarry is a source of basalt aggregate located on the slopes of Puʻu Makakilo on Oʻahu [TMKs (1)9-2-3-82, (1)9-2-3-74 & (1)1-16-4]. The quarry was initially permitted in 1973, and now encompasses 488.2 acres including the active quarry pit and landscaped buffer area. The current quarry operations are allowed under Conditional Use Permit (CUP) 2007/CUP-91 and Special Use Permit (SUP) 2007/SUP-6 (LUC File No. SP73-147) (collectively, "CUP and SUP"). The CUP and SUP are currently scheduled to expire in 2032. Operations at the quarry include processing basalt rock into aggregate, which in turn is sold as structural fill or further processed into concrete products, such as hot mix asphalt and ready-mix concrete, both of which are used in the construction industry. The Makakilo Quarry plays a vital role as a major supplier of aggregate to the island of Oʻahu.

1.4 PURPOSE AND SCOPE

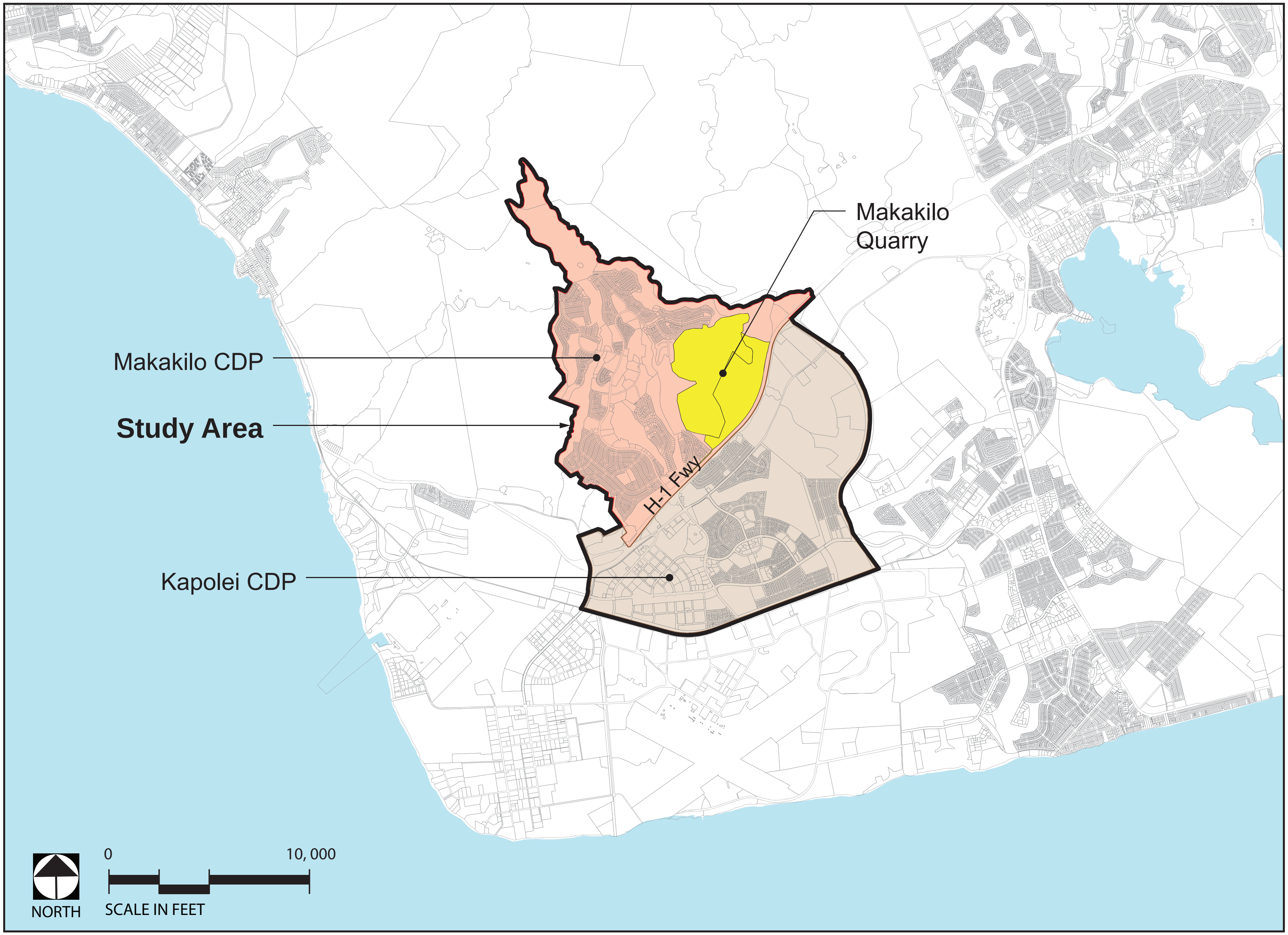
This SEIA will assess the proposed project for any impacts, both positive and negative, to the social infrastructure and economic conditions of the surrounding area to supplement Grace Pacific's application to amend the CUP and SUP. This SEIA report will primarily assess the socio-economic topics that are required to be assessed by the permitting authorities for the SUP and CUP application.

1.5 STUDY AREA

The Makakilo Quarry is located on the southern slopes of Puʻu Makakilo in the ʻEwa, District of Oʻahu, Hawaiʻi, and mauka of H-1 Freeway. All data in this SEIA regarding population, housing and economy was obtained from the U.S. Census Bureau, the U.S. Bureau of Economic Analysis, the Hawaiʻi State Department of Taxation, and the Hawaiʻi State Department of Business Economic Development and Tourism (DBEDT) . As shown in Figure 1 below, the study area for this SEIA includes the Makakilo Census Designated Place (CDP) and the Kapolei CDP (collectively, the "Study Area"). The Study Area includes the neighborhoods of Makakilo north of the H-1 Freeway, and Kapolei and Kapolei Knolls to the south of H-1 Freeway. The Study Area is bound by Renton Road to the south and by Kualakaʻi Parkway to the east.

Figure 1 - Study Area

©2022 Bowers + Kubota Consulting P: (MakakiloQuarry) 2009.33.0700/027p2.ai A 17Oct2022 3

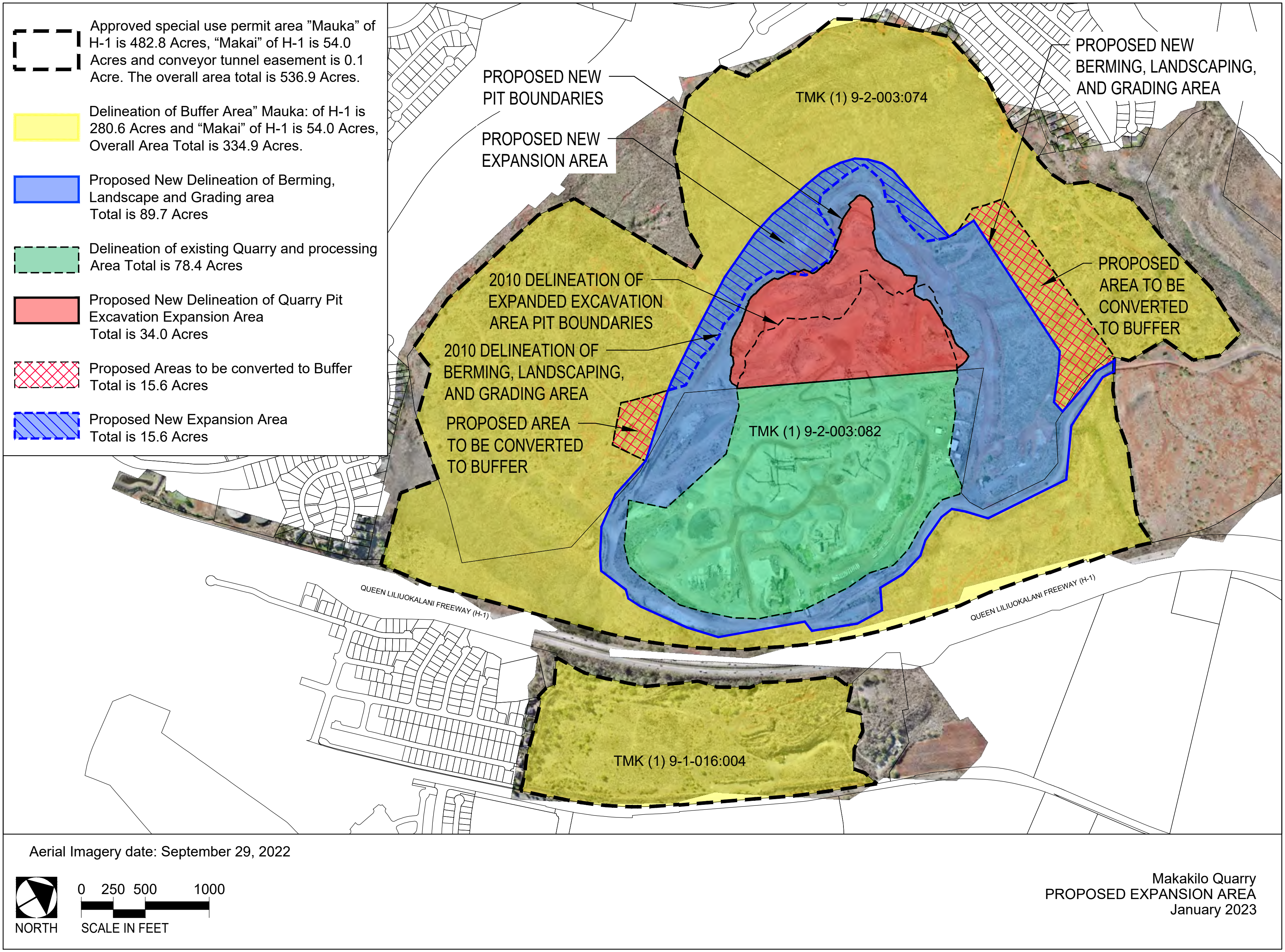


2 PROJECT DESCRIPTION

Grace Pacific is seeking a 15-year extension of the CUP and SUP to extend the life of the quarry to the year 2047. Other proposed amendments to the CUP and SUP include adjusting the boundary of the grading and landscaping portion of the quarry where excavation is allowed to occur. The amended boundary would remove 15.6 acres of land from the excavation area (3.2 acres from the southwest corner of the current grading and landscaping boundary and 12.4 acres from the north portion of the current grading and landscaping boundary). It would also extend the boundary mauka (west) to allow excavation operations to pursue the reserves of basalt of an additional 15.6 acres (an equal amount to that proposed for removal from the permitted boundary). These adjustments to the grading and landscaping boundary are illustrated in Figure 2.

Additionally, Grace Pacific is seeking to extend the operational hours of the processing and sales of materials to a 24-hours-per-day operation. Currently, the sale of material, unloading of permitted recycle materials, and the concrete plant are permitted to operate from 6:00 am to 6:00 pm. The project will also relocate an existing permitted hot-mix asphalt (HMA) plant from the Kalaeloa Industrial area to the quarry floor. The HMA plant will also be permitted operate 24-hours-a-day.

Figure 2 - Makakilo Proposed Boundary Alterations



3 SOCIO-ECONOMIC SETTING

3.1 POPULATION

According to the United States Census Bureau 2020 decennial census, the Study Area has a population of 40,517 people. Between 2010 and 2020, Study Area grew by 11,677 people, or 40.5 percent. The Proposed Action does not include any housing developments, and the additional employees assigned to the HMA plant are not anticipated to have any impact to the current or future population within the Study Area, as the distance between the current location of the HMA and the future location in the quarry pit is not far.

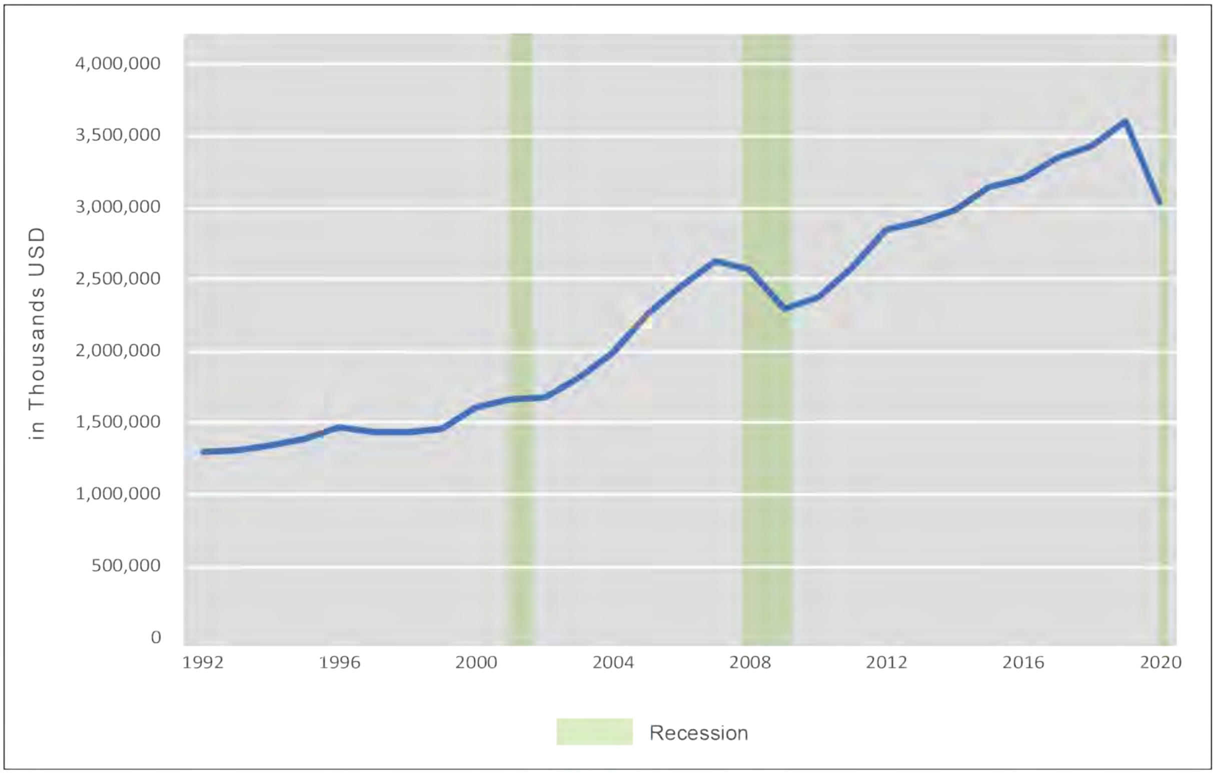
3.2 LOCAL ECONOMY

Within the Study Area, the Makakilo CDP primarily consists of residential neighborhoods and one small neighborhood commercial center, the Mālama Market Makakilo. Kapolei CDP has a diverse mixture of residential, commercial and retail businesses and agricultural lands. The local economy within the Study Area is less dependent on the visitor industry than the rest of the State of Hawaiʻi. Only 10.3 percent of Kapolei's occupations are in accommodations, food service sector, compared to 12.4 percent for the state. The "accommodations, food service" sector is the largest sector of employment outside of government employees in Kapolei.

The Hawaii Department of Business, Economic Development & Tourism (DBEDT) 3rd Quarter 2022 Statistical and Economic Report reported the most recent annualized Gross Domestic Product (GDP) estimate at $95 billion for 2022[1]. The general excise tax (GET) collected by the state in 2020 was $3.04 Billion. This was a 15.6 percent decline from 2019, largely due to the COVID-19 pandemic and subsequent travel restrictions. Figure 3 below displays the GET since 1992, illustrating that GET has generally trended higher except for periods of recession.

[1] DBEDT. *Quarterly Census of Employment and Wages by Industry - 2020 Annual Report*

Figure 3 - Hawai'i State General Excise Tax Collection. Source: Hawai'i State Department of Taxation



Since 2020, the U.S. and Hawai'i have experienced rising inflation that has impacted all levels of people and businesses. In 2022, Hawai'i has experienced the highest rates of inflation since the 2008 recession following the housing bubble. The U.S., as a whole, is experiencing the highest inflation in over 40 years. Figure 4 below displays the rates of inflation, or consumer price index (CPI), for the U.S. and the Honolulu County – Other Goods and Services, under which construction materials is classified. The latest CPI reading for the U.S. and Honolulu County – Other Goods and Services is 8.6 percent and 5.4 percent respectively.

Figure 4 - Consumer Price Index (1994-2022). Source: U.S. Bureau of Labor Statistics

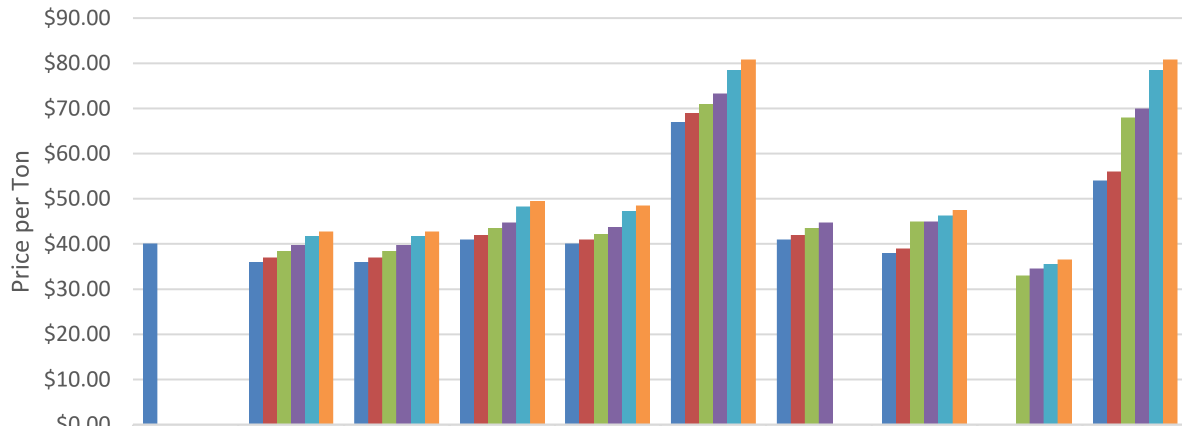
The Makakilo Quarry and the Proposed Action are not anticipated to have a significant impact to the economic indicators mentioned above due to the number of employees that work there relative to the population totals. The Proposed Action may have a positive impact to the local economy with the addition of and the staff relocating to the quarry site to operate the HMA. Income earned by the new employees will spent in the economy via housing expenses, at local Kapolei businesses or other retail and services throughout Honolulu County.

3.3 MAKAKIKO QUARRY PRODUCT PRICING

The Makakilo Quarry produces a variety of products and recycled materials that are sold to customers. There are three categories of products produced. In 2022, Grade A basalt products include: #3A coarse, #3A fine, #4A fine, commercial chips, basalt C-33 sand, BWS S4C, washed sand, and Orca C-33 sand. Grade B basalt products: include HDOT select borrow, #2B coarse, HDOT base course, commercial S4C, 3B fine, B-grade 3”-0”, and B surge-egress. Recycled asphalt and concrete products include recycled asphalt 1½”-0”, recycled concrete #3 fine, and recycled concrete scalping.

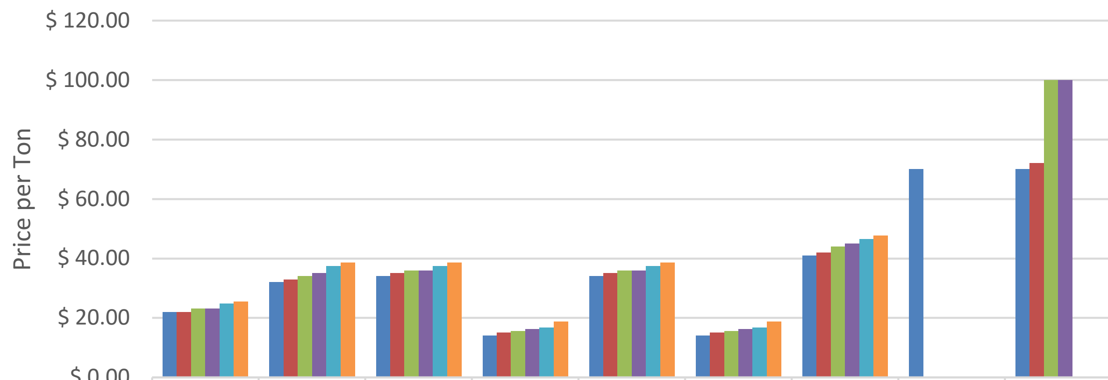
Figures 5, 6, and 7 below display the product pricing, provided by Grace Pacific, from 2016 to 2022 for the various products that are produced at the Makakilo Quarry. Some products have been discontinued during this period. The general price trend across all of these products has increased steadily over the past six years. The average price increase from 2021 to 2022 is 4.0%, which is less than the prevailing CPI of 5.4 for Honolulu County – Other Goods and Services.

Figure 5 - Grade A Basalt Product Pricing



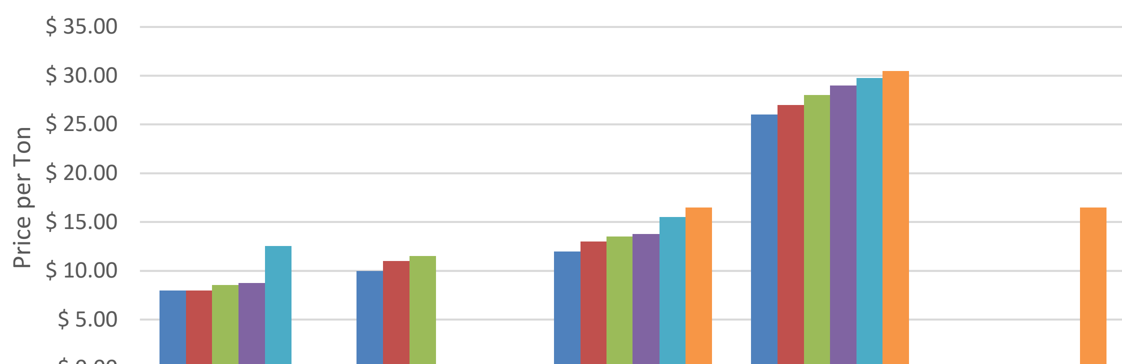
	#2A Coarse	#3A Coarse	#3A Fine	#4A Fine	Commer cial Chips	Basalt C-33 Sand	Basalt Choker	BWS S4C (Washed)	Washed Sand	Orca C-33 Sand
2016	$40.00	$ 36.00	$ 36.00	$ 41.00	$ 40.00	$ 67.00	$41.00	$ 38.00		$ 54.00
2017		$ 37.00	$ 37.00	$ 42.00	$ 41.00	$ 69.00	$42.00	$ 39.00		$ 56.00
2019		$ 38.50	$ 38.50	$ 43.50	$ 42.25	$ 71.00	$43.50	$ 45.00	$ 33.00	$ 68.00
2020		$ 39.75	$ 39.75	$ 44.75	$ 43.75	$ 73.25	$44.75	$ 45.00	$ 34.50	$ 70.00
2021		$ 41.75	$ 41.75	$ 48.25	$ 47.25	$ 78.50		$ 46.25	$ 35.50	$ 78.50
2022		$ 42.75	$ 42.75	$ 49.50	$ 48.50	$ 80.75		$ 47.50	$ 36.50	$ 80.75

Figure 6 - Grade B and Cinder Product Pricing



	HDOT Select Borrow	#2B Coarse	HDOT Base Course	Commercial S4C	3B Fine	B-Grade 3” - 0”	B Surge - Egress	Makakilo Red Cinder (Coarse)	Makakilo Red Cinder (Fine)
2016	$ 22.00	$ 32.00	$ 34.00	$ 14.00	$ 34.00	$ 14.00	$ 41.00	$ 70.00	$ 70.00
2017	$ 22.00	$ 33.00	$ 35.00	$ 15.00	$ 35.00	$ 15.00	$ 42.00		$ 72.00
2019	$ 23.00	$ 34.00	$ 36.00	$ 15.50	$ 36.00	$ 15.50	$ 44.00		$ 100.00
2020	$ 23.00	$ 35.00	$ 36.00	$ 16.25	$ 36.00	$ 16.25	$ 45.00		$ 100.00
2021	$ 24.75	$ 37.50	$ 37.50	$ 16.75	$ 37.50	$ 16.75	$ 46.50		
2022	$ 25.50	$ 38.50	$ 38.50	$ 18.75	$ 38.50	$ 18.75	$ 47.75		

Figure 7 - Recycled Asphalt and Concrete Pricing



	Recycled Asphalt 6” - 0”	Recycled Asphalt 3” - 0”	Recycled Asphalt 1 1/2” - 0”	Recycled Concrete #3 Fine	Recycled Concrete Scalping
2016	$ 8.00	$ 10.00	$ 12.00	$ 26.00	
2017	$ 8.00	$ 11.00	$ 13.00	$ 27.00	
2019	$ 8.50	$ 11.50	$ 13.50	$ 28.00	
2020	$ 8.75		$ 13.75	$ 29.00	
2021	$ 12.50		$ 15.50	$ 29.75	
2022			$ 16.50	$ 30.50	$ 16.50

Extending the life of the SUP and CUP will also extend the production of the various products at the quarry. Customers, contractors and individuals that currently benefit from the local availability of these products will be able to continue purchasing through the proposed extension.

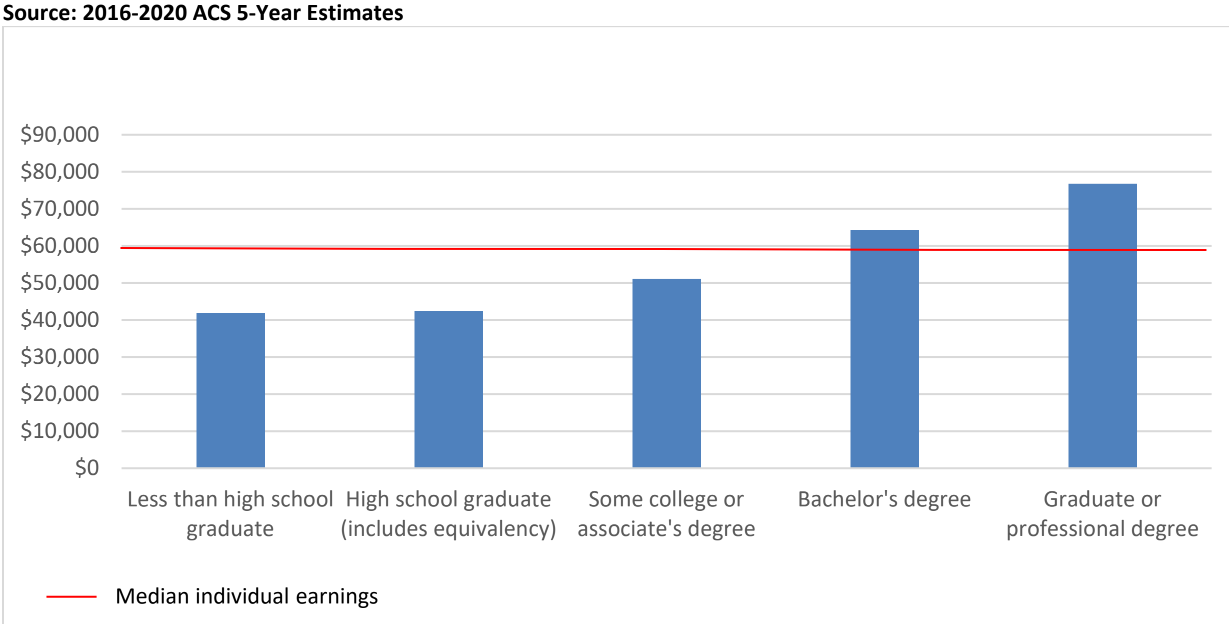
3.4 EMPLOYMENT & INCOME

Grace Pacific currently employs 45 personnel to operate the Makakilo Quarry and 12 employees are involved with excavation and hauling. The proposed extension of the SUP and CUP will provide an additional 15 years of stable employment at the quarry. Grace Pacific has experienced tremendous employee loyalty and longevity over its history. The average Grace Pacific employee stays with the company for approximately 14 years.

According to the 2016-2020 American Community Survey (ACS) 5-year estimates, the total working-age population (ages 16 to 64) living in the Study Area is 26,211. Approximately 15,920 people (or 60.7 of the population) have an employment rate of 60.7 percent and the largest class of worker is local, state and federal government workers at 25.2 percent. The current poverty rate is 7.5 percent for the Study Area.

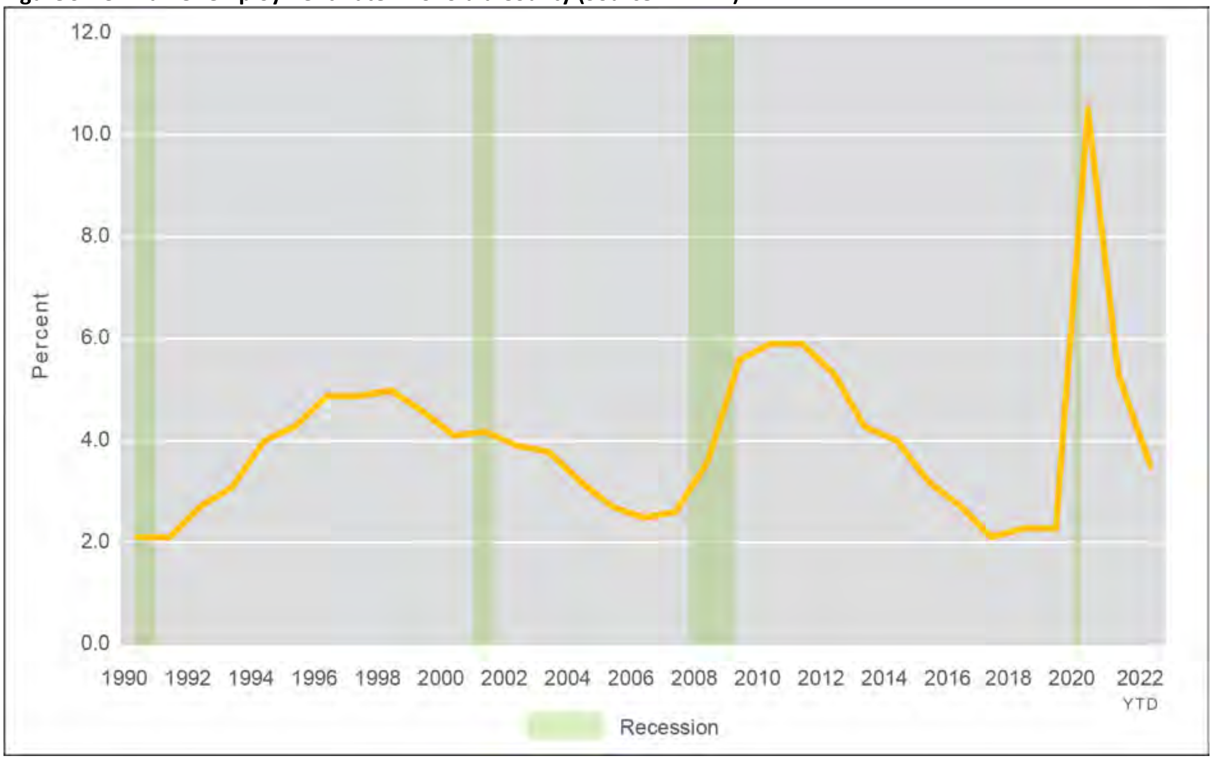
According to the 2016-2020 ACS 5-Year Estimates, the median individual earnings within the Study Area is $59,759. The data also shows that personal income increased with higher educational achievements. As shown in Figure 8 below, the median per capita income for earners attaining a bachelor's degree or higher is above the overall median per capita for all earners.

Figure *8* - Earnings in the past 12 months by educational attainment (2020 inflation-adjusted dollars).
Source: 2016-2020 ACS 5-Year Estimates



The current unemployment rate for year-to-date 2022 is estimated at 3.5 percent, as shown in Figure 9. This is continuing the downward trend following the COVID-19 pandemic induced travel restrictions and economic slowdown. This caused nearly the entire visitor and accommodations industry to close operations until restrictions were eased. However, 3.5 percent unemployment is higher than pre-pandemic rates.

Figure *9* - Civilian Unemployment Rate - Honolulu County (Source: DBEDT)



The Makakilo Quarry remained in operation throughout the pandemic and did not layoff any employees during that time. Grace Pacific anticipates the relocation of up to 12 additional staff for the operation of the HMA at the quarry. The median wage rate for employees working at the quarry is $49.07 per hour. At the median Makakilo Quarry wage rate, this equates to approximately $22.8 million in new personal income paid from Grace Pacific, assuming three percent annual raises, over the 15-year extension of the SUP and CUP.

3.5 FISCAL IMPACTS

The direct estimated cost to complete the Proposed Action is $1.2 Million. As stated above, the estimated cost will include the relocation of the HMA and other costs associated with adjusting the quarry area. Following the completion of the Proposed Action, the Makakilo Quarry's capacity to produce aggregate will be extended for an additional 15 years. In addition, the quarry site will also produce asphalt and concrete that will generate additional operating revenues that, in turn, will generate more GET for the state. The proposed action will also generate a positive economic impact of approximately $22.8 million in new salary/wages earned by the 12 positions moving to the quarry and continuing through the extended life of the quarry.

Relative to the local economy, the Gross Domestic Product (GDP) for the State of Hawaiʻi was $90 billion in 2021[2]. No adverse impacts are anticipated from the Proposed Action. The additional personal incomed earned by the HMA plant workers may likely provide a positive impact to the local economy within the Kapolei CDP.

3.6 CULTURAL RESOURCES

The Makakilo Quarry is located along the slopes of Puʻu Makakilo, in Honouliuli ahupuaʻa within the moku (district) of ʻEwa. Puʻu Makakilo translates to "observing eyes hill." The general area is referred to as Makakilo, or Makakilo City, but was once called Hanalei (Sterling & Summers 1978:34).

The initial Cultural Impact Assessment (CIA) of Puʻu Makakilo and adjacent areas was prepared by Pacific Legacy, Inc. in 2008 for Grace Pacific's initial expansion of the quarry's boundaries (Pacific Legacy, 2008). The CIA consisted of archival research and oral interviews to assess the significance of the project site and its immediate surroundings.

In 2008, only one archaeological site was documented within the project area. A 1988 archaeological survey discovered a deteriorated wall segment inside of Puʻu Makakilo (Bishop Site No. 50-oa-B-6-276 & State Site no. 50-80-12-1975). The wall may have served as erosion control in historic times, but due to its deteriorated state and the fact that the wall was not associated with any other features, the site did not warrant further archaeological investigation nor preservation according to the 1988 standards of National Register criteria of significance. Additionally, at the peak of the Puʻu Makakilo, there is a historic military bunker from World War II.

In 2022, Pacific Legacy conducted a field inspection on the proposed expansion area, finding five potential historic properties, with one of them possibly being the previously recorded historic wall identified in 1988 (Pacific Legacy 2022). The potential historic properties that were identified included a concrete ditch, two stone alignments representing segments of post-contact wall or terrace retaining features, and two modified outcrops of indeterminate function. As a result of these finds, an Archaeological Inventory Survey will be conducted in accordance with Pacific Legacy's recommendations to further study the sites.

The landscape of Puʻu Makakilo has been significantly altered from post-contact ranching and sugar cane farming activities on its slopes, leaving little evidence of traditional uses or cultural resources. Oral interviews with cultural informants suggest the slopes of Puʻu Makakilo were used for gathering medicinal plants and served as a pathway for Hawaiian bird catchers. The landscape has since been disturbed by human activity and natural events, causing significant erosion and allowing the growth of non-native vegetation.

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[2] GDP is reported at the state level. DBEDT does not break down GDP to the county or city level.

Interviews also mention Puʻu Makakilo's visual significance, as it was used traditionally as a viewpoint as well as a feature for those navigating offshore. The cultural informants identified Puʻu Makakilo as a landmark on the edge of the seasonal paths of the sun and moon, which indicated winter and summer solstices, thus an integral part of the solar/lunar calendar.

Makakilo area was described as "rough country" and "home of wandering spirits with no holdings, who ate spiders and moths for sustenance" (Kamakau 1964:83). The cultural informants explained in numerous ways the spiritual transcendence of this area is imbued into the physical landscape. Traditional accounts vary between esoteric and tangible, which illustrate the pre-contact Hawaiian perspective where myth and reality intermingle. Considering the abundance of both cultural features in adjacent areas, it is likely that Puʻu Makakilo played a larger role in cultural practices and mythology in earlier times. Records of events and stories tied to Puʻu Makakilo may not have survived or may exist via oral storytelling due to Puʻu Makakilo's spiritual nature. The limited amount of recorded information regarding Puʻu Makakilo combined with the significant alterations the slopes have undergone post-contact indicate that the proposed project will likely not have any adverse effect on cultural resources in the area (Pacific Legacy, 2008).

With the new expansion area proposed, Pacific Legacy prepared an addendum to update the 2008 CIA. The new oral interviews in the addendum mention characteristics in the proposed expansion area such as previous military use, concern for disturbance of Hawaiian sites, a path where otherworldly activities occur (e.g., Night Marchers, Akualele), and a mention of a historically significant house site. Pacific Legacy acknowledges that the expansion area has experienced significant ground disturbance from past industrial sugarcane agriculture and golf course construction, so if there were any cultural or historic resources present, they would have been disturbed by previous activities. Additionally, the historic house site mentioned could not be located in 2022 field inspections (Pacific Legacy, 2022).

The Proposed Action is not anticipated to impact any cultural resources; however, Pacific Legacy recommended to conduct an archaeological inventory survey prior to any ground disturbance in relation to the proposed expansion area of the quarry. In the event of inadvertent discovery of human skeletal remains (*ʻiwi kupuna*), quarry operations will be paused, and the State Historical Preservation Division and relevant county agencies will be notified pursuant to Chapter 13-300, Hawaiʻi Administrative Rules.

3.7 HOUSING

As of the 2020 Decennial Census, there are 12,866 households within the Study Area and a homeownership rate of 73.4 percent. This exceeds the state homeownership rate of 60.3 percent. The average number of persons per household is 3.4. The Proposed Action does not involve any residential construction or any proposed improvements to the infrastructure and utilities in the area, therefore there is no direct or secondary impact on housing.

3.8 RECYCLING AND SOLID WASTE REDUCTION

The Makakilo Quarry has a recycle plant that processes salvaged concrete and asphalt from construction sites into recycled materials that are subsequently sold to customers. Table 1 below displays the amount of material that was recycled at the plant. The recycle plant is very efficient at minimizing solid waste that is sent to the landfill. From FY2017-21, more than 110,000 tons of concrete and asphalt were accepted at the plant. This resulted in nearly 87,000 tons of recycled material that was sold to customers. Less than 0.2 tons of material was deposited at the PVT Landfill during the same time period. The Proposed Action does not include any changes to the recycling plant, therefore, no impacts are anticipated to the plant's operation. The environment and customers will continue to benefit from the additional 15 years of operation at the recycling plant. While the quarry and the recycling remain in operation during the 15-year extension period, this prevents tens of thousands of tons annually from needing to be deposited at a landfill.

Table 1 - Grace Pacific Recycle Plant Annual Report (FY2017-21)

	FY 2017-18	FY 2018-19	FY 2019-20	FY 2020-21	Total
Incoming Materials (Tons)					
Concrete	8,437	14,232	15,140	22,926	60,735
Asphalt	29,859	7,193	6,971	5,892	49,915
Total Incoming	38,296	21,425	22,111	28,818	110,650
Recycled Materials (Tons)					
Concrete	0	305	4,968	6,325	11,598
Asphalt	20,469	7,305	9,423	38,073	75,270
Steel	62	0	48	15	125
Total Recycled	20,531	7,610	14,439	44,413	86,993
Landfilled Materials (Tons)					
Total Landfilled	0.000	0.000	0.000	0.135	0.135

4 SOCIAL INFRASTRUCTURE

4.1 EDUCATION

Within the Study Area, there are four elementary schools operated by the Hawaiʻi Department of Education (DOE). Mauka of the H-1 Freeway area Makakilo Elementary School and Mauka Lani Elementary School. Makai of the H-1 Freeway are Hoʻokele Elementary School and Kapolei Elementary School. Both Makakilo and Mauka Lani Elementary Schools are located within the DOE's Campbell-Kapolei Complex Area.

According to the US Census Bureau 2016-2020 ACS 5-Year Estimates, 94.6 percent of the adult population 25 years and older living in the Study Area achieved a high school diploma, or equivalent, or higher. Approximately 36.1 percent of the adult population has achieved a bachelor's degree or higher. As shown in Figure 8 above, an individual's earning potential increased as the higher level of education is attained.

The Proposed Action, if approved, is not anticipated to have an adverse impact on the local school enrollment or impact any operations at the schools. At this time, the impact of the employees assigned to the HMA plant moving to the Makakilo Quarry on existing schools is unclear. It is not known the future hired personnel will relocate to the Study Area or if they have school-aged children.

4.2 FIRE AND POLICE

Fire protection for the Makakilo Quarry is provided by the Honolulu Fire Department (HFD). There are three fire stations located within the Study Area. Fire Station 35-Makakilo, Fire Station 43-East Kapolei, and Fire Station 40-Kapolei are within three miles of the Makakilo Quarry.

Law enforcement is provided by the Honolulu Police Department (HPD). The Makakilo Quarry and the surrounding area is in Patrol District 8 – Kapolei. District 8 has one police station in Kapolei and serves the ʻEwa, Makakilo, Nānākuli, Waiʻanae, and Mākaha communities.

The proposed 24-hour, 7-days-per-week operating schedule is an increase from the existing operating hours. The additional operating hours may result in an increased potential demand for fire and police services; however, it is not anticipated to have an adverse impact on HPD or HFD service or result in the need for additional officers or fire fighters.

5 MUNICIPAL INFRASTRUCTURE

5.1 TRAFFIC

Fehr and Peers prepared a Mobility Analysis Report (MAR) for the Proposed Action (Fehr and Peers 2022). [Note: for this section only, the terms "Proposed Action" and "project" are used interchangeably] The MAR contains an assessment of mobility and access associated with the proposed expansion and extension of services at the Makakilo Quarry. Existing vehicular access to the site is provided via Palehua Road at the H-1/Kualakaʻi Parkway interchange and that access is proposed to be maintained with the Proposed Action. The MAR analysis was conducted for a project opening year of 2024, at which point expanded facilities and modified operations are assumed to be in place.

Two study intersections in the vicinity of the project were evaluated during the weekday morning (AM) and evening (PM) peak hours for existing conditions, future year (2024) no project conditions, and future year (2024) plus project conditions. No extension of Makakilo Drive was assumed for the analysis given that the project was removed from the 2019-2022 Statewide Transportation Improvement Project/Transportation Improvement Program list and won't be completed by 2024.

The key roadways providing vehicular access in the vicinity of the project site are Kualakaʻi Parkway, H-1 Freeway, and Palehua Road. For existing conditions, both study intersections (H-1 Westbound Ramps/Palehua Road/Kualakaʻi Parkway and H-1 Eastbound Ramps/Kualakaʻi Parkway) operate acceptably with little delay.

For the future year (2024) plus project conditions, the anticipated vehicle trip generation for the facility was determined based on future employee and truck estimates provided by Grace Pacific, as well existing counts taken at the site driveway for existing land uses. The proposed project is expected to generate a total of 137 net new daily vehicle trips, including 35 net new vehicle trips during the AM peak hour (19 inbound/16 outbound) and 19 net new vehicle trips during the PM peak hour (5 inbound/14 outbound).

The mobility analysis determined that the Proposed Action will have no significant impacts to any roadway segments or intersections. Based on a multimodal evaluation of mobility effects from the project, no potential impacts to pedestrian facilities, bicycle facilities, and transit facilities are anticipated.

5.2 WASTEWATER

The Makakilo Quarry is not connected to the City's wastewater systems. Portable toilets are provided for employees at the quarry. The Proposed Action does not plan for a new connection to the municipal system and the existing conditions will remain.

5.3 WATER

The Makakilo Quarry is supplied with non-potable water from State Well #3-2103-006, owned by Grace Pacific, located in the upper portion of the quarry area. Current maximum permitted pumpage is 0.256 million gallons per day (or 7.68 million gallons per month) of non-potable water. Uses of the non-potable water include dust control and landscaping. Water tank trucks are used at the quarry to spray water on the roadways, stockpiles and excavated areas. Potable water is supplied by the Board of Water Supply. The connection to the municipal water system is located in the northwest portion of the quarry property.

The Proposed Action seeks to extend operating hours for some uses to a 24-hour-per-day, 7-days-per-week schedule. Grace Pacific anticipates that the Proposed Action will increase water usage by approximately .05 mgd at the Makakilo Quarry. While operating the HMA plant and the expansion of the operating hours will increase the demand for water at the Makakilo Quarry, no changes to the existing water facilities or the permitted allocations for the quarry are anticipated under this Proposed Action.

6 CUMULATIVE IMPACTS

In the State of Hawaiʻi, there are only three quarries that are in operation that are the primary source for basalt aggregate for the island of Oʻahu and the state: Makakilo Quarry – Grace Pacific, Kapaʻa Quarry – HC&D, and Halawa Quarry – Hawaiian Cement. As shown in Figure 10 below, the Halawa Quarry's conditional use permit (CUP) is scheduled to expire in 2026.

Even with three quarries, it is not enough to supply all of the construction projects across the state. To meet the current construction demand, the aggregate is imported from other parts of the country. Imported aggregate is more expensive than the locally mined aggregate due to freight and shipping costs. Freight and shipping costs have increased in the past few years due to increased fuel prices and a high inflation.

In the event Hawaiian Cement does not extend their CUP, then the state will only have two operating quarries for aggregate and the amount of imported aggregate needed will significantly increase to fill the reduced local supply for aggregate. This would create a duopoly[1] for the two remaining aggregate quarries operated by Grace Pacific and HC&D. It is likely that prices for aggregate, asphalt and concrete will increase.

In the event that Hawaiian Cement does not extend their CUP and Grace Pacific's proposed SUP and CUP extension is not approved, then the aggregate market will become a monopoly[2] for HC&D as the Kapaʻa Quarry would be the lone operating aggregate quarry in the state. HC&D would be in a dominant position in regard to pricing power for aggregate and the state would need to significantly increase the amount of imported aggregate to fill the demand a single quarry can't cover.

Figure 10 - Aggregate Quarries on O'ahu and Expiration Year

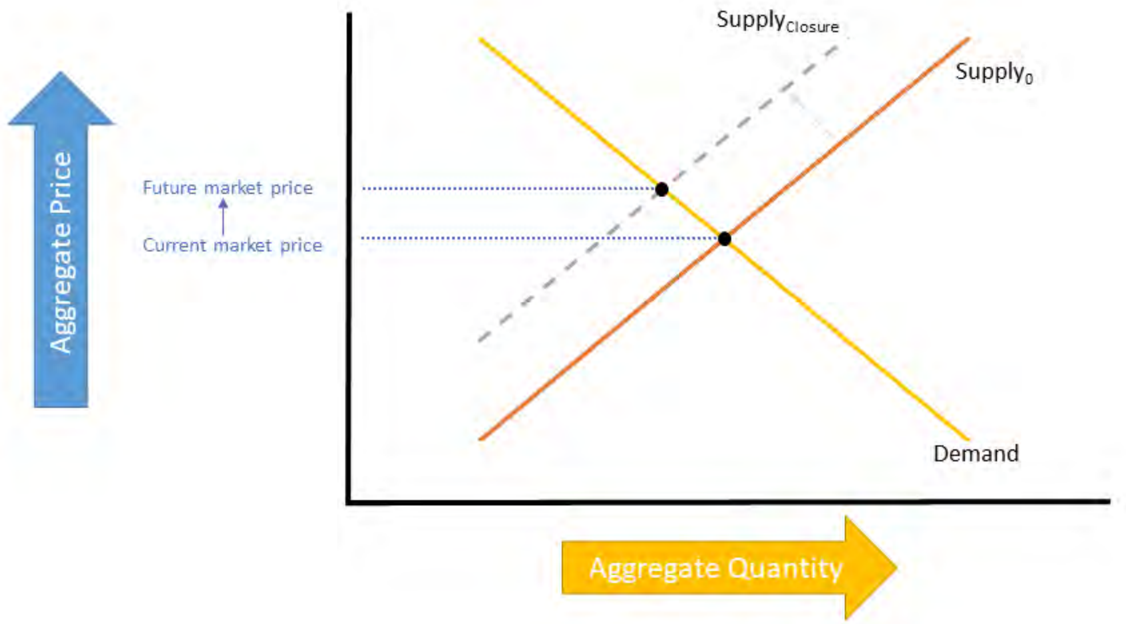
	GP	HC&D ROCK SOLID SINCE 1908	HAWAIIAN CEMENT A Subsidiary of Knife River Corporation
Location:	Makakilo Quarry	Kapaʻa Quarry	Halawa Quarry
Permit Expiration:	2032	2042	2026

If the Proposed Action is approved, and Makakilo Quarry is allowed to extend its operations beyond 2032, then the local economy will benefit from an extended period of competitive balance in pricing for aggregate. The local construction industry will continue to have at least two quarries producing aggregate and other asphalt and concrete products depending on the status of the Halawa Quarry after 2026.

[1] Duopoly – a market condition in which two suppliers dominate the market for a commodity or service.
[2] Monopoly – a market condition in which one supplier dominates the market for a commodity or service.

Figure 11 illustrates how pricing is impacted with changes in the supply-side for aggregate. General supply/demand theory suggests that the market price is determined at where the supply and demand lines intersect. When there is a shift in either supply or demand lines, this will impact the market price one way or the other. In the event of a local aggregate quarry closing, this would shift the supply line to the left, which represents a reduction in local supply in the market. As a result, the intersection supply and demand lines moves up the (y) axis that represents the price for aggregate. Increased price for aggregate is further impacted by the increase dependance of the higher-priced imported aggregate.

Figure 11 - Impact to Aggregate Pricing following Makakilo Quarry Closure



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Pacific Legacy

Historic Preservation

DRAFT

ARCHAEOLOGICAL INVENTORY SURVEY FOR THE PROPOSED 15.6-ACRE EXPANSION AREA AT THE MAKAKILO QUARRY, KAPOLEI, HONOULIULI AHUPUA‘A ‘EWA MOKU O‘AHU ISLAND

[TMK: (1) 9-2-003:074 (POR.)]

Pacific Legacy: Exploring the past, informing the present, enriching the future.

CULTURAL RESOURCES CONSULTANTS

Hawai‘i Office:
Kailua, O‘ahu

California Offices:
Bay Area
Sierra/Central Valley

Exhibit "Z"

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DRAFT

ARCHAEOLOGICAL INVENTORY SURVEY FOR THE PROPOSED 15.6-ACRE EXPANSION AREA AT THE MAKAKILO QUARRY, KAPOLEI, HONOULIULI AHUPUAʻA ʻEWA MOKU OʻAHU ISLAND

[TMK: (1) 9-2-003:074 (POR.)]

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May 2023

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Note: In this report, the spellings and the use of diacritical marks (glottal stops and macrons) follow conventions issued by Pukui and Elbert (1986) and Pukui et al. (1974) with limited exceptions – spellings and diacritical marks are used as the original sources used them in quotations, titles, and proprietary names.

Cover image: *Excavation in progress at SIHP 50-80-12-01975, Feature 3, Test Unit 1, showing the exposed internal alignment. View to the east.*

MANAGEMENT SUMMARY

Reference	Archaeological Inventory Survey for the Proposed 15.6-Acre Expansion Area at the Makakilo Quarry, Kapolei, Honouliuli Ahupuaʻa, ʻEwa Moku, Oʻahu Island [TMK: (1) 9-2-003:074 (por.)] (Swift et al. 2023)
Date	May 2023 (DRAFT)
Project Number(s)	Pacific Legacy, Inc. Project No. 3986.02
Project Location	The Makakilo Quarry Proposed Expansion Project Area is located in Honouliuli Ahupuaʻa, ʻEwa Moku, within a portion of TMK: (1) 9-2-003:074. The proposed expansion area extends to the northwest of the current Makakilo Quarry footprint and comprises roughly 15.6 acres in total. The quarry lies on the southwest flank of Puʻu Makakilo, just outside the city of Kapolei and inland of the H-1 Freeway.
Project Description and Related Ground Disturbance	The proposed expansion will provide Grace Pacific, LLC with access to a seam of high-quality rock for use in concrete and asphalt paving. In addition to the proposed expansion, Grace Pacific, LLC intends to apply for modifications to their current quarry permit that would extend the permit 15 years beyond its current expiry (from 21 December 2032 to 21 December 2047) and modify their existing operating hours (6 am to 6 pm) to permit hot mix asphalt production and sales in the pit of the quarry 24 hours per day, 7 days per week. Mining would continue to be restricted to daytime use only. They also plan to expand the footprint of the Hot Mix Asphalt Plant within the existing quarry and install a new recycle sub-feed plant on the quarry floor, adjacent to the B-Rock Finishing Plant.
Project Area Land Jurisdiction	Private, Grace Pacific, LLC
Project Proponent	Grace Pacific, LLC
Investigation Permit Number	Fieldwork for this project was performed under Pacific Legacy's Hawaiʻi State Historic Preservation Division (SHPD) annual archaeological permits 22-17 (2022) and 23-04 (2023), issued per Hawaiʻi Administrative Rules (HAR) §13-282.
Agency	City and County of Honolulu
Project Area Acreage	15.6 acres
Document Purpose and Historic Preservation Regulatory Context	This document was prepared to support the project's historic preservation review under Hawaiʻi Revised Statutes (HRS) §6E-42 and to satisfy the requirements of Hawaiʻi Administrative Rules (HAR) §13-284. This document was designed to fulfill the State requirements for an archaeological inventory survey (AIS), in accordance with HAR §13-276-5.
Fieldwork Effort	Pedestrian survey with 100% coverage of the project area was carried out over the course of three days in November and December 2022, with follow-up test excavations carried out over the course of two days in January 2023. Fieldwork was conducted under the overall supervision of Principal Investigator Mara Mulrooney, Ph.D. The fieldwork team consisted of Jillian Swift, Ph.D., Jennifer Robins, B.A., Caleb Fechner, B.A., and James McIntosh, B.A. In total, five days of fieldwork and 12 person-days were required.
Survey Results	The AIS resulted in the re-identification of one historic property (SIHP 50-80-12-01975), and the addition of four newly identified features to SIHP -01975, for a total of five features within the project area all belonging to SIHP -01975. All five features were found to be associated with pre-Contact agricultural activities and/or post-Contact water management. All are assessed as significant under Criterion d, and recommended for no further work.

1.0 INTRODUCTION

At the request of Grace Pacific, LLC, Pacific Legacy, Inc. conducted an archaeological inventory survey (AIS) in the *ahupuaʻa* (traditional land division) of Honouliuli in the *moku* (district) of ʻEwa on the island of Oʻahu (Figure 1 and Figure 2). The AIS focused on a proposed 15.6-acre expansion to the footprint of quarrying activities at Makakilo Quarry. The AIS consisted of a 100% pedestrian survey and limited test excavations to identify the nature, type, and extent of all historic properties within the project area. The project area is within TMK: (1) 9-2-003:074 (por.) (Figure 3 and Figure 4).

1.1 PROJECT DESCRIPTION

The Makakilo Quarry Proposed Expansion Project Area is located in Honouliuli Ahupuaʻa, ʻEwa Moku, island of Oʻahu, within a portion of TMK: (1) 9-2-003:074. The quarry lies on the southwest flank of Puʻu Makakilo, just outside the city of Kapolei and *mauka* (inland) of the H-1 Freeway.

Grace Pacific, LLC is proposing an expansion area of approximately 15.6 acres on the northwest side of the current Makakilo Quarry footprint. The proposed expansion will provide Grace Pacific, LLC with access to a seam of high-quality rock for use in concrete and asphalt paving. In addition to the proposed expansion, Grace Pacific, LLC intends to apply for modifications to their current quarry permit that would extend the permit 15 years beyond its current expiry (from 21 December 2032 to 21 December 2047) and modify their existing operating hours (6 am to 6 pm) to permit hot mix asphalt production and sales in the pit of the quarry 24 hours per day, 7 days per week. Mining would continue to be restricted to daytime use only. They also plan to expand the footprint of the Hot Mix Asphalt Plant within the existing quarry and install a new recycle sub-feed plant on the quarry floor, adjacent to the B-Rock Finishing Plant (Figure 5 and Figure 6).

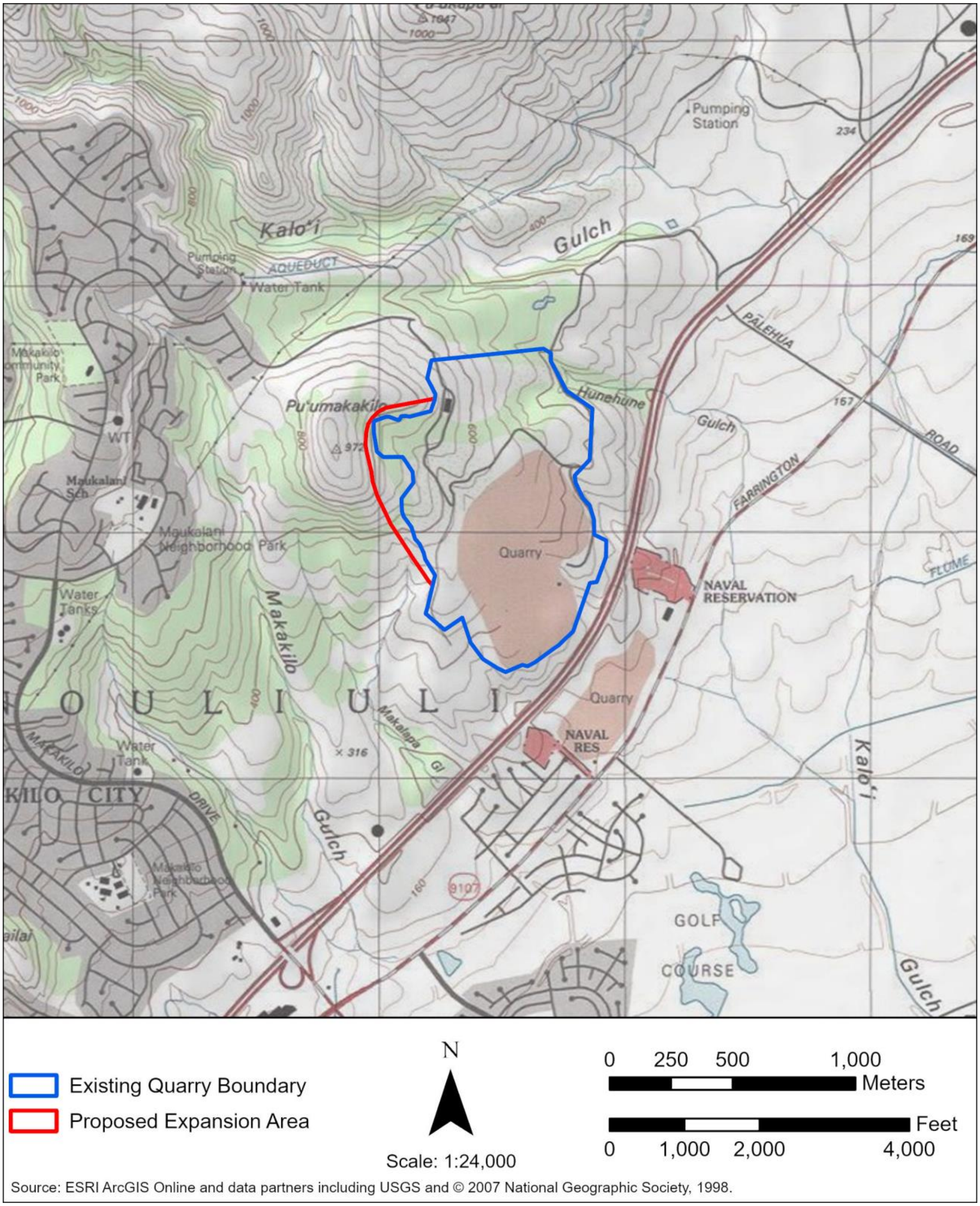

Figure 1. Location of the Makakilo Quarry Proposed Expansion Project Area, adjacent to the existing Makakilo Quarry footprint, Kapolei, Honouliuli Ahupuaʻa (base map: USGS Ewa Quadrangle 1998).

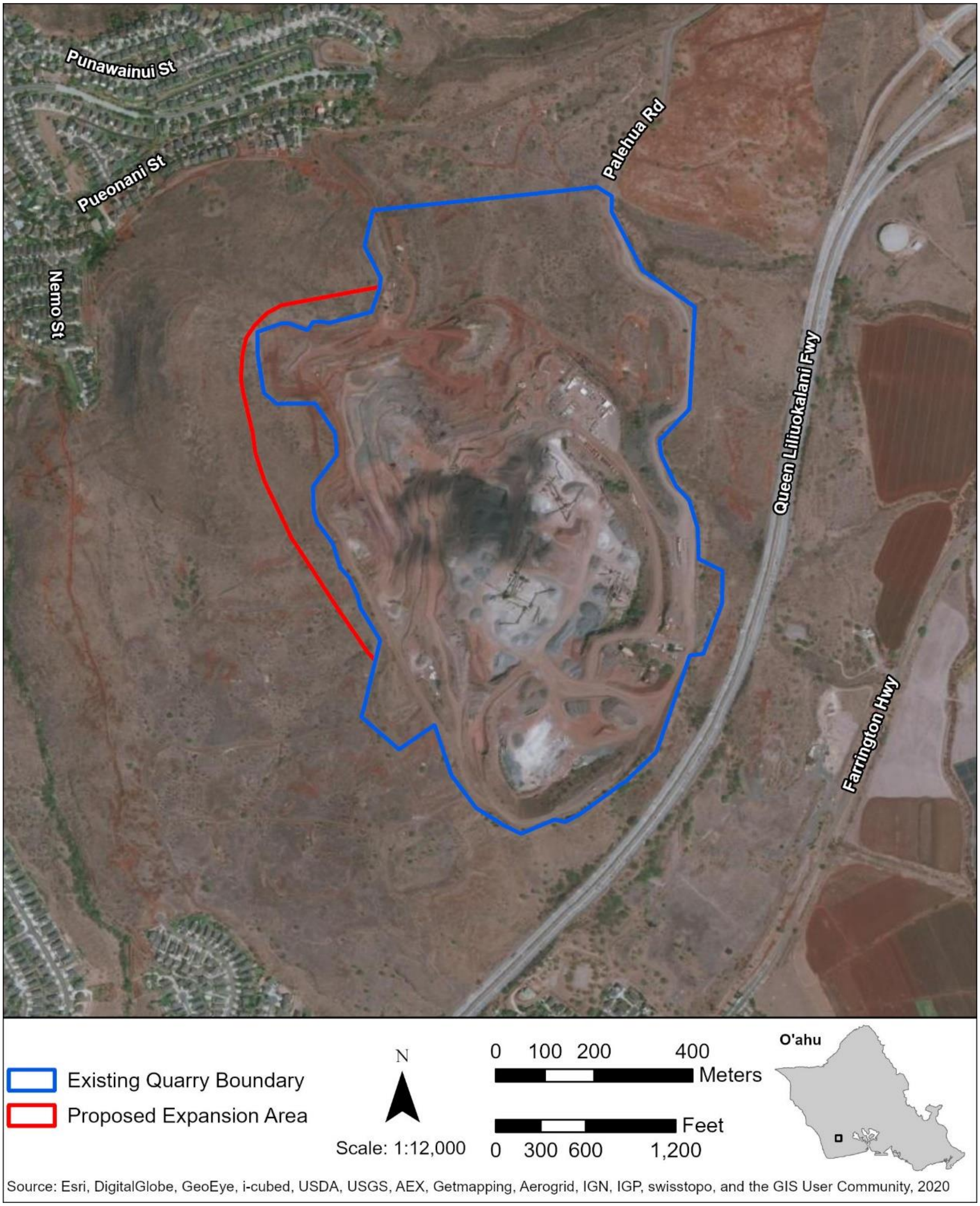

Figure 2. Location of the existing Makakilo Quarry boundary (blue) with outline of proposed expansion project area (red), and nearby roadways (base map: Esri World Imagery 2020).

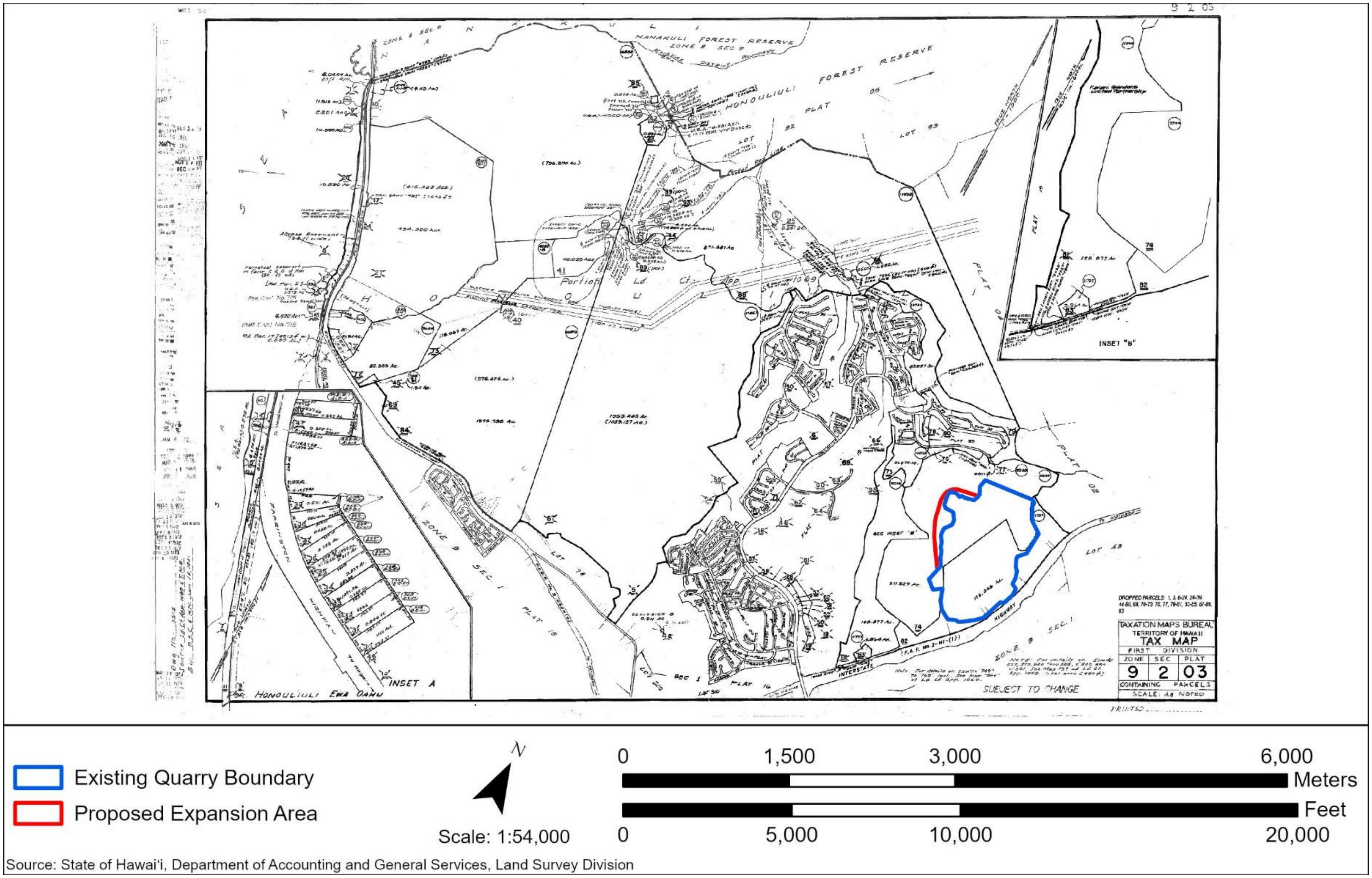

Figure 3. Tax map plat for TMK: (1) 9-2-003, with current Makakilo Quarry footprint and proposed expansion area outlined (source: State of Hawai'i, Department of Accounting and General Services, Land Survey Division, TMK: (1) 9-2-003:074 por.).

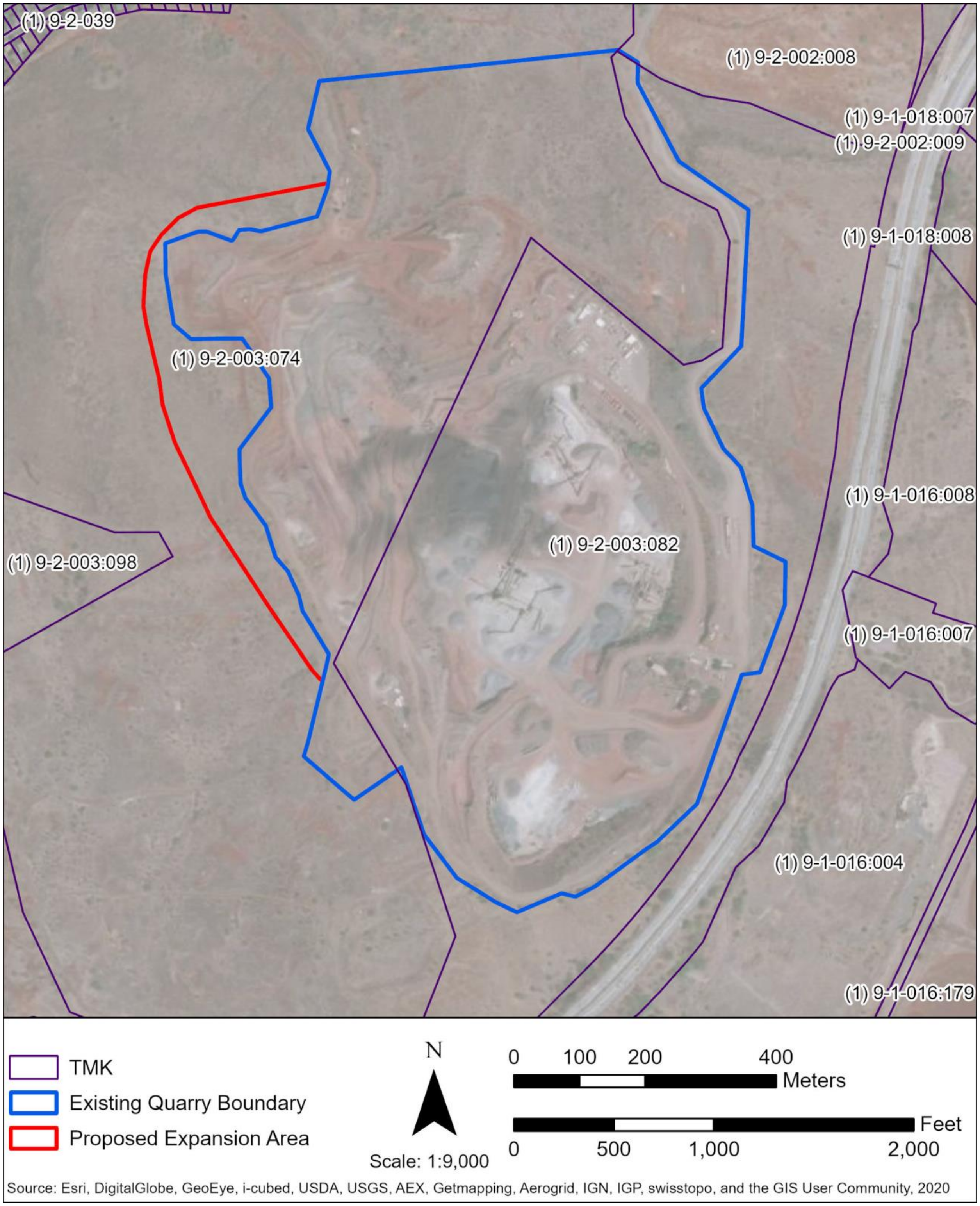

Figure 4. Location of TMK: (1) 9-2-003:074 and the Makakilo Quarry Proposed Expansion Project Area (source: State of Hawai'i, Department of Accounting and General Services, Land Survey Division; base map: Esri World Imagery 2020).

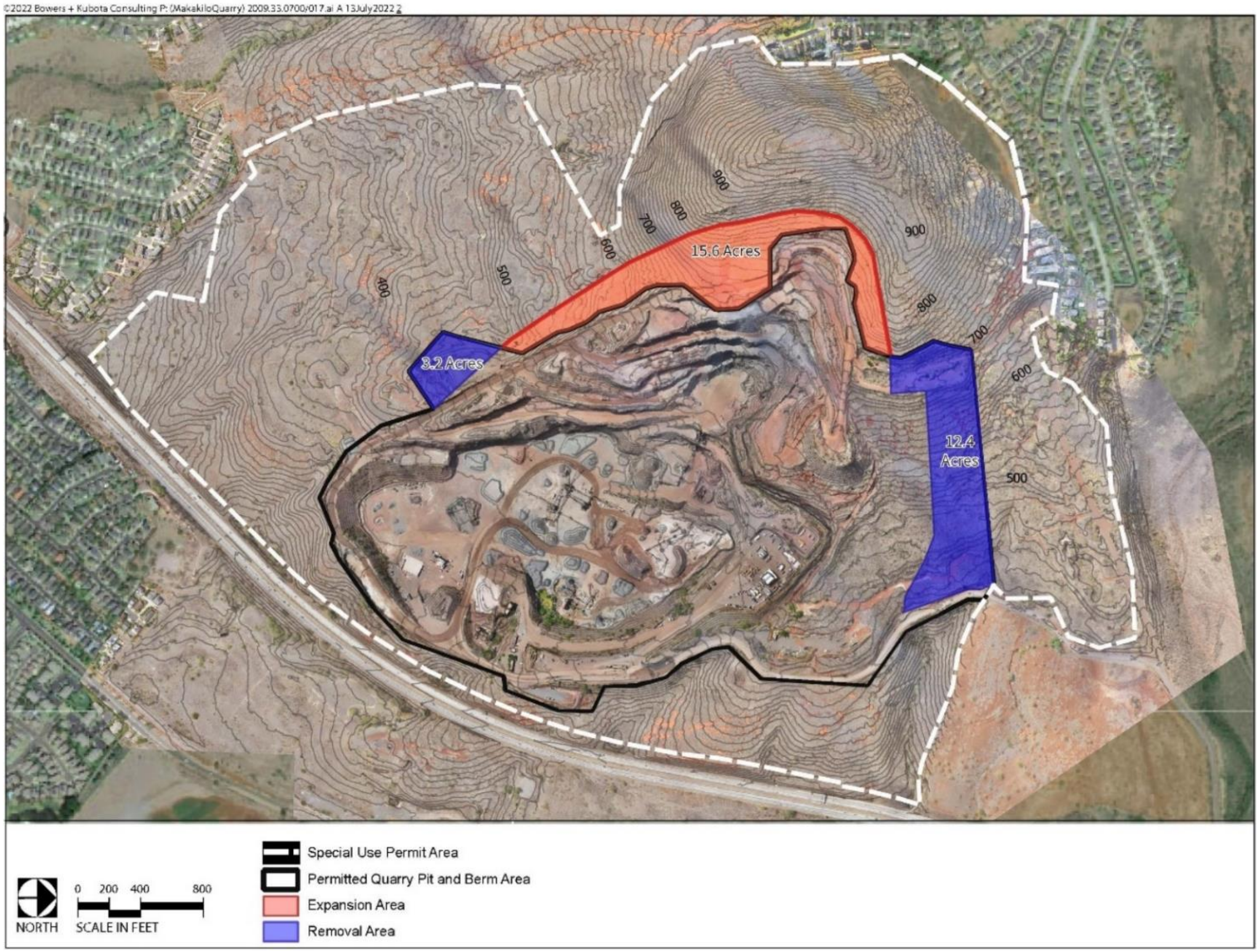

Figure 5. Site plans for the Makakilo Quarry Proposed Expansion Project Area, illustrating proposed boundary amendments (courtesy of Grace Pacific, LLC, 2022).

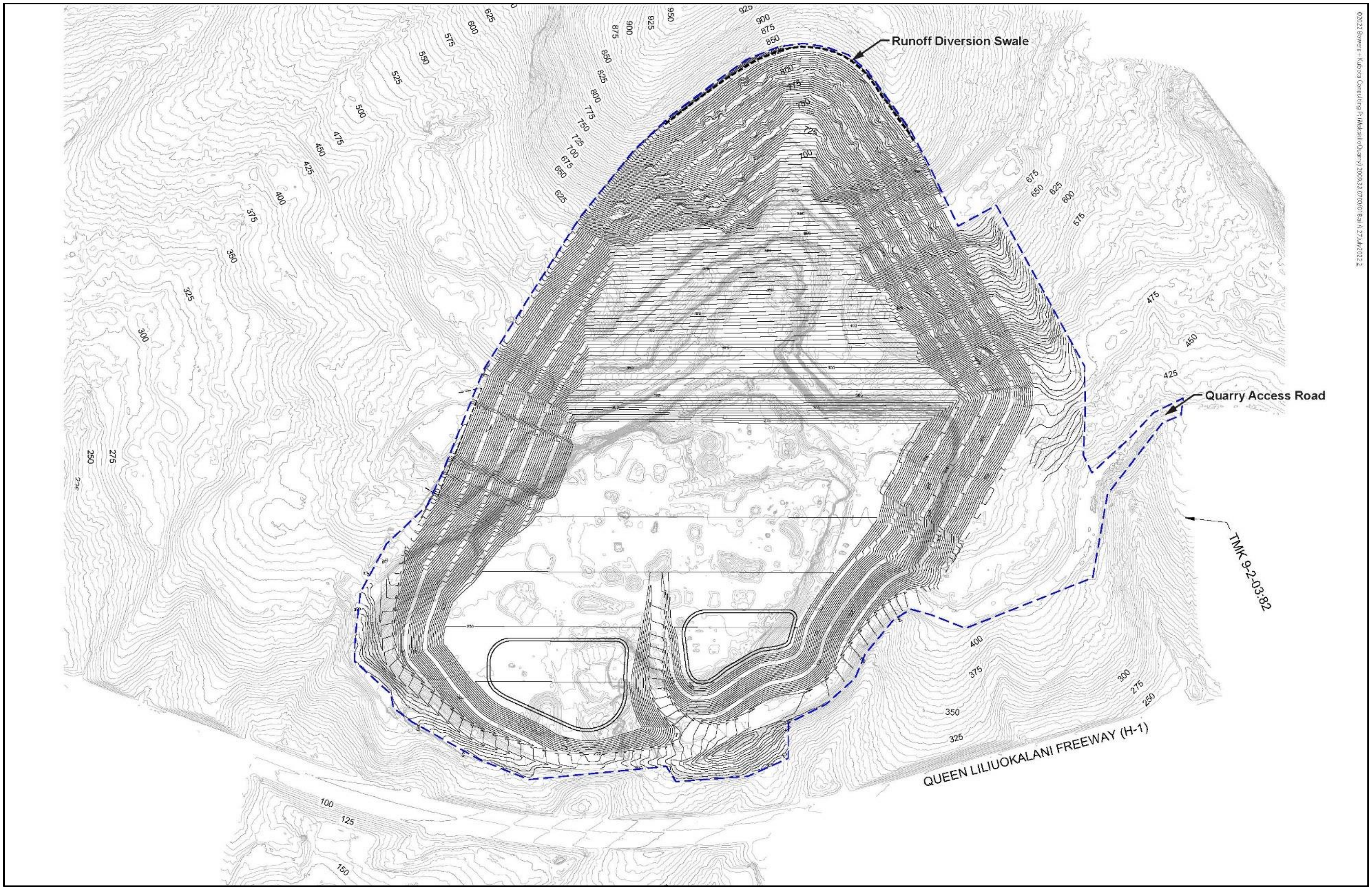

Figure 6. Grading plans for the proposed Makakilo Quarry Expansion Area (courtesy of Grace Pacific, LLC, 2022).

1.2 ENVIRONMENTAL SETTING

The project area lies on the southwest flank of Puʻu Makakilo, just outside the city of Kapolei and *mauka* (inland) of the H-1 Freeway. It is surrounded by Makakilo and Makalapa Gulches to the west, Kaloʻi Gulch to the north, and Hunehune Gulch to the east, all of which are seasonal drainages.

Puʻu Makakilo has a steep, kidney-shaped peak that rises to ca. 950 feet above mean sea level (AMSL) and is the most prominent of several cinder cones that lie at the southern foot of the Waiʻanae Mountain Range. The summit of Puʻu Makakilo (ca. 800–972 ft AMSL) has a 70%–90% slope, while the base (ca. 200–800 ft AMSL) has only a 12%–20% slope and is relatively broad.

According to the U.S. Department of Agriculture (USDA) Soil Survey for Oʻahu and the State of Hawaiʻi's Natural Resources Conservation Service (NRCS), the soils that comprise the surface and substrate of Puʻu Makakilo are quite varied due to the contrast of lower depositional areas versus upper eroded elevations (Foote et al. 1972). The soils within the project area are a patchwork of four main soil types (Figure 7):

> **Helemano silty clay, 30 to 90 percent slopes (HLMG)** – Helemano series soil, located on the sides of V-shaped gulches. Permeability is moderately rapid, with runoff medium to very rapid, and erosion hazard severe to very severe. Soil is used for pasture, woodland, and wildlife habitat (Foote et al. 1972:40).
>
> **Mahana silty clay loam, 12 to 20 percent slopes, eroded (McD2)** – Like Mahana silt loam, 6 to 12 percent slopes (MaC), except for the texture of the surface layer. Runoff rapid, and erosion hazard severe; most of the surface layer has been removed by erosion. Soil used for sugarcane, pineapple, and pasture (Foote et al. 1972:86).
>
> **Mahana-Badland complex (MBL)** – Complex of Mahana soils and Badland. Similar to Mahana silt loam, 6 to 12 percent slopes (MaC), except the texture is silty clay loam and soils are moderately steep to very steep. Runoff is medium to very rapid, and erosion hazard moderate to very severe. Used for pasture (Foote et al. 1972:86–87).
>
> **Stony steep land (rSY)** – Occurs on the island of Oahu. Consists of a mass of boulders and stones deposited by water and gravity on side slopes of drainageways. Slopes range from 40–70%. Elevations range from 100 to 1,500 feet, and annual rainfall amounts to 20 to 80 inches. Stones and boulders cover 50-90% of the surface, and rock outcrops occur in many areas. A small amount of soil among stones provides footholds for plants. Land is used for wildlife habitat and recreation. Natural vegetation includes kiawe, koa haole, and grasses (Foote et al. 1972:121).

Makakilo has an average annual rainfall of approximately 60 cm, with as little as 1 cm in the dry months of June and July and as much as 10 cm in the wet months of December and January (Giambelluca et al. 1986:138–150).

Vegetation observed in the Makakilo area includes *kiawe* (*Prosopis pallida*), *haole koa* (*Leucaena glauca*), klu (*Acacia fanesiana*), lantana (*Lantana camara*), and a wide variety of other non-native grasses and weeds. Few native plant species remain in the Makakilo area due to post-Contact introduced flora and fauna and land alterations for agriculture. Sterling and Summers (1978) note that the area of Hanalei (a former name for Makakilo or Makakilo City) used to hold *milo* (*Thespesia populnea*), *neneleau* (*Rhus sandwicensis*), *kamani* (*Calophyllum inophyllum*), and other trees, as well as the *ʻiʻiwi* (*Drepanis coccinea*) and *ʻōʻō* (*Moho nobilis*) birds.

The Makakilo landscape has been modified by a variety of agricultural and construction activities since the post-Contact period. The most significant change in the vicinity of the project area was the development of the Makakilo Golf Course, which was built in the late 1980s to early 1990s. Creation of the golf course grounds required significant bulldozing and reshaping of the landscape to create fairways, berms, and ponds. Golf course construction was terminated in the middle phase of its development, and the area has largely lain fallow ever since (a little over 30 years). As a result, invasive non-native flora has crept back into the landscape. At above ca. 800 ft AMSL, the *puʻu* has remained relatively undisturbed, aside from the construction of two types of features: a historic wall segment recorded by Sinoto (1988; SIHP 50-80-12-01975), and a historic bunker with associated small concrete structures located at the pinnacle of Puʻu Makakilo (Mooney and Cleghorn 2008).

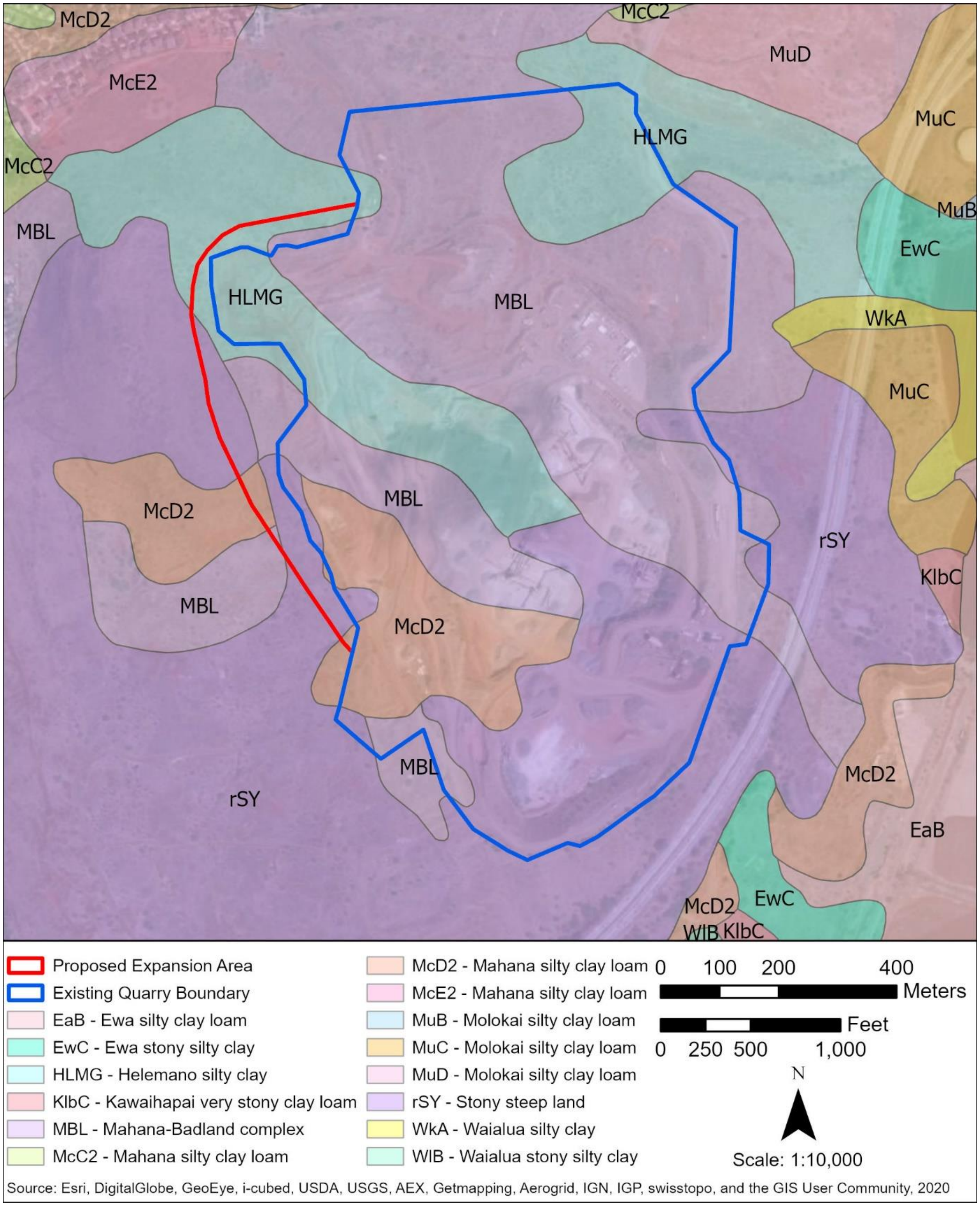

Figure 7. Map of soil types within the vicinity of the Makakilo Quarry Proposed Expansion Project Area (data from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, 2022).

2.0 METHODS

This section outlines the methods used during background research, fieldwork, data analysis, and preparation of the archaeological inventory survey report.

2.1 Background Research Methods

Relevant archaeological reports were obtained from the library of the Hawaiʻi State Historic Preservation Division (SHPD). Online sources of information included the United States Department of Agriculture (USDA), Department of Accounting and General Services (DAGS), the Office of Hawaiian Affairs Kīpuka and Papakilo Databases, and the Hawaiʻi Office of Planning Statewide GIS Program.

2.2 Field Methods

Fieldwork for pedestrian survey was undertaken over a period of three non-consecutive days (November 14, November 30, and December 7, 2022) under the overall supervision of Principal Investigator Mara Mulrooney, Ph.D. The survey team included Jillian Swift, Ph.D. and Jennifer Robins, B.A. The survey built on results from an earlier Literature Review and Field Inspection (LRFI) of the project area conducted by Jillian Swift and Caleb Fechner, B.A. (Swift et al. 2022). Subsequent test excavations of two features within the project area (SIHP 50-80-12-01975, Feature 1 and Feature 2) were conducted over the course of two days: January 11 and January 13, 2023. Test excavations were carried out by Jillian Swift, Jennifer Robins, Caleb Fechner, and James McIntosh, B.A. In total, five days of fieldwork and 12 person-days were required.

2.2.1 Pedestrian Survey

Fieldwork for this project included pedestrian survey of the project area, and full recordation of all historic properties within this approximately 15.6-acre area. The previous LRFI for the project area (Swift et al. 2022) determined that the southern portion of the parcel had been severely disturbed. The 100% pedestrian survey was conducted by a team of two archaeologists spaced at 5 m apart.

Historic properties within the project area were fully documented (scaled plan maps, photographs, and narrative descriptions) using custom forms in Esri Survey123 on Android tablets. Documentation also included digital photography of each site and individual features. A 50-cm-long red and white photo scale and a north arrow were used for photography. Plan-view maps were prepared for each site using tape and compass declinated to True North. All newly identified features, or locales where previously identified features received updated documentation, were assigned a temporary field number to facilitate identification and correlation with GNSS locations. This consisted of a T (for temporary) followed by a consecutive number (i.e., T-001). Temporary field numbers were converted to feature numbers during post-field analysis.

The accurate location of each historic property was mapped using a handheld Trimble R1 GPS receiver and positions were differentially corrected in real time to provide submeter precision. An individual GPS point was taken for individual feature. Linear features were recorded as lines by walking alongside the feature holding the GNSS receiver.

2.3 GEOSPATIAL METHODS

Historic maps were georeferenced in ArcGIS Pro using ESRI's USGS The Nation Map (2023). Known points were used to correlate the location of historic maps relative to this base layer; however, the location of the project area on historic maps should be considered approximate.

Geospatial data was recorded in the field using a handheld Trimble R1 GNSS receiver to sub-meter precision, differentially corrected in real time and subsequently uploaded to ArcGIS Online. GNSS positions were collected in the field as Esri shapefiles with a WGS 1984 Web Mercator (auxiliary sphere) projection and projected in WGS 1984 Web Mercator (auxiliary sphere).

2.4 SUBSURFACE TESTING OF HISTORIC PROPERTIES

Subsurface test excavations were undertaken at two features of SIHP 50-80-12-01975 (Feature 1 and Feature 2). Test excavations were completed by hand and conformed to current scientific standards. The locations of each unit were established in an effort to clarify the form, function, and age of the recorded features. The stratigraphy of each excavation was recorded and photographed. Both excavations proceeded by natural stratigraphic layers. Excavated materials were passed through nested ¼-inch and ⅛-inch wire mesh screens. Scaled drawings and photographs were taken for the archaeological record and detailed notes were recorded on digital tablets. At least one face of each excavation unit was drawn in profile and the strata was described using standard U.S. Department of Agriculture soil description nomenclature and characterized using Munsell color designations (Munsell Color 2000). Sediment samples were collected from each unit and submitted for macrofossil analysis (pollen, phytolith and starch). The location of each unit was plotted on the feature plan view maps. The location of sediment samples were plotted on scaled profile drawings. All collected materials (sediment samples) were assigned unique bag numbers by test unit for tracking, analysis, and cataloging purposes.

3.0 BACKGROUND

The division of Oʻahu lands into political land divisions occurred in the fifteenth century under the rule of Māʻilikūkahi (Kamakau 1991:54–55). These divisions resulted in the creation of six districts, or *moku*: ʻEwa, Kona, Koʻolaupoko, Koʻolauloa, Waialua, and Waiʻanae. The Makakilo Quarry Proposed Expansion Project Area is located in the traditional land division of Honouliuli Ahupuaʻa, in the ʻEwa District (Figure 8). Honouliuli, which translates to "dark bay" (Pukui et al. 1974:51), is the largest *ahupuaʻa* on the island of Oʻahu (approximately 40,640 acres), and it forms a portion of the ʻEwa Plain. Welser et al. (2020) suggest that the name "dark bay" may refer to the dark waters of West Loch at the mouth of Honouliuli Stream.

3.1 TRADITIONAL HISTORY

Most known oral historical accounts of Honouliuli focus on the eastern periphery of the ʻEwa Plain, in the area surrounding West Loch, as this was generally known to be the political and cultural center of Honouliuli Ahupuaʻa. However, a small number of accounts also pertain to central inland Honouliuli. Some of these accounts are related here, and the reader is referred to Maly (2022) for a detailed account of significant place names and *moʻolelo* (oral traditions) of Honouliuli Ahupuaʻa.

Puʻu Makakilo literally translates as "observing eyes hill," and is located in the center of Honouliuli Ahupuaʻa within the ʻEwa Moku (Pukui et al. 1974:201). A manuscript housed in the T. Kelsey Collection at Bishop Museum (Kelsey, *Hawaiian Ethnological Notes Vol. 1*, unpublished ms, p. 820) notes that the area referred to as Makakilo or Makakilo City was once called Hanalei, and was described as "a small flat land with a little gulch on either side on the right of Puuloa mauka of Puu-o-Kapolei" (as cited in Sterling and Summers 1978:34).

Puʻu o Kapolei translates to "hill of the beloved Kapo," referring to an elder sister of the Goddess Pele (Pukui et al. 1974:89). Sterling and Summers (1978) note Puʻu o Kapolei as "one of the most famous hills in the olden days" (Sterling and Summers 1978:33), and a major point of reference for travelers going east or west through Honouliuli. McAllister (1933) observed that the old government road passed behind Puʻu o Kapolei, and the area was covered in sugarcane by the late 1890s (McAllister 1933:108). ʻĪʻī also references this trail as one of the three routes to Waiʻanae: "As mentioned before, there were three trails to Waianae, one by way of Puu o Kapolei, another by way of Pohakea, and the third by way of Kolekole" (ʻĪʻī 1959:97).

Significantly, Puʻu o Kapolei was the landmark used to mark the changing of the seasons on Oʻahu:

> When the sun reached the equator and (began to) move northward, it set right over (the islet of) Kaʻula and it moved on and set over Kawaihoa; and the Makaliʻi season when the sun set (kau) from Kaʻula to Kawaihoa was called Kau, and the Kau season was also called after the resting place of Kane (Kau-lana-a-Kane). When it set (again) at Kaʻula and turned south the season was called Hoʻoilo. In the same way the people of Oahu reckoned from the time when the sun set over Puʻuokapolei until it set in the hollow of Mahinaona and called this period Kau, and when it moved south again from Puʻuokapolei and it grew cold and the time came when young sprouts started, the season was called from their germination (oilo) the season of Hoʻoilo. There were therefore two seasons, the season of Makaliʻi and the season of Hoʻoilo. (Kamakau as quoted by Sterling and Summers 1978:34)

Kamaunuaniho, the grandmother of Kamapuaʻa, is said to have had a house on Puʻu o Kapolei, less than two miles south of Makakilo. However, the area around this house may have been disturbed or dismantled during post-Contact cane and sisal planting. A story of Kamaunuaniho is recounted in Sterling and Summers (1978):

> Kamapuaa subsequently conquered most of the island of Oahu, and, installing his grandmother as queen, took her to Puuokapolei, the lesser of the two hillocks forming the southeastern spur of the Waianae mountain range, and made her establish court there. This was to compel the people who were to pay tribute to bring all the necessities of life from a distance, to show his absolute power over all.
>
> Puuokapolei is some little distance from Sisal, towards Waianae, and is as desolate a spot as could be picked out on the whole island. It is almost equally distant from the sea, from which came the fish supplies; from the taro and potato patches of Ewa, and from the mountain ravines containing the banana and sugarcane plantations.
>
> A very short time ago the foundations of Kamaunuaniho's house could still be seen at Puuokapolei; also the remains of the stone wall surrounding her home. It has even been said that her grave could then be identified, but since the extension of cane and sisal planting to the base of Puukapolei, it is possible that the stones may have been removed for wall-making.
> (Nakuina as quoted by Sterling and Summers 1978: 34)

McAllister (1933) observed a large rock shelter on the side of Puʻu o Kapolei which was rumored to be this dwelling place of Kamapuaʻa and Kamaunuaniho. He also documented the Puʻu Kapolei Heiau (Site 138) in the same vicinity (McAllister 1933:108). Puʻu o Kapolei has been nominated as a traditional cultural property (Monahan 2020).

In addition to this AIS, Swift and Mulrooney (2022) completed an addendum update to a previous Cultural Impact Assessment conducted by Mooney and Cleghorn (2008) for the Makakilo Quarry area. One participant in the updated CIA interviews (McD Philpotts) noted the significance of the area due to its connection with the five brothers who watch over Oʻahu: Makaīwa, Makaʻike, Makaloa, Maka-Io, and Makakilo. Philpotts referenced a *moʻolelo* on this subject related by Analu Kameeiamoku Josephides in a CIA for the Waimanalo Gulch Sanitary Landfill Expansion conducted by Cultural Surveys Hawaiʻi, Inc.:

> Another concern that I may have is the place names of this particular area. A story that has been passed down to me from my kupuna is that there were five brothers who were the watchers. Their names were Makaīwa, Makaʻike, Makaloa, Maka-Io, and Makakilo. It was known that Makaīwa was to the farthest west and that Makakilo was to the farthest east. That these five brothers were the eyes of the Oʻahu people and were their protectors. They would watch for enemy intruders and relay messages to their makulu (runners). If enemy canoes were seen the makulu would run to the various districts and warn the chief and his/her people. This is why Oʻahu was a hard island to conquer in the ancient times. By the time the war canoes of the enemies would reach the shores they would be greeted by the warriors of Oʻahu, thus the enemies were never allowed to land upon the shores of Oʻahu. (Analu Kameeiamoku Josephides, in Souza et al. 2008:7–128, 129)

Josephides also related being told that in the old days, homes were not built in this region, "except for the mauka area of Makaīwa to the west, the mauka area to the east known as Makakilo, and the makai area below where in ancient time was the dwelling place of the Kamapuaʻa ʻohana" (Souza et al. 2008:7–118), as these were the paths of the Night Marchers.

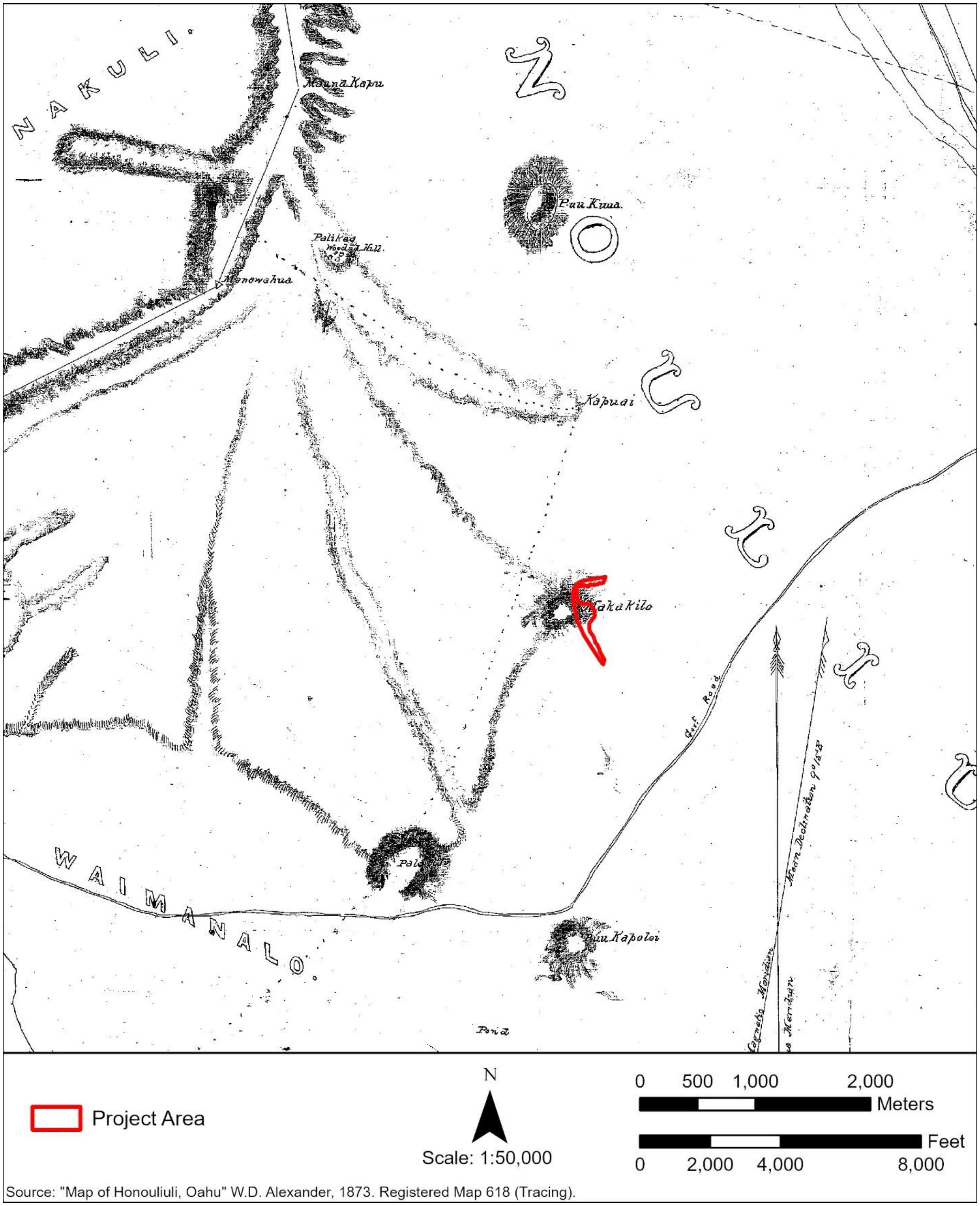

Figure 8. The Makakilo Quarry Proposed Expansion Project Area overlaid on a map of Honouliuli Ahupuaʻa by Alexander (1873).

3.2 POST-CONTACT RANCHING AND AGRICULTURE

The first European historical account of the Honouliuli area was written on the arrival of Vancouver to ʻEwa in 1793. Vancouver observed that the land did not seem to be particularly populous or fertile. Regarding the area between Waiʻanae and the Koʻolau Mountains, he commented:

> This tract of land was of some extent but did not seem to be populous, nor to possess any great degree of natural fertility; although we were told that a little distance from the sea, the soil is rich, and all necessaries of life are abundantly produced. (Vancouver 1798, as cited in Sterling and Summers 1978:31)

Vancouver later commented on what he found to be the relatively dismal condition of west Honouliuli coast:

> From these shores we were visited by some of the natives, in the most wretched canoes I had ever yet seen amongst the South-sea islanders; they corresponded however with the appearance of the country, which from the commencement of the high land to the westward of Opooroah (Puuloa), was composed of one barren rocky waste, nearly destitute of verdure, cultivation or inhabitants, with little variation all the way to the west point of the island. (Vancouver 1798, as cited in Lewis 1970:6)

However, Handy et al. (1972:469–472) describe several areas rich in terrestrial resources and cultivable land across the ʻEwa Plain. This includes the spacious *wao*, or upland jungle, which was home to native avifauna, wild bananas and yams, *wauke* (paper mulberry, or *Broussonetia papyrifera*), *mamake* (*Pipturus albidus*), and *olonā* (*Touchardia latifolia*). They also describe a rare and delicious *kalo* (*Colocasia esculenta*) variety native to ʻEwa known as *kai*, or as *kai koi* ("*kai* that pierces") due to its long rhizomes. The *kai* was grown in mounds, and known to be fragrant, multiply abundantly, and last as long as ten years. According to Handy et al. (1972), "No other variety or locality can equal this. This fragrant taro was likened to a woman with whom a man falls in love. And it was said that anyone who married a native of ʻEwa would come and settle there and never leave, because of the *kai koi* of ʻEwa" (Handy et al. 1972:471).

As with other areas of Hawaiʻi, European-introduced plants and animals generally had adverse impacts on the local ecosystems. The sandalwood trade, and the introduction of grazing animals such as goats, sheep, and cattle, dramatically transformed the landscape. Introduced plants such as lantana (*Lantana camara*), *kiawe* (*Prosopis pallida*), *haole koa* (*Leucaena leucocephala*), and invasive grasses like *Cynodon dactylon* and *Eleusine indica* replaced the forested areas once populated by sandalwood trees and other native plants. Many of these introduced plants still dominate the vegetation in and around the project area.

After traversing much of the island of Oʻahu in the early 1800s, Edwin Hall, Hawaiian Minister of Finance, described west ʻEwa as a "barren, desolate plain" (Hall 1839 as cited in Lewis 1970:8). The first missionary to build a church in ʻEwa noted that the people were generally of ill health and overtaxed by Oʻahu's chiefs (Lewis 1970). In the mid-1800s, introduced European diseases devastated the island and led to a steep decline in the Native Hawaiian population (Kamakau 1961).

By the mid-nineteenth century, private land ownership was introduced to the islands by way of the Mahele. Crown and *aliʻi* lands were awarded beginning in 1848 and *kuleana* titles were awarded to the general populace beginning in 1850 (Chinen 1958). Awarded lands in this process are referred to as Land Commission Awards (LCAs). During the Mahele, the entire *ahupuaʻa* of Honouliuli was awarded to Miriam Keʻahikuni Kekauʻōnohi, granddaughter to Kamehameha I and heir of Kalaniomōkū (Yucha et al. 2015:26). Upon her death in 1851 her lands were transferred to her husband, Levi Haʻalelea. In 1864, the land was passed on to Haʻalelea's second wife and widow Anadelia Amoe and subsequently to her brother-in-law John H. Coney (Yucha et al. 2015:26).

The Kuleana Act of 1850 was a law intended to support native tenant rights by granting fee-simple titles for their lands and house lots if their claims were deemed "genuine" through written testimony to the Land Commission Board. Maly and Maly (2014:253–509) conducted extensive research of the Honouliuli land claims and provide a complete list of the LCA claimant names, associated place names, land uses, and cultural features cited in the Land Commission testimonies. According to Maly and Maly (2014:248), out of a total 106 claims made for Honouliuli, 74 were awarded as Land Commission Awards (LCAs), 31 were denied, and the status of the remaining claim is not given (or the correct number of denied claims is 32).

Most of the Honouliuli LCAs were awarded to claimants for parcels along Honouliuli Stream at its juncture with the waters of Puʻuloa or the West Loch area of Pearl Harbor. These claims, covering a roughly 287-acre area, are shown on an 1878 "Map of Honouliuli Taro Land" (Monsarrat 1878; Figure 9). Monsarrat's 1878 map shows the distribution of LCAs with the stream at the center and the presence of two churches, a schoolhouse, and a parcel with multiple structures in J. Campbell's name. No other Honouliuli maps with LCA locations were identified through archival research.

After the death of Levi Haʻalelea, his wife rented the Honouliuli lands to James Dowsett and John Meek for stock running and grazing in 1871 (Frierson 1972). In 1877 after the land passed to J.H. Coney, he sold 41,000 acres in Honouliuli to James Campbell for $95,000, and Campbell repurposed the land for cattle ranching under the name Honouliuli Ranch. There are no LCAs in the immediate vicinity of the project area.

Between 1885 and 1886, Campbell worked with B.F. Dillingham to develop small tracts of agricultural lands and homesteads in Honouliuli, but met with little success. In 1888, Dillingham and Campbell partnered to develop a railway to transport sugarcane. Campbell had considered selling his property to Dillingham for these purposes, but ultimately decided on a 50-year lease of his lands from Pearl Harbor to Waimānalo (Frierson 1972). In 1889, Dillingham signed the lease and formed the Oahu Railway and Land Company (OR&L). Dillingham established five ranches along his proposed railway line, all under the banner of the OR&L Ranches. There were ranches in Honouliuli, Nānākuli, Mokulēʻia, Kawailoa, and Kahuku.

Dillingham sublet a portion of the Honouliuli lands for agricultural ventures. All land below 200 ft in elevation was sublet to William Castle, who then sublet this area to the Ewa Plantation Company for sugarcane cultivation. Any land above 200 ft in elevation that was suitable for sugarcane cultivation was sublet to the Oahu Sugar Company. Any of these *mauka* lands that were unsuitable for sugarcane agriculture remained as pastureland for grazing livestock (Figure 10).

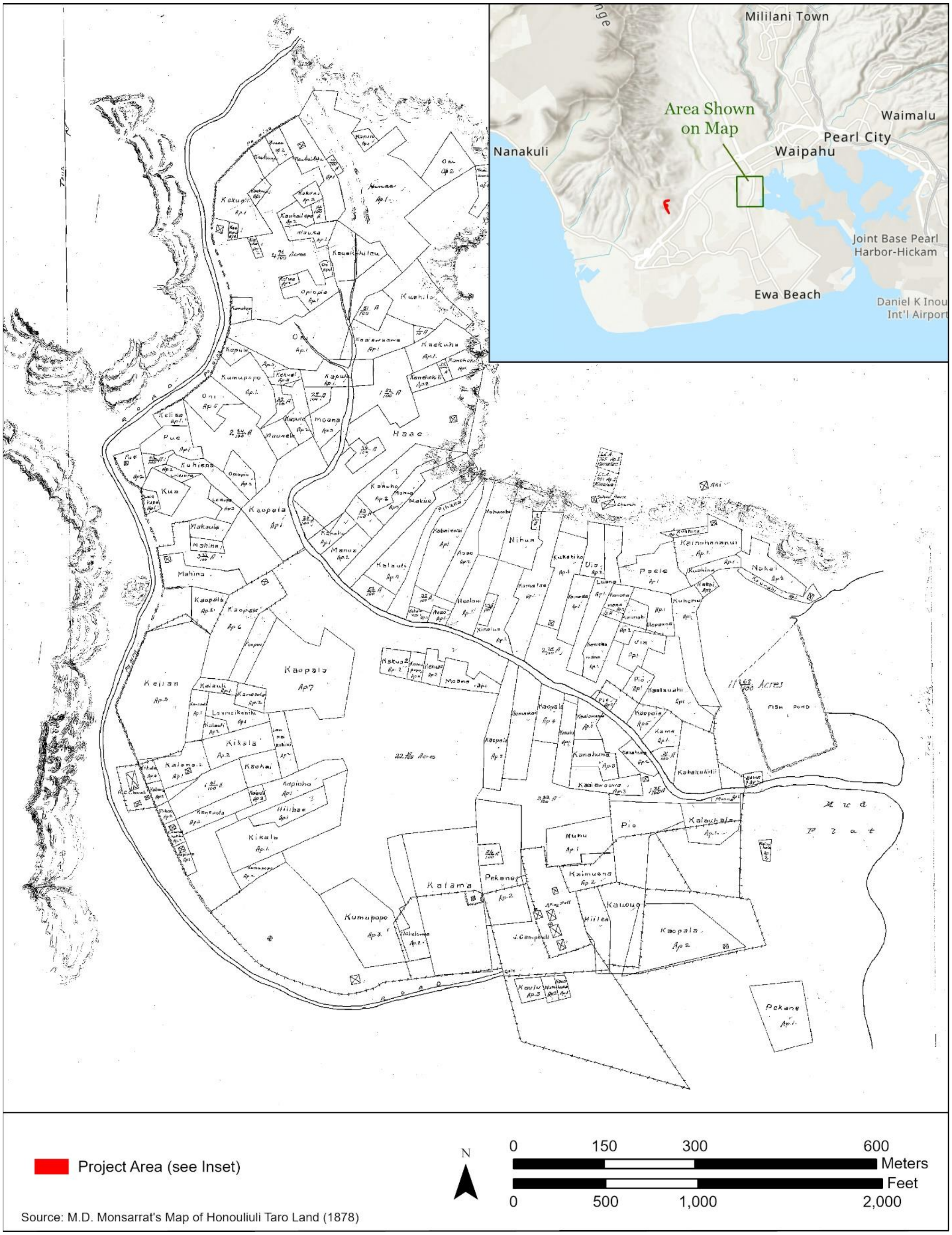

Figure 9. Map of Honouliuli Land Commission Awards (Monsarrat 1878).

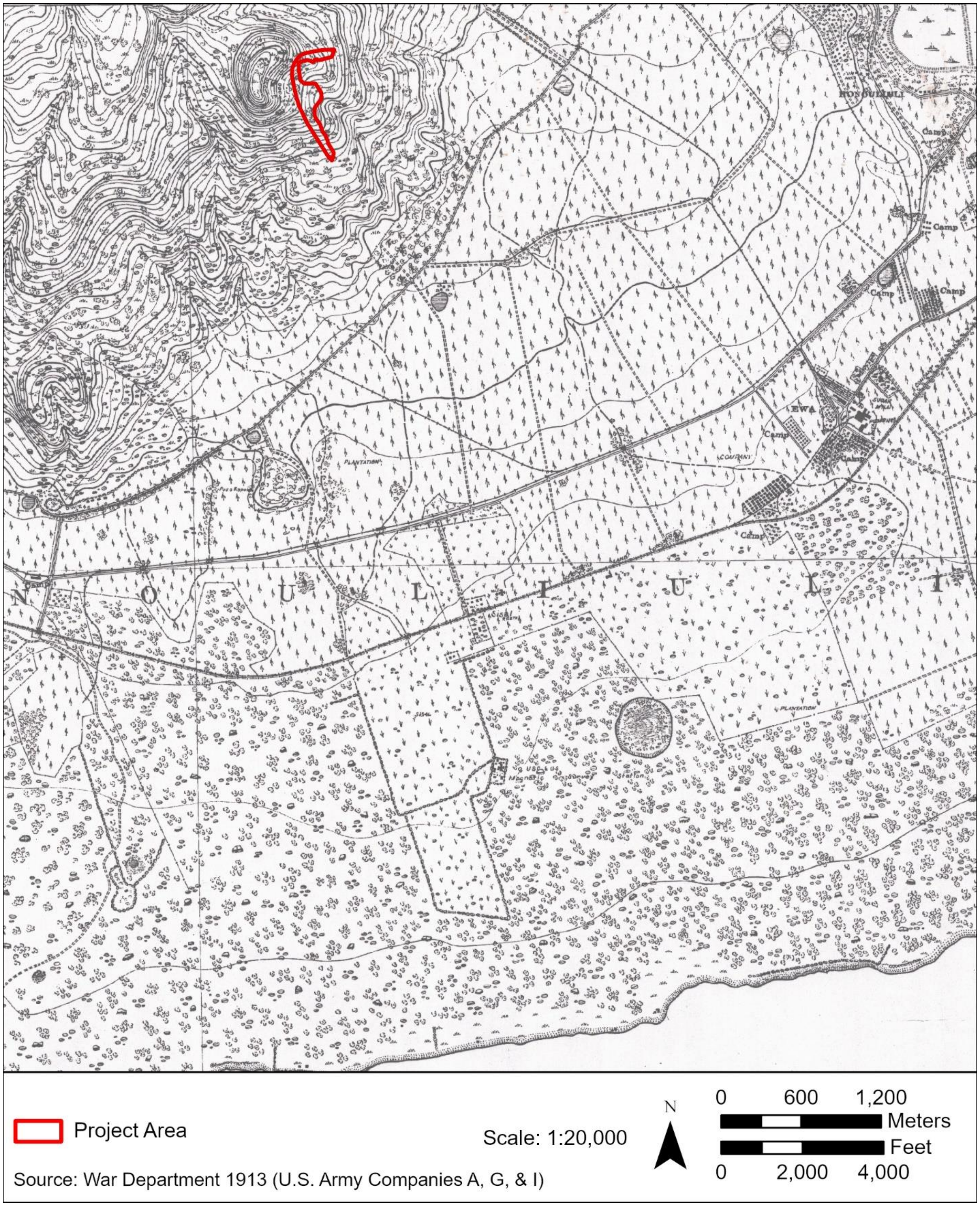

Figure 10. A 1913 map of the project area illustrating the early development of surrounding lands for sugarcane agriculture, ranching, and other industries.

The Ewa Plantation Company was established in Honouliuli in 1890, after the sub-subletting of more than 11,000 acres of land from B.F. Dillingham to Castle, then to Ewa Plantation Company (Campbell 1994). By 1899, Ewa Plantation had an operational mill and over 2,000 acres in sugarcane cultivation (Frierson 1972). By 1931, Ewa Plantation Company was known as one of the most prosperous plantations in the Hawaiian Islands and, by the 1930s, most of the eastern half of Honouliuli was plantation land (Yucha et al. 2015:37). A 1939 map of the Ewa Plantation Co. illustrates the numerous subdivided agricultural plots to the north and northeast of the project area (Figure 11). In 1970, Oahu Sugar Company took over ownership of Ewa Plantation and continued its operation until 1995.

Water, and often its scarcity, is a constant theme in the history of the Makakilo area. In the 1800s, it was said that Kaloʻi ("the taro patch"), the gulch located directly north of Makakilo, was one of the few places in the area that showed any potential for procuring fresh water. William R. Castle named a spring he tapped in the gulch "Wai o Kakela," though *kamaʻāina* (local residents) continued to refer to it as Kaloʻi (von Holt 1953 as cited in Sterling and Summers 1978:35). Tulchin and Hammatt (2005) identified what appears to be the remains of the spring during an archaeological inventory survey (AIS) of the Pālehua East B Project Area. The 11,000-acre Ewa Plantation Company, started in 1890, initially started with 775 acres of sugarcane planted at Honouliuli and irrigated with underground water (Campbell 1994). During this period, cattle were still ranched in the margins of the cane fields, and the *mauka* lands in western Honouliuli that were ill-suited to sugar production. A descendant of the ranch manager claimed that fishermen squatters lived in shanties by the beach and traded fish for taro at ʻEwa. That same individual reported that there was also a shrimp pond in the Barber's Point (Kalaeloa) area (Lewis 1970).

In 1913, the Waiāhole Water Company, a subsidiary of the Oahu Sugar Company, installed a water system known as the Waiāhole Ditch, which collected water from Kahana Valley in the north and transported it by tunnel through the Koʻolau Range to Waiawa Ahupuaʻa, then westward to Honouliuli by ditch (Figure 12). The entire system was completed in 1916 and covered roughly 22 miles (Condé and Best 1973:37). Much of the system remains in use to this day, and portions of the Waiāhole Ditch system, State Inventory of Historic Places (SIHP) number 50-80-09-02268, were identified in previous archaeological inventory surveys by Dega et al. (1998), Tulchin and Hammatt (2004), and Hunkin and Hammatt (2009).

In the early 1900s, the Ewa Plantation operators began installing a system of drainage ditches that ran from the lower slopes of Honouliuli into the lowlands, in order to wash soil from the slopes into the plain and "reclaim" parts of the coral plain. Just before the rainy season, the hill slopes would be plowed vertically to induce soil erosion. At least 373 acres were reportedly reclaimed this way in a matter of years, though notably, this "gullying and soil removal" process had already been underway as a natural effect of removing vegetation (Frierson 1972).

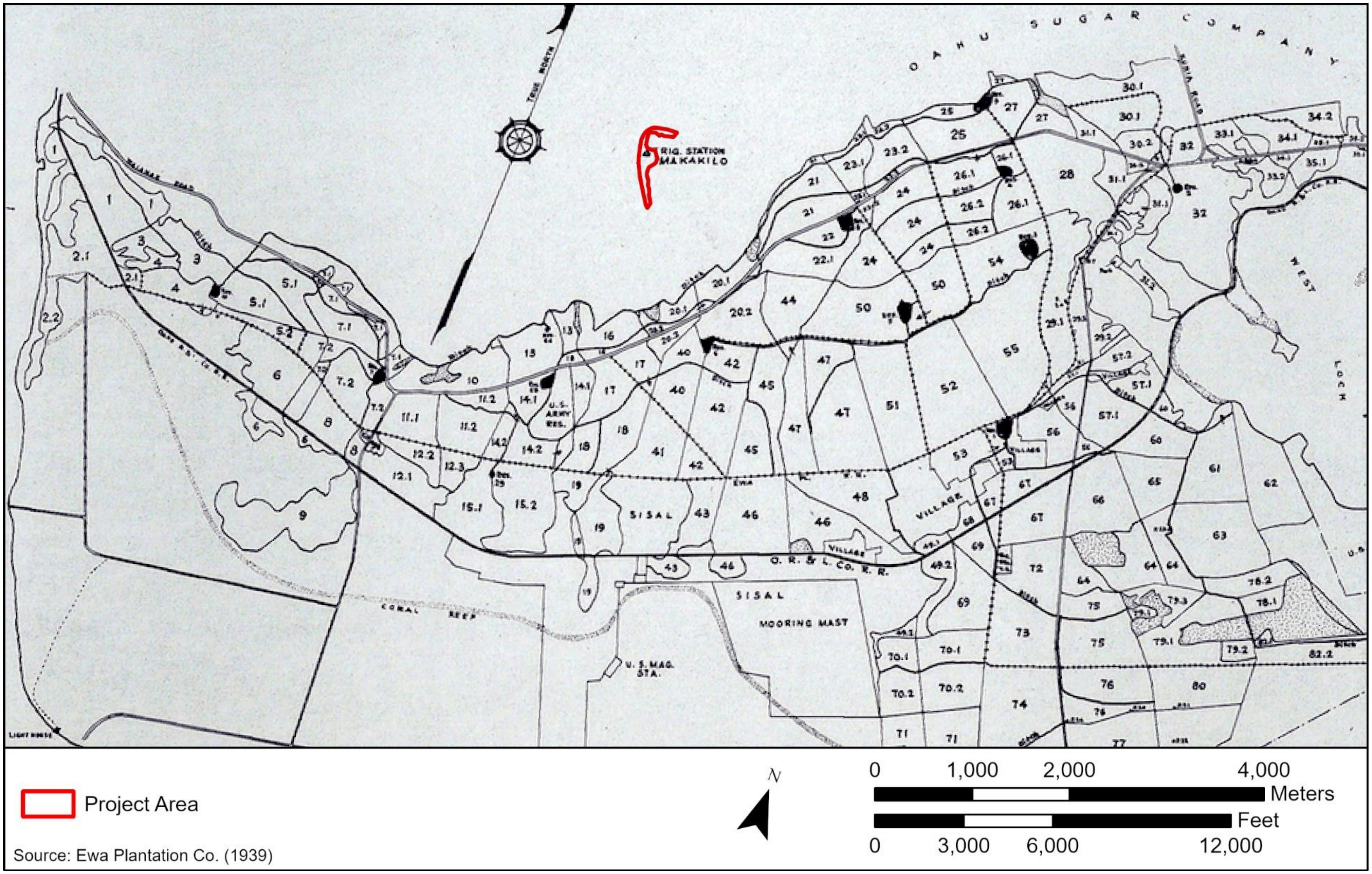

Figure 11. A 1939 map of sugarcane plots held by the Ewa Plantation Co., illustrating intensive sugarcane cultivation to the north and northeast of the project area.

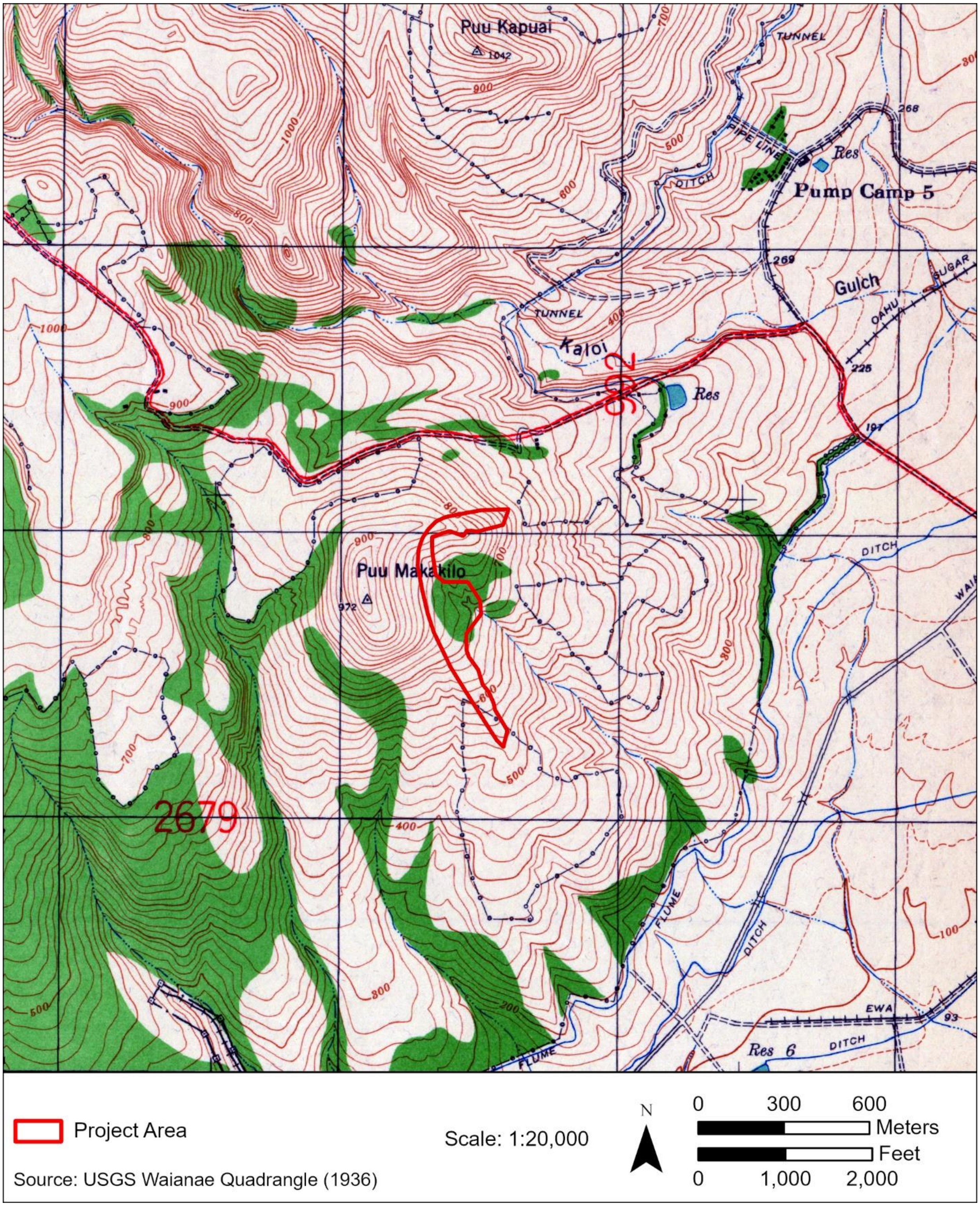

Figure 12. A 1936 USGS map with the project area overlaid, showing Kaloʻi Gulch, the Waiāhole Ditch, and other landscape features.

3.3 MILITARY AND POST-WAR DEVELOPMENT

World War II–era military development also brought significant change to the Honouliuli landscape, as military installations were constructed in numerous areas of the coast and the uplands. This included the Honouliuli Internment Camp, now the Honouliuli National Historic Site (SIHP 50-80-08-09068, National Register of Historic Places #90000855, and National Monument under Proclamation 9234), as well as Barber's Point Military Reservation at Barber's Point Beach, Camp Malakole Military Reservation, Gilbert Military Reservation, Barber's Point Naval Air Station, Fort Barrette, and a number of other installations related to military surveillance and defense (Figure 13).

On top of Pu'u Makakilo, Fire Control Station A was installed (and Fire Control Station B atop Pu'u Pālailai), and the Pu'u Makakilo Training Area was used for military training from 1942 to 1945 (Environment Hawai'i 1992, as cited in Hunkin and Hammatt 2009) (Figure 14). In 1945, the U.S. Army returned the Pu'u Makakilo Training Area, along with 24 other training areas in Hawai'i, to their original owners (*Honolulu Advertiser* 1945).

Between the end of the war and the residential boom of the early 1960s, the land in Makakilo remained primarily agricultural. Advertisements in local newspapers dating to the 1950s and early 1960s advertise simple, locally made terra cotta pots manufactured by Gaspro and made from "Makakilo Clay" (e.g., Figure 15 and Figure 16).

In 1960, it was announced that work would start on a "Giant New Oahu City" in a 1,300-acre area of the Campbell Estate named Makakilo (Penny 1960). At the time, Makakilo was planned to be the largest residential area in the Campbell Estate 20-year master plan for Honouliuli. It would include a civic center, churches, schools, small and large shopping centers, playgrounds, parks, a cemetery, and an apartment area. Houses would be offered on a 55-year lease for $15,000 to $40,000 (Penny 1960). Ground was broken for the Makakilo development on December 11, 1961 (*Honolulu Advertiser* 1961). By the next year, Makakilo City was heavily advertised in the local newspapers as "Oahu's First Planned City" (Figure 17). During the first public open house for Makakilo City, the Finance Realty Company hosted a "treasure hunt," inviting the community to bring picks and shovels and dig for a $1,000 cash prize (*Honolulu Advertiser* 1962), which was ultimately won by Nānākuli resident Henry Kawaakoa (Figure 18). Over time, subdivisions have gradually replaced many of the areas previously used for ranching, sugar cultivation, or military activities (Figure 19).

In 1975 and in the midst of financial woes, Pacific Concrete & Rock Co, Ltd. opened the Makakilo Rock Quarry, then valued at $5 million (Smith 1975). In 1984, Grace Brothers Ltd. acquired Pacific Concrete & Rock Co., and renamed the combined entities to Grace Pacific Corp. (*Honolulu Advertiser* 1984).

In the late 1980s/early 1990s, parts of the project area were subject to significant disturbance from the development of the 232-acre Makakilo Golf Course by Chiyoda Pacific, Inc., which included significant landform shaping for fairways and the partial construction of a two-story golf clubhouse. The grading, terracing, and other landscape modifications required for the creation of the front nine holes, which would be visible from the H-1 freeway, was nearly completed when the project encountered financial difficulties (Catterall 1993). The property was foreclosed in 1994 and purchased in a bankruptcy auction for $12.6 million by Grace Pacific, LLC (Smyser 1995).

Figure 13. A 1953 USGS map of the project area showing military installations, agricultural infrastructure, and industrial development across Honouliuli Ahupuaʻa.

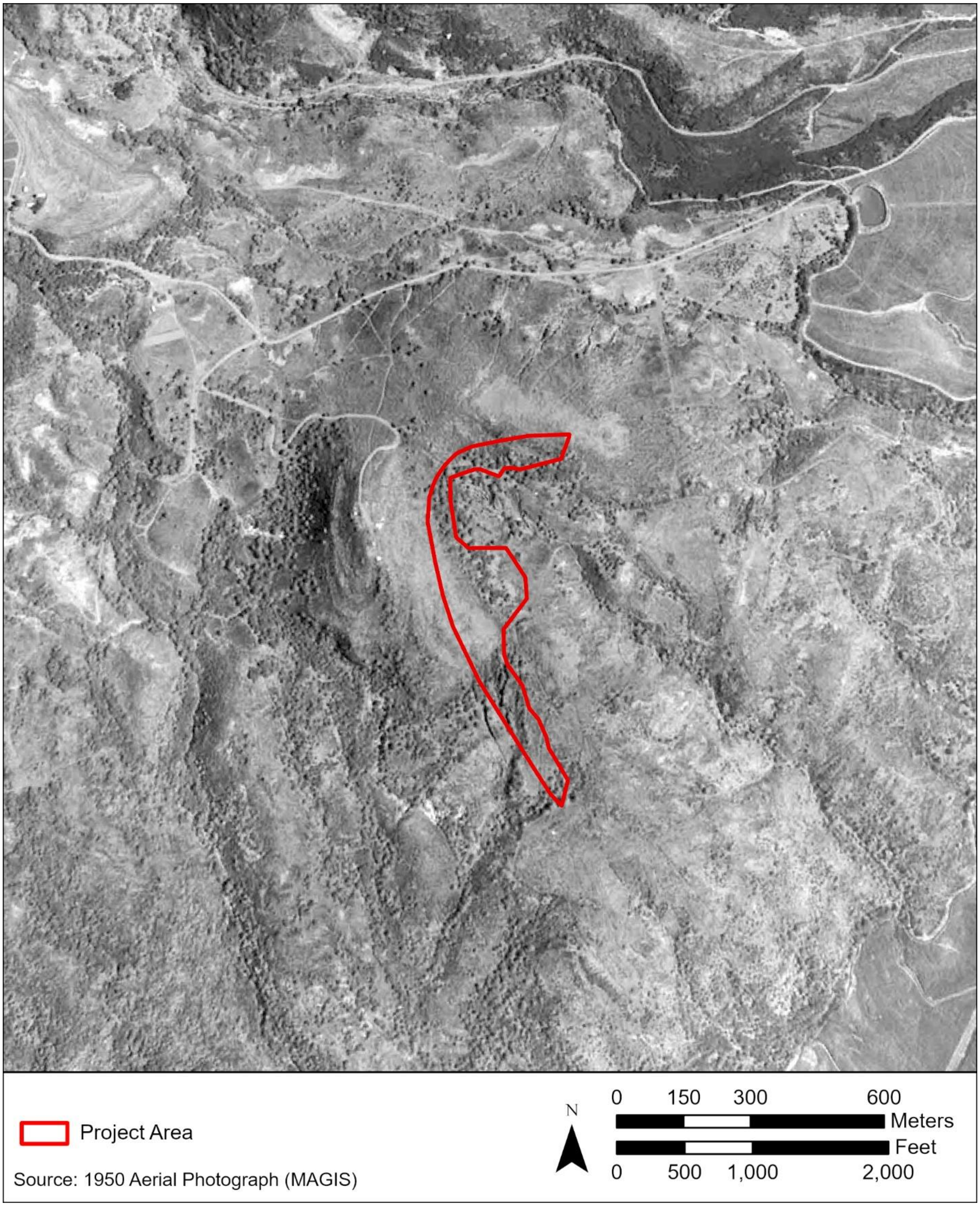

Figure 14. A 1950 aerial photograph of the project area showing a road leading up to the military installations atop Pu‘u Makakilo.

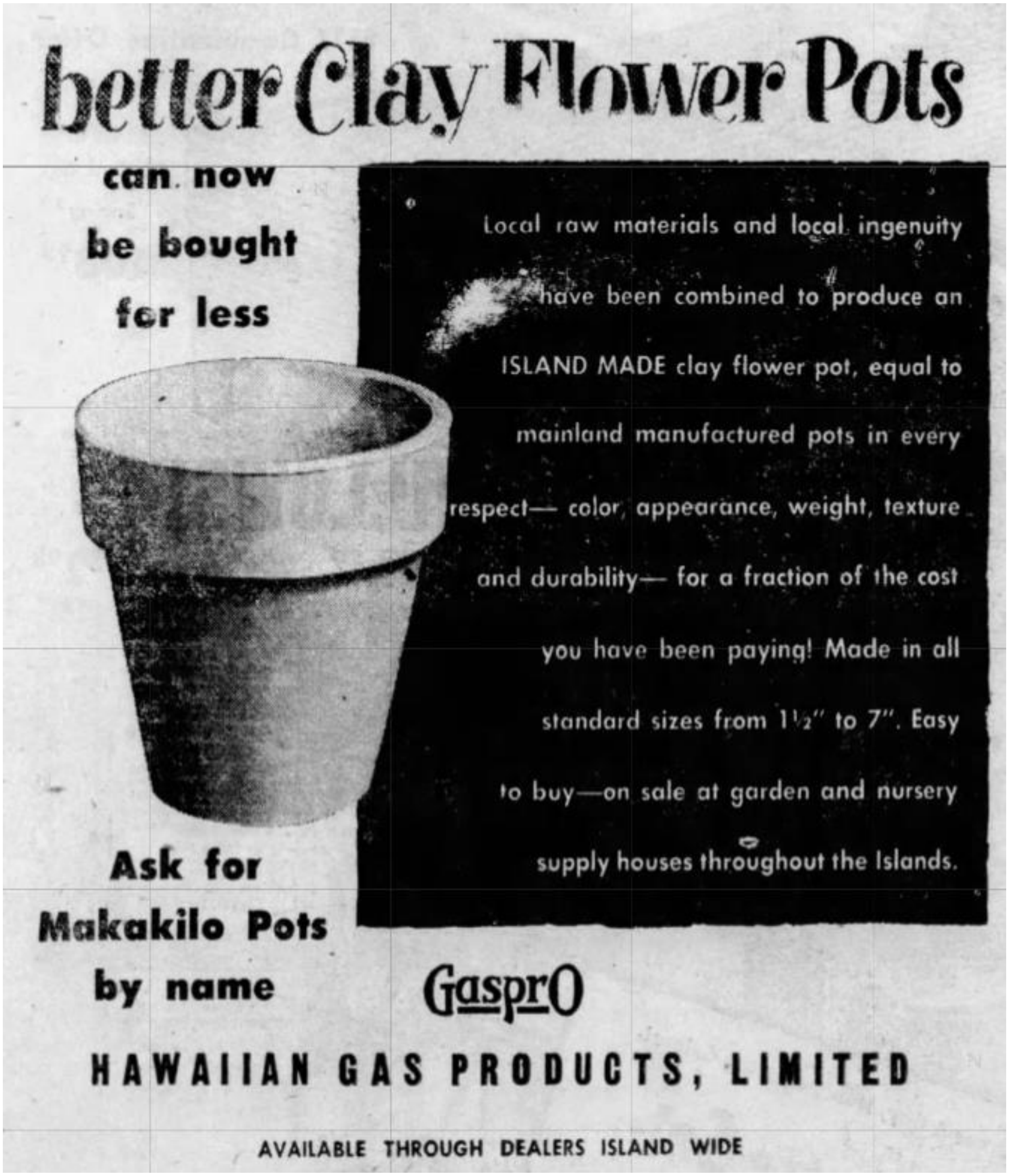

Figure 15. Advertisement for Makakilo Clay Pots manufactured by Gaspro, from the May 17, 1951 issue of the *Hawaii Tribune-Herald*.

Figure 16. Sears Roebuck and Co. advertisement for Makakilo clay pots from the April 16, 1956 issue of the *Honolulu Star-Bulletin*.

Figure 17. Advertisement for Makakilo City printed in the July 15, 1962 issue of the *Honolulu Advertiser*.

A $1,000 "treasure" was uncovered by Henry Kawaakoa, of Nanakuli, yesterday in a treasure hunt at Makakilo housing development in Leeward Oahu. Mun On Chun, executive vice-president of Finance Realty Company, developers of the planned 5,000-home development opposite Barber's Point presented the $1,000 in one dollar bills to Kawaakoa and his happily weeping wife. About 2,000 persons brought their own picks and shovels for the hunt. Kawaakoa, who is unemployed, uncovered the lucky box after nearly four hours of digging.—Camera Hawaii photo.

Figure 18. Photograph of Henry Kawaakoa, the winner of Finance Realty Company's Makakilo City treasure hunt, receiving his cash award. Printed in the July 9, 1962 issue of the *Honolulu Star-Bulletin*.

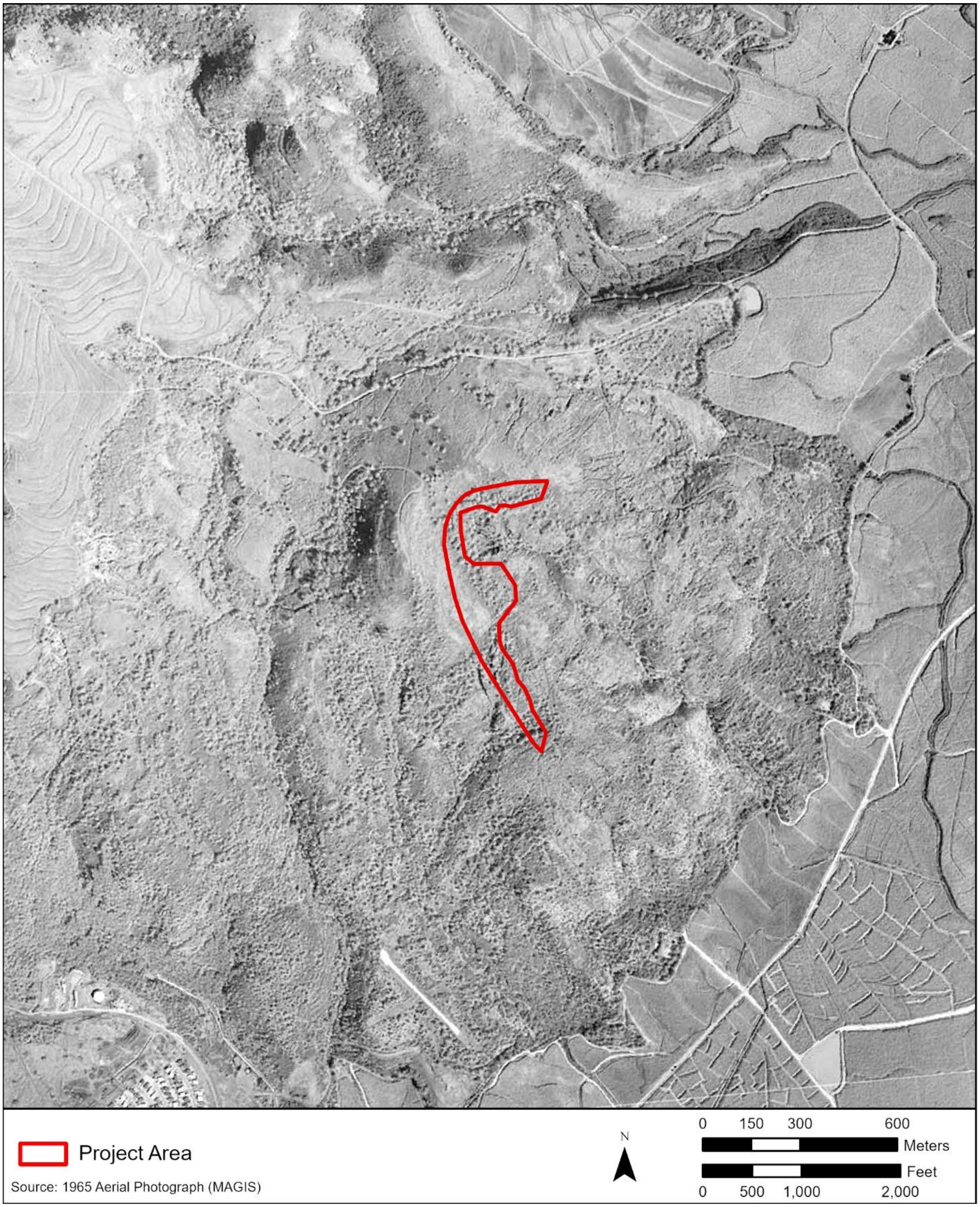

Figure 19. A 1965 aerial image of Puʻu Makakilo and the project area. Although Makakilo was rapidly developing at this time, the areas immediately surrounding the project area remained relatively untouched.

3.4 Previous Archaeological Investigations

A number of archaeological investigations have occurred in the vicinity of the Makakilo Quarry Proposed Expansion Project Area, most resulting in modest finds. Most of these studies are associated with the continued development of Makakilo within the greater Kapolei region (Table 1, Figure 20, and Figure 21). The previous archaeological investigations within a 0.5-mile radius of the project area are summarized below.

The earliest archaeological investigation in the vicinity of the project area was conducted in the 1930s by Bishop Museum archaeologist J. Gilbert McAllister (1933). McAllister recorded several sites around the peripheries of Puʻu Makakilo; however, the site recording methods available to him in the early twentieth century were rudimentary by today's standards. McAllister noted that on the side of Puʻu Kapolei, a mile south of Puʻu Makakilo, was a large rock shelter rumored to be the dwelling of Kamapuaʻa and his grandmother, Kamaunuaniho. He also documented Puʻu Kapolei Heiau (Site 138) in the same vicinity (McAllister 1933:108). McAllister also described Puʻu Kuina Heiau (Site 134), located in a gulch at the foot of Mauna Kapu, 2.5 miles north of Makakilo, but which had been destroyed and reduced to "a suggestion of a terrace" (as cited in Sterling and Summers 1978:32). In the same area, McAllister recorded a four- to six-foot square basalt and coral platform (Site 136) which was purportedly a sacred Hawaiian altar (McAllister 1933:107), though apparently the site was destroyed by the late 1950s (Sterling and Summers 1978:32).

In 1977, Archaeological Research Center Hawaiʻi, Inc. (ARCH) performed an archaeological reconnaissance survey for the Kaloʻi Gulch Landfill, just north of Puʻu Makakilo. Bordner (1977) identified three walls of stacked *pāhoehoe* slabs with possible pre-Contact associations (SIHP 50-80-12-02600 through -02602). He considered them to be of marginal significance and did not recommend further work (Bordner 1977).

In 1986, Paul H. Rosendahl, Inc. (PHRI) conducted a preliminary archaeological reconnaissance survey for the ʻEwa Town Center / Secondary Urban Center, a project area of roughly 1,400 acres (Haun 1986). Haun identified an irrigation ditch that followed the 200 ft contour of Puʻu Pālalai, and noted the existence of a WWII-era structure. He recommended no further archaeological work in the project area.

In March of 1988, a letter report was written by Aki Sinoto of Bishop Museum about the pedestrian surface survey performed by Williams and Duckworth for the Makakilo Golf Course. According to this report, the survey was conducted in an area which extends beyond the Makakilo Quarry Proposed Expansion Project Area. Sinoto commented on the topography of the southeastern flank of Puʻu Makakilo by stating:

> As anticipated, large portions of the project area have been and still undergo severe erosion. Barren areas of exposed substrate is interspersed with areas dominated by dry grasses and small kiawe. Steep erosional gullies with vertical walled heads, bare areas of sheet wash, and pedestaled rocks attest to the severe and continuing erosion. (Sinoto 1988:1)

While no significant archaeological sites were located in the Makakilo Golf Course surface survey, Sinoto did discover a deteriorated wall segment inside of Puʻu Makakilo (Bishop Museum Site No. 50-OA-B6-276 and SIHP 50-80-12-01975). The site was located just outside (northwest) of the golf course project area's *mauka* extension. Sinoto (1988) described the 10.5 by 1.4 by 1.4 m wall as "double-faced" and "core-filled" with a north/south orientation. Sinoto speculated that the wall may have served as erosion control in historic times. However, due to its deteriorated state and the fact that the wall was not associated with any other features or structures, Sinoto determined that it did not meet the National Register criteria of significance and no further work was recommended (Sinoto 1988:1).

An AIS was conducted in 1993 on the parcels located southwest of the current project area (TMK: [1] 9-2-003:074, [1] 9-2-003:075, and [1] 9-2-003:081) by Aki Sinoto Consulting (Nakamura et al. 1993). This survey recorded a single historic site (SIHP 50-80-12-04664), described as a segment of an irrigation system constructed by the Ewa Plantation Company in 1941. Nakamura et al. (1993) documented the site in detail and deduced that "the significance can be considered to have been realized and no further work is necessary" (1993:32). The remaining area within the survey was also determined by Nakamura et al. to have a very low probability of subsurface remains.

In 1996, Scientific Consultant Services, Inc. (SCS) conducted an archaeological reconnaissance survey of an area extending from the H-1 freeway to the north side of Renton Road. No historic properties were identified (Spear 1996).

In 1997, Cultural Surveys Hawaiʻi, Inc. (CSH; Hammatt and Chiogioji 1997) carried out an archaeological reconnaissance survey of a 4.5-kilometer land corridor. No historic properties were identified.

In 1998, SCS (Dega et al. 1998) conducted an AIS of the University of Hawaiʻi, West Oʻahu Campus project area. They identified a complex of irrigation features associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). SIHP -05593 was assessed as significant under Criteria a and d. The report concurred with previous assessments of the Waiāhole Ditch system as significant, but did not list criteria. No further work was recommended for either site (Dega et al. 1998).

In 1999, International Archaeological Research Institute, Inc. (IARII) carried out an archaeological reconnaissance survey for the Farrington Highway Expansion Project (Magnuson 1999). Magnuson identified six concrete bridges, a railroad track, and a set of unidentified concrete features. However, all features were determined to be not significant. No SIHP numbers were assigned, and Magnuson recommended no further work beyond the recordation from the reconnaissance survey.

In 2004, CSH (Tulchin and Hammatt 2004) carried out an AIS for the Pālehua Community Association (PCA) common areas at Makakilo, a group of discrete parcels of agricultural land, which combine to cover a total area of roughly 86 acres (TMK: [1] 9-2-003:078 [por.] and [1] 9-2-003:079). Although historic accounts point to a substantial Hawaiian population within the vicinity of the project area, Tulchin and Hammatt recorded only four new sites and 10 features. The sites included a complex of concrete and iron structures associated with industrial rock quarrying (SIHP 50-80-12-06880), three boulder mounds they associated with land clearing or ditch construction by the Oahu Sugar Co. (SIHP 50-80-12-06881), a water diversion terrace associated with the post-Contact period (SIHP 50-80-12-06682), and a remnant portion of the Waiāhole Ditch (SIHP 50-80-09-02268). They suggest that the limited number of findings might be due to extensive land modification from ranching, commercial sugar plantations, and industrial rock quarrying, or that extensive erosion of topsoil into the project area may have concealed surface archaeological features. SIHP -06680, -06681, and -06682 were evaluated as significant under Criterion d. SIHP -02268 was evaluated as significant under Criteria a and d.

No further work was recommended for any of these sites beyond documentation that was completed for the AIS (Tulchin and Hammatt 2004).

In 2005, CSH (Tulchin and Hammatt 2005) carried out an AIS for the Pālehua East B Residential Development Project at Makakilo, an approximately 71-acre parcel bordered by the Royal Ridge Subdivision on the west, Puʻu Makakilo on the south, and Kaloʻi Gulch on the north and east (TMK: [1] 9-2-003:076 and [1] 9-2-003:078). They found that the area had already undergone significant erosion of topsoil, as well as substantial land modifications from development (e.g., machine grading, bulldozer clearing, excavation ditches, and landscape irrigation). They recorded three newly identified historic properties and a total of six component features, which they ascribed to agricultural or water diversion functions. These included a boulder alignment and mound (SIHP 50-80-12-06666), a basalt wall and ditch feature (SIHP 50-80-12-06667), and a boulder alignment (SIHP 50-80-12-06668). SIHP -06666 and -06668 were evaluated as significant under Criterion d, and SIHP -06667 was evaluated as significant under Criteria c and d. They recommended no further work beyond the testing completed during the AIS (Tulchin and Hammatt 2005).

In 2006, CSH (O'Hare et al. 2006) conducted an AIS for the East Kapolei or Hoʻopili Project. They identified several previously identified historic properties, including plantation infrastructure (SIHP 50-80-12-04344), a railroad berm (SIHP 50-80-12-04345), the northern pumping station (SIHP 50-80-12-04346), central pumping station (SIHP 50-80-12-04347), and southern pumping station (SIHP 50-80-12-04348). They recorded four additional features associated with the plantation infrastructure of SIHP -04344: two linear walls, a stone-faced berm, and a concrete ditch and masonry catchment basement (Features D through G). They noted that during a 1990 survey of the West Loch Bluffs project area (Hammatt and Shideler 1990), all of these sites were evaluated as significant under Criteria c and d. However, since that time, many of the original features of SIHP -04344 had deteriorated, and O'Hare et al. (2006) revised their determination for SIHP -04344 to significance under Criterion d only. No further work was recommended for SIHP -04344, and SIHP -04345 through -04348 were all recommended for preservation.

In 2006, IARII (Rasmussen 2006) carried out a three-part archaeological assessment in Makakilo and Makalapa Gulches for a D.R. Horton – Schuler Division development located approximately 2 km west and southwest of the project area (TMK: [1] 9-2-003:081, [1] 9-2-019:003, [1] 9-2-003:072, [1] 9-2-003:081, [1] 9-2-003:084, [1] 9-2-003:085). For the project, Rasmussen (2006) conducted three separate investigations which involved two pedestrian surface surveys and one test excavation unit. The 2004 survey yielded no archaeological sites, and Rasmussen concluded that there was little chance of finding sites due to heavy disturbance from off-roading trails, bulldozing, and natural erosion. In the 2006 survey, Rasmussen recorded one new historic property (SIHP 50-80-12-04664) with eight associated features related to sugarcane cultivation, including a flume, double drain culvert, walled drainage, rock-lined ditch, plow scars, crushed coral roadbed, crushed basalt cobble foundation or paving, and a curved rock alignment. SIHP -04664, inclusive of all component features, was evaluated as significant under Criterion d, and no further work was recommended.

In 2006, IARII (Rasmussen and Tomonari-Tuggle 2006) conducted archaeological monitoring work along the Waiau Fuel Pipeline Corridor. No historic properties were identified during monitoring.

In 2007, CSH (Tulchin and Hammatt 2007) carried out an Archaeological Literature Review and Field Inspection (LRFI) for a parcel measuring approximately 790 acres within Pālehua (TMK:

[1] 9-2-003:002 por., [1] 9-2-003:005 por.), located just north of Makakilo City and encompassing portions of Makaīwa Gulch, Awanui Gulch, and Kalo‘i Gulch. They found that much of the pre-Contact cultural landscape remained intact because most of the land within this project area was used almost exclusively for ranching purposes up to the present. This included pre-Contact archaeological features such as habitation, agricultural, and ceremonial features, as well as post-Contact features associated with historic ranching and quarrying activities. They recommended an AIS with a pedestrian survey with 100% coverage to identify and document all historic properties and evaluate their significance should plans arise to further develop the area.

In 2007, CSH (Tulchin et al. 2007) carried out an Archaeological Field Inspection, Literature Review, and Cultural Impact Evaluation for the proposed Kapolei 215 Reservoir No. 2 Project (TMK: [1] 9-2-003:083). No historic properties were identified.

In 2008, Pacific Legacy, Inc. (Mooney and Cleghorn 2008) carried out an Archaeological Inventory Survey for the Proposed Makakilo Quarry Expansion, Kapolei, Honouliuli Ahupua‘a, ‘Ewa, O‘ahu (TMK: [1] 9-2-003:018). No historic properties were identified and an Archaeological Assessment Report was submitted.

In 2009, CSH (Hunkin and Hammatt 2009) carried out an AIS for the Makakilo Drive Extension Project (TMK: [1] 9-2-002:006 and [1] 9-2-002:079), bound on the south by Quarry Road, which connects Old Pālehua Road with the Grace Pacific Makakilo Quarry. The AIS recorded two newly identified historic properties and documented one previously identified historic property (a portion of Waiāhole Ditch, SIHP 50-80-09-02268). The two newly identified historic properties were both irrigation ditches, likely associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-09-06950 and 50-80-09-06951). SIHP -06950 and -06951 were evaluated as significant under Criterion d, and no further work was recommended for these sites. SIHP -02268 was evaluated as significant under Criteria a, c, and d and avoidance and mitigation of inadvertent adverse impact was recommended.

In 2010, CSH conducted archaeological monitoring for Phase 1B of the North-South Road Project (TMK: [1] 9-1-017:004, 095, 096, 097, 098) and identified no historic properties (Runyon et al. 2010).

In 2011, CSH (Runyon et al. 2011) completed archaeological monitoring for Phase 1C of the North-South Road Project (TMK: [1] 9-1-018:001, 003, 004, 005; 9-2-002:001, 006). They identified one historic property previously identified by Nakamura et al. (1993), a historic water diversion structure (SIHP 50-80-12-04884), and documented one newly identified historic property, a burnt trash fill layer found under Pālehua Road, on the west edge of Ramp A (SIHP 50-80-12-07128). Both sites were evaluated as significant under Criterion d, and no further work was recommended.

In 2014, IARII (Pacheco and Rieth 2014) carried out an AIS for the East Kapolei Solar Farm (TMK: [1] 9-2-002:006 por.). They recorded one newly identified historic property, an unpaved early twentieth-century road, likely associated with either industrial ranching or sugarcane cultivation activities (SIHP 50-80-12-07433). The site was evaluated as significant under Criterion d. No further work was recommended beyond the recordation involved in the AIS.

In 2014, IARII (Rieth et al. 2014) carried out an AIS of an area including SIHP 50-80-12-07664, a site comprised of two basalt boulders carrying five petroglyph figures, and approximately 0.16 acres of the surrounding area (TMK: [1] 9-2-048:092 por.). Aside from thorough documentation of the petroglyph site, no additional historic properties were identified. The site was evaluated as significant under Criteria d and e, and relocation and passive preservation was recommended.

In 2018, CSH (Zapor et al. 2018 as cited by Welser et al. 2020) conducted a supplemental archaeological inventory survey (SAIS) for the Makakilo Drive Extension Project. They identified two historic properties: portions of the previously documented Waiāhole Ditch (SIHP 50-80-09-02268), and an irrigation ditch with associated components (SIHP 50-80-09-06951). They documented an additional component feature of the Waiāhole Ditch (SIHP -02268, Feature D) consisting of an earthen mound and stacked stone wall which are likely the remnants of a reservoir. They assessed SIHP -02268 as significant under Criteria a, c, and d (Zapor et al. 2018 as cited by Welser et al. 2020). Significance assessment for SIHP -06951 and mitigation recommendations for both sites have not been made available.

In 2020, CSH (Welser et al. 2020) conducted an AIS for the AES West Oʻahu Solar Project (TMK: [1] 9-2-002:007 por.). They identified two previously documented historic properties: a complex of irrigation features previously identified by Dega et al. (1998) and associated with post-Contact industrial sugarcane agriculture, including aqueducts, ditches, pumps, and flumes (SIHP 50-80-08-05593), and a portion of the Waiāhole Ditch system (SIHP 50-80-09-02268). SIHP -05593 was evaluated as significant under Criteria a and d, and SIHP -02268 was evaluated as significant under Criteria a, c, and d. Mitigation commitments included avoidance of adverse impact to component features within the project area, data recovery in the form of archaeological monitoring, Historic American Engineering Record (HAER) documentation of SIHP -05593, Feature 2 (mill building and Pump House 12 complex), and incorporation of the portions of SIHP -02268 within the project area to an existing Addendum to the Waiāhole Ditch Historic Context Study (Mason Architects, Inc. 2018).

Table 1. Summary of Previous Archaeological Investigations within 0.5-mile Radius of the Makakilo Quarry Proposed Expansion Project Area. Studies that Include the Project Area are Highlighted.

Reference	Type of Study	Location	Findings
McAllister 1933	Island-wide Survey	Oʻahu Island	Recorded several sites around the peripheries of Puʻu Makakilo and Puʻu Kapolei, including a rock shelter, Puʻu Kapolei Heiau (Site 138), Puʻu Kuina Heiau (Site 134), and a basalt and coral platform (Site 136).
Bordner 1977	Archaeological Reconnaissance Survey	Kaloʻi Gulch [TMK: (1) 9-2-003]	Recorded abandoned quarry, pathway, retaining wall, and three walls of stacked *pāhoehoe* slabs (SIHP 50-80-12-02600 through 50-80-12-02602).

Reference	Type of Study	Location	Findings
Haun 1986	Archaeological Reconnaissance Survey	ʻEwa Town Center [TMK: (1) 9-1-015: 004, 005, 017 pors.; (1) 9-1-016:001, 004, 006, 009, 016, 018, 024, 030 pors.; (1) 9-2-019: 001 por.]	Documented a single irrigation ditch and noted the presence of a WWII-era structure.
Sinoto 1988	Surface Survey	Makakilo Golf Course [TMK: (1) 9-2-003:018]	Documented a deteriorated, double-faced, core-filled wall segment, recommended for no further work (SIHP 50-80-12-01975, Bishop Museum number 50-Oa-B6-276).
Nakamura et al. 1993	Archaeological Inventory Survey	Development Parcels D and D-1, Makakilo [TMK: (1) 9-2-003:018 por., 075 por., 081 por.]	Documented a segment of an irrigation system constructed by the Ewa Plantation Company (SIHP 50-80-12-04664).
Spear 1996	Archaeological Reconnaissance Survey	From the H-1 Freeway to the north side of Renton Road	No historic properties.
Hammatt and Chiogioji 1997	Archaeological Reconnaissance Survey	H-1 corridor east of the project area	No historic properties.
Dega et al. 1998	Archaeological Inventory Survey	UH West Oʻahu [TMK: (1) 9-2-002:001]	Historic irrigation complex associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-08-05593) and remnant portions of the Waiāhole Ditch system (SIHP 50-80-09-02268).
Magnuson 1999	Archaeological Reconnaissance Survey	Farrington Highway	Recorded a railroad track, concrete bridges, and other concrete features, that were determined to be not significant. No SIHP numbers were assigned, and no further work was recommended.
Tulchin and Hammatt 2004	Archaeological Inventory Survey	Pālehua Community Association, Makakilo [TMK: (1) 9-2-003:078 por. and 079]	Recorded four archaeological sites and ten individual features associated with rock quarrying, water diversion, and agricultural activities (SIHP 50-80-12-02268, 50-80-12-06680 through 50-80-12-06682).

Reference	Type of Study	Location	Findings
Tulchin and Hammatt 2005	Archaeological Inventory Survey	Pālehua East B Development, Makakilo [TMK: (1) 9-2-003:076 and 078]	Recorded three new archaeological sites and six component features associated with agriculture and water diversion (SIHP 50-80-12-06666 through 50-80-12-06668).
O'Hare et al. 2006	Archaeological Inventory Survey	Hoʻopili, East Kapolei	Identified several previously identified historic properties, including plantation infrastructure (SIHP 50-80-12-04344), a railroad berm (SIHP 50-80-12-04345), and northern, central, and southern pumping stations (SIHP 50-80-12-04346 through 50-80-12-04348). Recorded four additional features associated with SIHP -04344: two linear walls, a stone-faced berm, and a concrete ditch and masonry catchment basement (Features D through G).
Rasmussen 2006	Archaeological Inventory Survey	Makakilo and Makalapa Gulches [TMK: (1) 9-2-003:081, 9-2-019:003, 072, 081, 084, 085]	Recorded site with 7 component features related to sugarcane cultivation (SIHP 50-80-12-04664). Components include drainage and irrigation features, a transport road, and crushed basalt paving.
Rasmussen and Tomonari-Tuggle 2006	Archaeological Monitoring	Waiau Fuel Pipeline Corridor, southeast of H-1 corridor	No historic properties.
Tulchin and Hammatt 2007	Archaeological Literature Review and Field Inspection	790-acre parcel in Pālehua [TMK: (1) 9-2-003:002 por. and 005 por.]	Numerous sites related to pre-Contact Hawaiian habitation and activities and post-Contact ranching and quarrying. No SIHP numbers were assigned during the LRFI.
Tulchin et al. 2007	Archaeological Field Inspection, Literature Review, and Cultural Impact Evaluation	Kapolei 215 Reservoir [TMK: (1) 9-2-003:083]	No historic properties.
Mooney and Cleghorn 2008	Archaeological Inventory Survey	Makakilo Quarry Expansion [TMK: (1) 9-2-003:018]	No historic properties.

Reference	Type of Study	Location	Findings
Hunkin and Hammatt 2009	Archaeological Inventory Survey	Makakilo Drive [TMK: (1) 9-2-002:006 and 079]	Recorded two new archaeological sites associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-12-06950 and 50-80-12-06951) and documentation of previously identified Waiāhole Ditch site (SIHP 50-80-09-02268).
Runyon et al. 2010	Archaeological Monitoring	North-South Road [TMK: (1) 9-2-002:006; (1) 9-2-003:075]	No historic properties.
Runyon et al. 2011	Archaeological Monitoring	North-South Road [TMK: (1) 9-1-018:001, 003, 004, 005; (1) 9-2-002:001, 006]	Identified one previously recorded site (historic water diversion structure, SIHP 50-80-12-04664) and recorded one new site (burnt trash fill layer, SIHP 50-80-12-07128).
Pacheco and Rieth 2014	Archaeological Inventory Survey	East Kapolei Solar Farm [TMK: (1) 9-2-002:006 por.]	Recorded one new archaeological site, an unpaved road likely associated with early 20th-century industrial ranching or sugarcane agriculture (SIHP 50-80-12-07433).
Rieth et al. 2014	Archaeological Inventory Survey	SIHP 50-80-12-07664 and surrounding area	Thorough documentation of SIHP 50-80-12-07664 and associated petroglyphs.
Zapor et al. 2018	Archaeological Inventory Survey	Makakilo Drive Extension Project [TMK: (1) 9-2-002: 007, 009; (1) 9-2-003:074, 092; (1) 9-2-039:110, 114; and (1) 9-2-045:001]	Identified two previously recorded sites (Waiāhole Ditch, SIHP 50-80-09-02268 and an irrigation ditch 50-80-12-06951), and recorded one new component feature (SIHP -02268 Feature D, an earthen mound and stacked stone wall).
Welser et al. 2020	Archaeological Inventory Survey	Southeastern foothills of the Waiʻanae Range [TMK: (1) 9-2-002:007 por.]	Identified two previously recorded sites (Waiāhole Ditch, SIHP 50-80-09-02268), and irrigation complex associated with post-Contact industrial sugarcane agriculture (SIHP 50-80-08-05593).

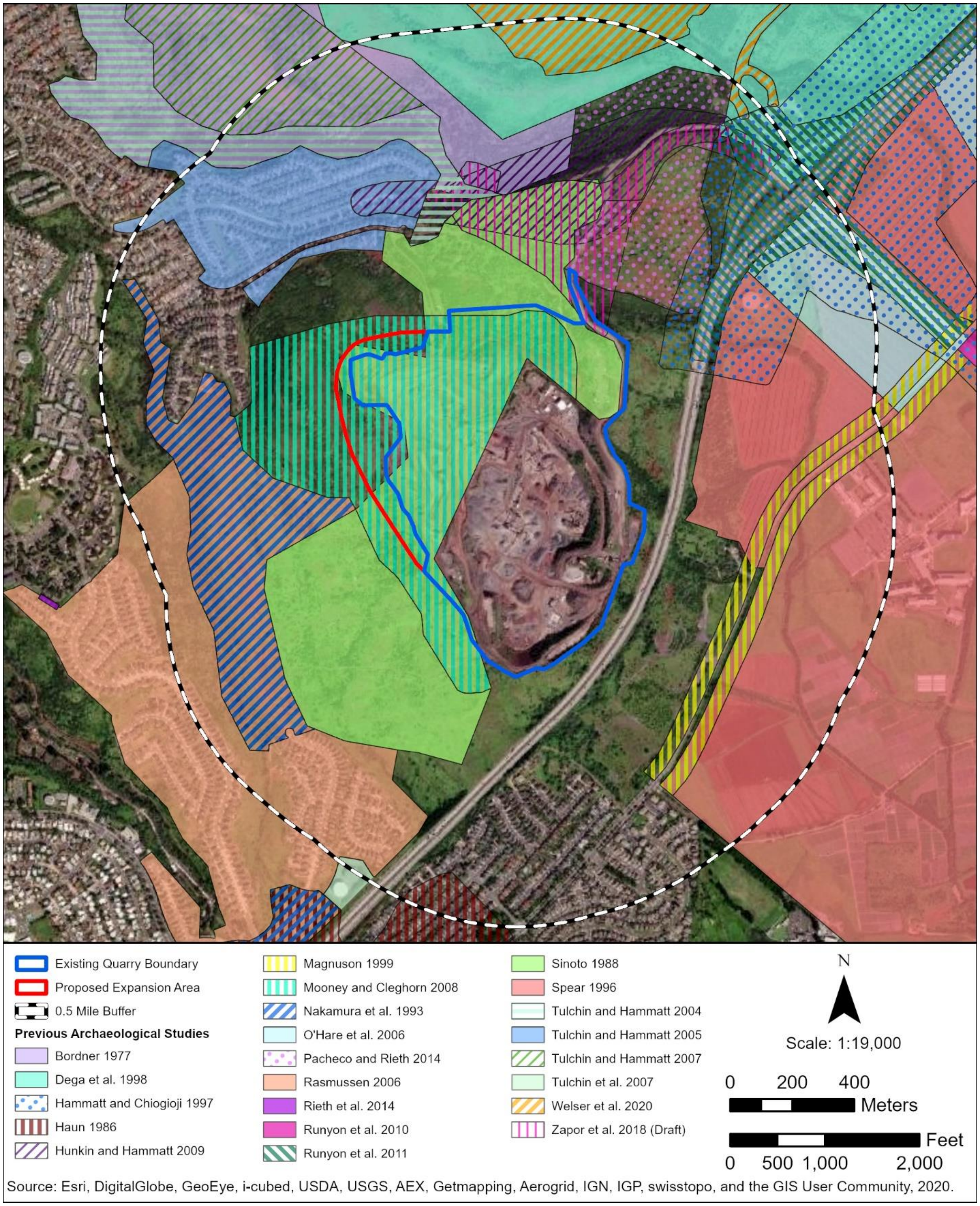

Figure 20. Locations of previous archaeological investigations in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2020).

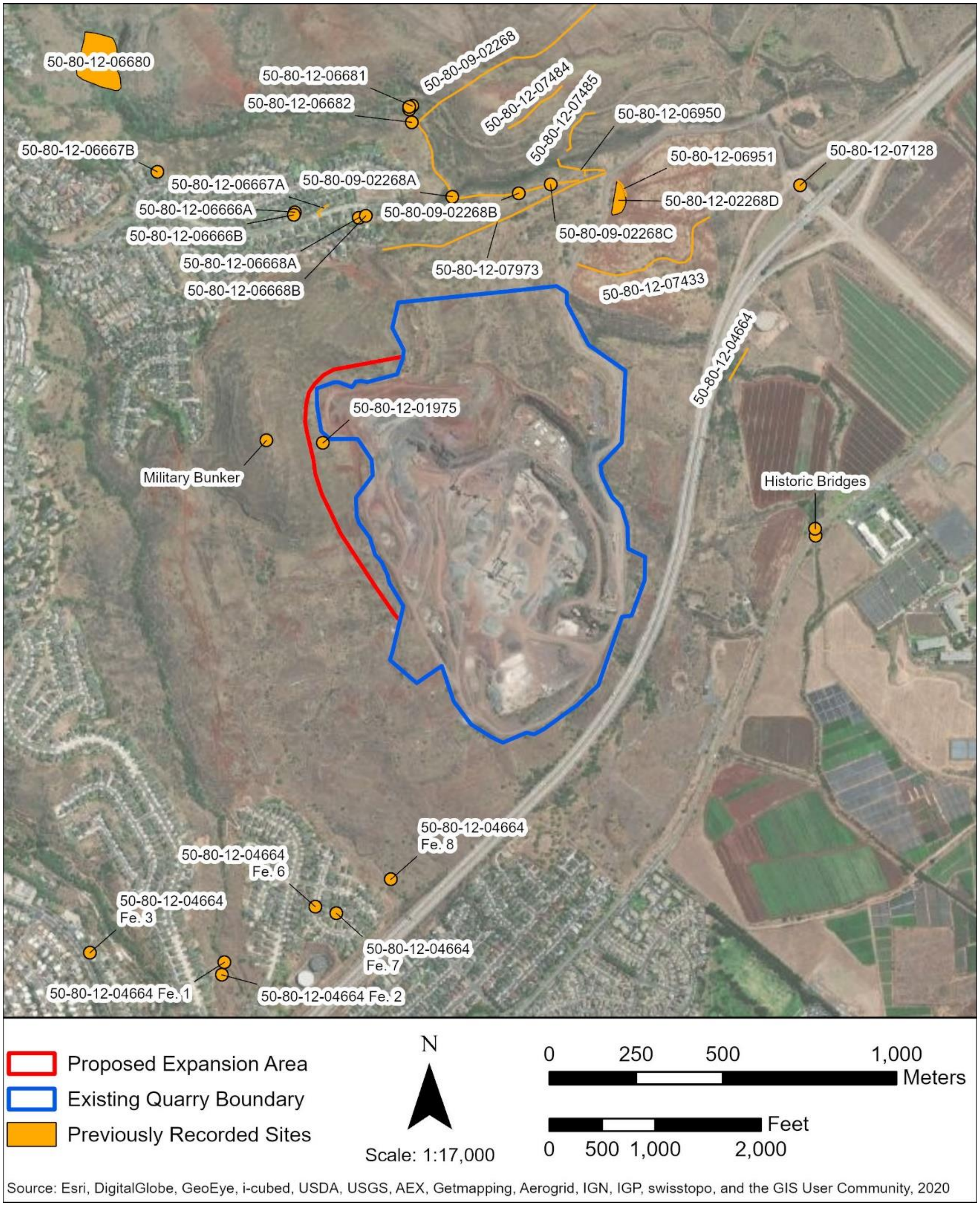

Figure 21. Map of previously identified sites in the vicinity of the Makakilo Quarry Proposed Expansion Project Area (base map: Esri World Imagery 2020).

3.5 BACKGROUND SUMMARY AND PREDICTIVE MODEL

Previous archaeological investigations indicate that evidence for pre-Contact activities in the immediate vicinity of the project area is likely to be sparse. This is due in some part to the nature of pre-Contact activities in this portion of the ʻEwa Plain, as well as the extensive modern development activities that have impacted the lands in and around the project area. Although there are few direct references to Puʻu Makakilo, the nearby Puʻu o Kapolei holds a great deal of traditional significance due to its role in marking the change of seasons on Oʻahu as well as its associations with Kamapuaʻa and his grandmother, Kamaunuaniho. Settlement in Honouliuli was primarily concentrated in the West Loch region, whereas the area around Makakilo was home to a number of native forest species including *milo* (*Thespesia populnea*), *neneleau* (*Rhus sandwicensis*), *kamani* (*Calophyllum inophyllum*), and other trees, as well as the *ʻiʻiwi* (*Drepanis coccinea*) and *ʻōʻō* (*Moho nobilis*) birds (Sterling and Summers 1978). Evidence for pre-Contact activities in the project area is expected to be limited.

The ruptures to the traditional land tenure system brought about by the Mahele introduced significant changes to land use practices around the Makakilo Quarry Proposed Expansion Project Area. Shortly after the death of Levi Haʻalelea, the husband of the high chiefess who was awarded Honouliuli Ahupuaʻa (M.W. Kekauʻōnohi), the land was sold and repurposed to cattle ranching, and later pineapple and sugarcane cultivation. Water management was a consistent priority for the ʻEwa Plain, a region that experienced relatively low annual rainfall. Underground irrigation was the primary source for early post-Contact ranching and agricultural activities. However, water demand increased with the scaling up of industrial sugarcane and pineapple cultivation and by 1916, the 22-mile long Waiāhole Ditch was completed, and ran from Kahana Valley through the Koʻolau Range to Waiawa, and finally westward to Honouliuli via a ditch system. Several previous archaeological surveys in the immediate vicinity of the project area have identified portions of the Waiāhole Ditch, and/or components of other historic irrigation systems (Dega et al. 1998; Haun 1986; Hunkin and Hammatt 2009; Nakamura et al. 1993; O'Hare et al. 2006; Rasmussen 2006; Runyon et al. 2011; Tulchin and Hammatt 2004, 2005; Welser et al. 2020; Zapor et al. 2018).

Previous archaeological work, including a Literature Review and Field Inspection carried out for the project area prior to this AIS (Swift et al. 2022), provides a good indication of the types of sites that may be encountered during the survey. The partial development of the Makakilo Golf Course in the 1980s/90s caused significant impacts to the landscape and cultural resources in and around the project area. In particular, the southern portion of the proposed expansion area appears to have been severely impacted by the grading, terracing, and installation of a subterranean sprinkler system. Swift et al. (2022) identified five potential sites within the project area, which included two modified outcrops of undetermined function and three water diversion/management features. These findings were consistent with expectations based on the land use history of the project area. Given the intensity of land use and disturbance in the immediate vicinity of the project area and the focus of water use and management during ranching, industrial agricultural, and modern development activities, it is likely that any additional historic properties within the project area will also broadly relate to water management and/or possible soil retention features.

4.0 RESULTS OF FIELDWORK

Fieldwork involved pedestrian survey, detailed recordation of historic properties, and testing of selected features using hand-excavation techniques.

4.1 SURVEY COVERAGE

To ensure that all the archaeological features present within the survey area were located and identified, pedestrian transects were undertaken in 100% of the survey area with field crew spaced at 5-m intervals. Visibility ranged from fair to good, depending on the density of vegetation and visibility of the ground surface. Vegetation in the project area consisted largely of introduced dryland grasses, shrubs, and small trees. This included *kiawe* (*Prosopis pallida*), *haole koa* (*Leucaena glauca*), klu (*Acacia fanesiana*), lantana (*Lantana camara*), and a wide variety of other non-native grasses and weeds. Few native plants remain in the Makakilo area due to the introduction of nonnative species as well as recent alterations associated with partial development of the Makakilo Golf Course during the late 1980s and early 1990s.

The project area traversed sloping lands on the eastern side of the horseshoe-shaped Puʻu Makakilo. Gentle undulations in the landscape suggested the presence of several small, shallow erosional channels that are not significant enough to be identifiable on aerial maps, but which may have intermittently channeled water, particularly during periods of heavy rains. There are no permanent streams in the project area. The total size of the area surveyed was approximately 15.6 acres.

4.2 ARCHAEOLOGICAL SURVEY FINDINGS WITHIN PROJECT AREA

The AIS resulted in the identification and detailed recording of one archaeological site (SIHP 50-80-12-01975) that was previously identified by Sinoto (1988) during the Makakilo Golf Course survey as a single "double-faced and core-filled wall section" in deteriorated condition. Sinoto (1988) interpreted the site as a possible historic erosional control feature that he evaluated as not meeting the National Register criteria for significance because of its deteriorated condition and lack of associated features; no further work was recommended.

During the current survey, Sinoto's original site (now designated Feature 1 of SIHP -01975) was re-identified as a soil-retaining terrace with no evidence of a core-fill interior. Four similarly constructed soil-retaining walls were identified in proximity to Feature 1 and subsumed within the SIHP -01975 nomenclature as Features 2 through 5 (Figure 23 and Table 2). The five features documented within SIHP -01975 are all linear, stone-built forms constructed perpendicular to erosional channels. The site is likely associated with past land-use activities such as agriculture and/or drainage control.

Subsurface test excavations were conducted at two features of SIHP -01975 (Feature 1 and Feature 2), to determine whether or not subsurface cultural deposits were present and to assist with determining the probable function and/or age of selected features. Sediment samples were collected from both test units, and three samples from Test Unit 1 (Feature 2) were submitted for microfossil analysis.

The AIS also identified an abundance of recently constructed features associated with the partial construction of the Makakilo Golf Course, including a well, PVC piping, sprinkler heads, and a concrete ditch.

Table 2. Summary of Historic Properties Recorded during the Current AIS

SIHP No.	Feature No.	Subsurface Testing	Formal Type	Possible Age	Possible Function
50-80-12-01975	1	No	Terrace	Unknown	Agriculture/drainage control
	2	Yes	Terrace	Unknown	Agriculture/drainage control
	3	Yes	Terrace	Unknown	Agriculture/drainage control
	4	No	Terrace	Unknown	Agriculture/drainage control
	5	No	Terrace	Unknown	Agriculture/drainage control

Note: shaded feature previously identified by Sinoto (1988).

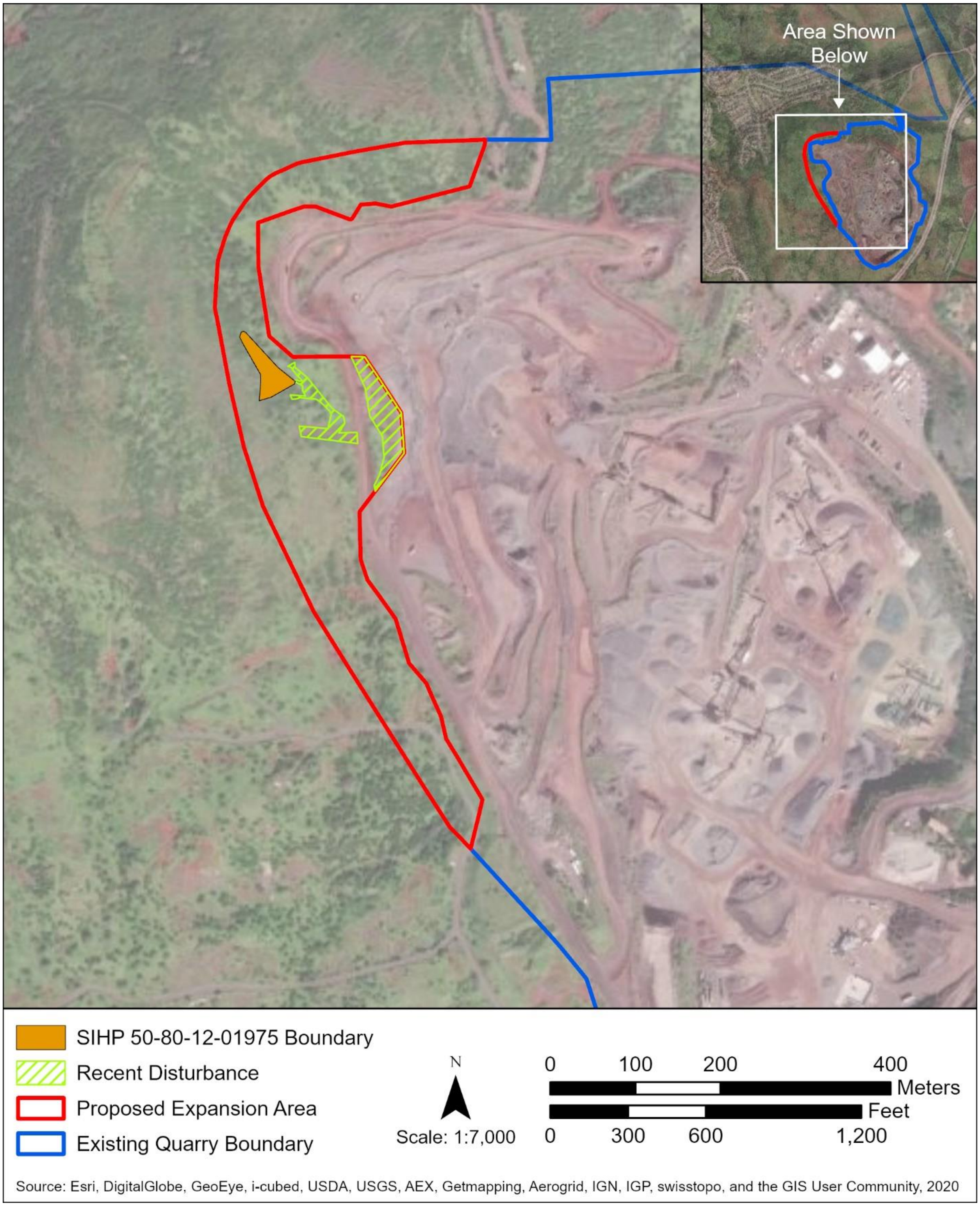

Figure 22. The Makakilo Quarry Proposed Expansion Project Area with the boundaries of SIHP 50-80-12-01975 and areas of recent disturbance overlaid on USGS map.

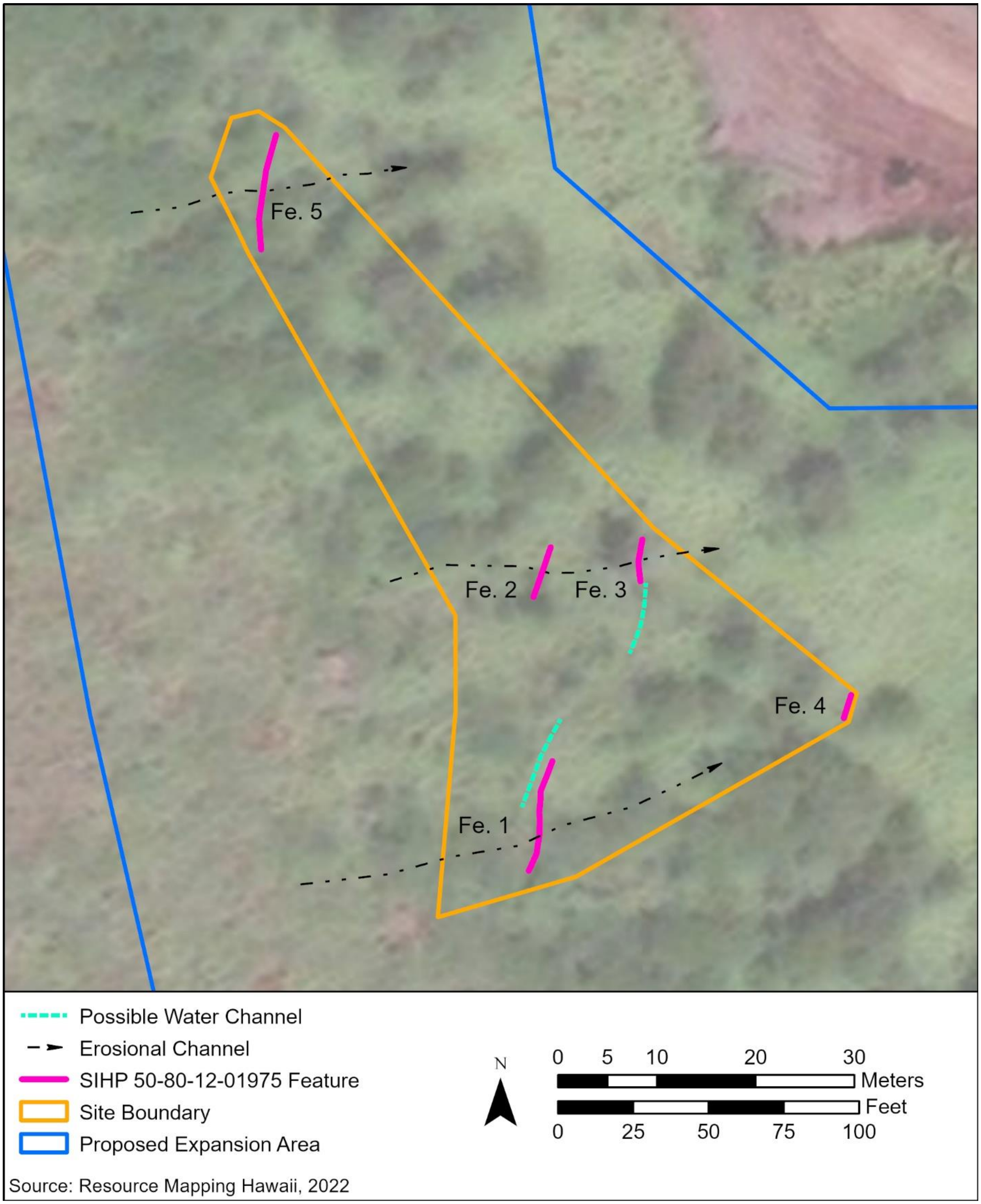

Figure 23. Distribution of SIHP 50-80-12-01975, Features 1–5 within the Makakilo Quarry Proposed Expansion Project Area.

4.2.1 Distribution of Historic Properties

SIHP 50-50-80-12-01975 is a single historic property composed of five features, designated Features 1 through 5. The site features are distributed within an approximately 0.4-acre area in the central portion of the project area. The site features are situated within and modify several narrow erosional channels that ascend moderately to steeply down the eastern slope of Puʻu Makakilo. This eastern slope would have formed the interior flank of the former cinder cone. A portion of the SIHP 50-80-12-01975 complex (Feature 4) was partly disturbed by recent grading activities that are highlighted in Figure 22.

The existing archaeological record might have been impacted by extensive ground disturbance activities undertaken within and beyond the SIHP 50-80-12-01975 complex area as a result of the expansion of Makakilo Quarry over the past 50 years as well as the partial development of the Makakilo Golf Course.

4.2.2 Site Description

SIHP No.: 50-80-12-01975
Site Type: Complex (5 walled terraces)
Number of Features: 5
Dimensions: 80 m L × 40 m W × 1.2 m H
Condition: Fair to Good
Possible Age: Unknown
Possible Function: Agriculture/Water Control
Significance: d
Integrity: Location, association, materials, and setting
Recommended Treatment: No further work

Site Description

SIHP 50-80-12-01975 is a complex of five features that are most likely associated with pre-Contact agricultural activities and/or post-Contact water control infrastructure. The terrace features are spatially separated on the moderate slope of Puʻu Makakilo and situated 30 to 50 m west of the northwestern edge of the active quarry (Figure 22 and Figure 23).

The five features are linear, basalt rock walls aligned roughly north-south across shallow, natural erosional drainages. The five features retain level soil areas on their *mauka* or west sides. Although it is presently unclear whether these level surfaces were anthropogenic or the result of natural deposition, the form of all five features are referred to here as terraces.

The function of these features is not entirely clear; however, the land use history of the project area, the placement of the features along erosional features, and the accumulation of level soil on the *mauka* side of the stone walls suggest two likely functions: pre-Contact agricultural terraces and/or post-Contact ditch features employed to control water and sediment flow along the slopes of Puʻu Makakilo.

Although there is no archaeological record for pre-Contact agricultural activities on the slopes of Makakilo, previous settlement pattern studies for the Hawaiian Archipelago suggest that agricultural activities had expanded to even the most marginal dryland regions by the late pre-Contact period (e.g., Kirch et al. 2004, Ladefoged et al. 2009, McCoy and Graves 2010). It is possible that the slopes of Puʻu Makakilo may have been used for small-scale, intermittent agricultural activities during periods of favorable climatic conditions.

There is some evidence for post-Contact modifications to the uplands of Honouliuli in order to control the flow of water and sediment into the lowlands. Such controls may have been installed on the slopes of Puʻu Makakilo with the purposes of either limiting flooding in the lowlands or encouraging sediment to flow downslope towards the coastal plains. For example, Frierson (1972) observed that Ewa Plantation operators installed drainage ditches on the lower slopes of Honouliuli in the early 1900s with the intent of inducing soil erosion during the rainy season and "reclaiming" parts of the coral plain (Frierson 1972).

Given the high level of recent disturbance throughout the project area, it is possible that portions of SIHP -01975 have been removed or destroyed, and that the remaining five features inside the project area are remnants of what was once a more expansive agricultural and/or drainage control system. Feature 4 of SIHP -01975 also appears to have been recently impacted by bulldozing and grading activities. There is a cleared road leading up to a push pile that abuts the north side of the Feature 4 wall, and a number of loose stones are scattered around the adjacent area.

Two test units were excavated in order to determine the function of SIHP -01975 (Test Unit 1 at Feature 2 and Test Unit 2 at Feature 1). No cultural material was identified within either excavation, though excavations did provide some further insight into feature construction. Sediment samples were collected from test units for microfossil (pollen, phytolith, starch grain) analysis.

All five features of SIHP -01975 are of unknown age. This historic property has been assessed as significant under Criterion d, as it has provided information about the past use of stone terracing on the slope of Puʻu Makakilo for agricultural and/or water control activities. No further work is recommended for this historic property beyond the detailed recordation and test excavations conducted for this AIS.

Feature 1 Description

Feature 1 of SIHP 50-80-12-01975 was previously documented by Sinoto (1988) during the Makakilo Golf Course survey, who described the site as follows:

> A deteriorated wall segment … located inside of Puʻu Makakilo, probably outside of the project area. The wall is double-faced and core-filled and measures 10.5 meters in length, 1.14 meters in width, and .74–1 meter in height. It is oriented North/South across the slope and may have served as an historic erosional control feature. (Sinoto 1988)

The current AIS identified the feature as a stone retained soil terrace measuring 5.5 m wide (E/W) by 12 m long (N/S) with a maximum height of 1.2 m. The wall is bi-faced along a 4-m long section at the center, while the remaining built portion consists of a single retaining wall on its east or downslope side. The retaining wall is in good condition and is constructed of a 6 to 7 course face of subangular basalt large cobbles and small to medium boulders with the underlying outcrop incorporated into the wall at its base. The bi-faced portion of the wall is 1.2 m wide, and its interior or western edge is defined by a 0.2 m to 0.3 m high two-course facing or alignment of small boulders. The interior of the bi-faced section is composed of soil. The northernmost end of the wall is dilapidated and consists of an alignment of subangular basalt cobbles and small boulders.

A possible natural or constructed water channel descends off the northern end of the Feature 1 retaining wall. The roughly 1 m wide channel is bounded on the downslope or east side by a low soil berm and west side by the steep slope of the *puʻu*. A similar narrow channel was identified on the south side of Feature 3, which ascends in the direction of the possible channel of Feature 1 (see Figure 23). Although the channel sections were likely connected at one time, the only preserved sections observed during the AIS are shown on Figure 23. Overall, Feature 1 is in good condition.

Figure 24. Plan view of SIHP 50-80-12-01975, Feature 1 terrace, showing bi-faced section at center beneath scale (view to south).

Figure 25. Oblique view of SIHP 50-80-12-01975, Feature 1 terrace, showing the *makai* (eastern) retaining wall (view to northwest).

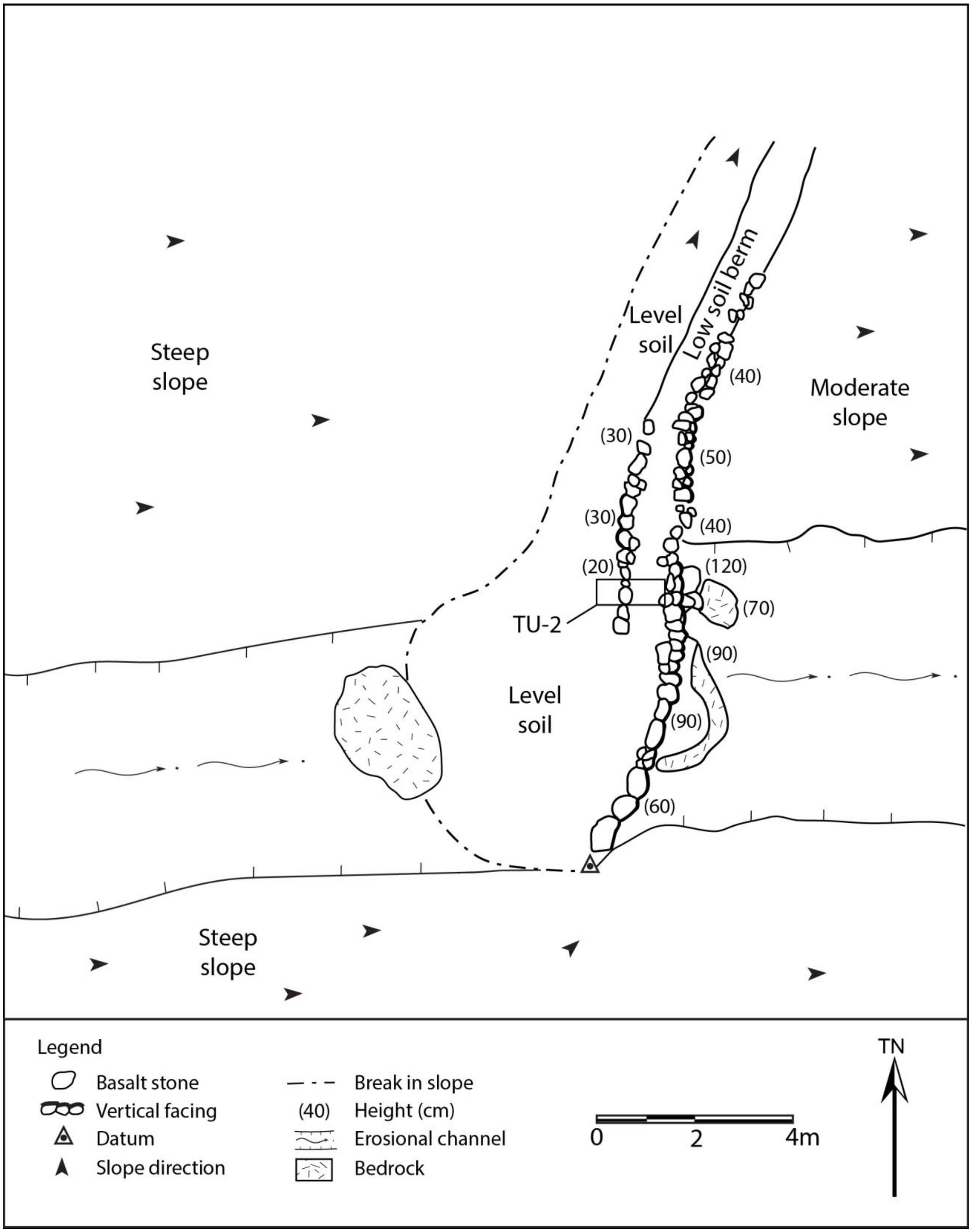

Figure 26. Plan-view map of SIHP 50-80-12-01975, Feature 1, with location of Test Unit 2 (TU-2).

SIHP 50-80-12-01975, Feature 1, Test Unit 2 Results
Test Unit 2 (TU-2) consisted of a 1.5 by 0.5 m unit (Table 3 and Figure 27 to Figure 32) that was placed to overlap the bi-faced portion of the Feature 1 wall and the level soil area on the west side of the wall. TU-2 was excavated using a vertical datum situated 10 cm above the ground surface on the north side of the test unit.

TU-2 was excavated until reaching an impenetrable layer of natural outcrop boulders that was reached at a maximum depth of 72 cmbd. Two soil layers, Layers I and II, were identified within the test unit. The base of the Feature 1 architecture was identified within Layer II.

Both layers consisted of a silty clay with a slight variation in color and structure (Table 3). No cultural materials were identified within the excavation. Two soil samples were collected from the north wall of the test unit but were not submitted for analysis, as those samples collected from TU-1 were determined to be more suitable for analysis and were submitted (see below).

Figure 27. Overview of SIHP 50-80-12-01975, Feature 1, TU-2, prior to excavation (view to east).

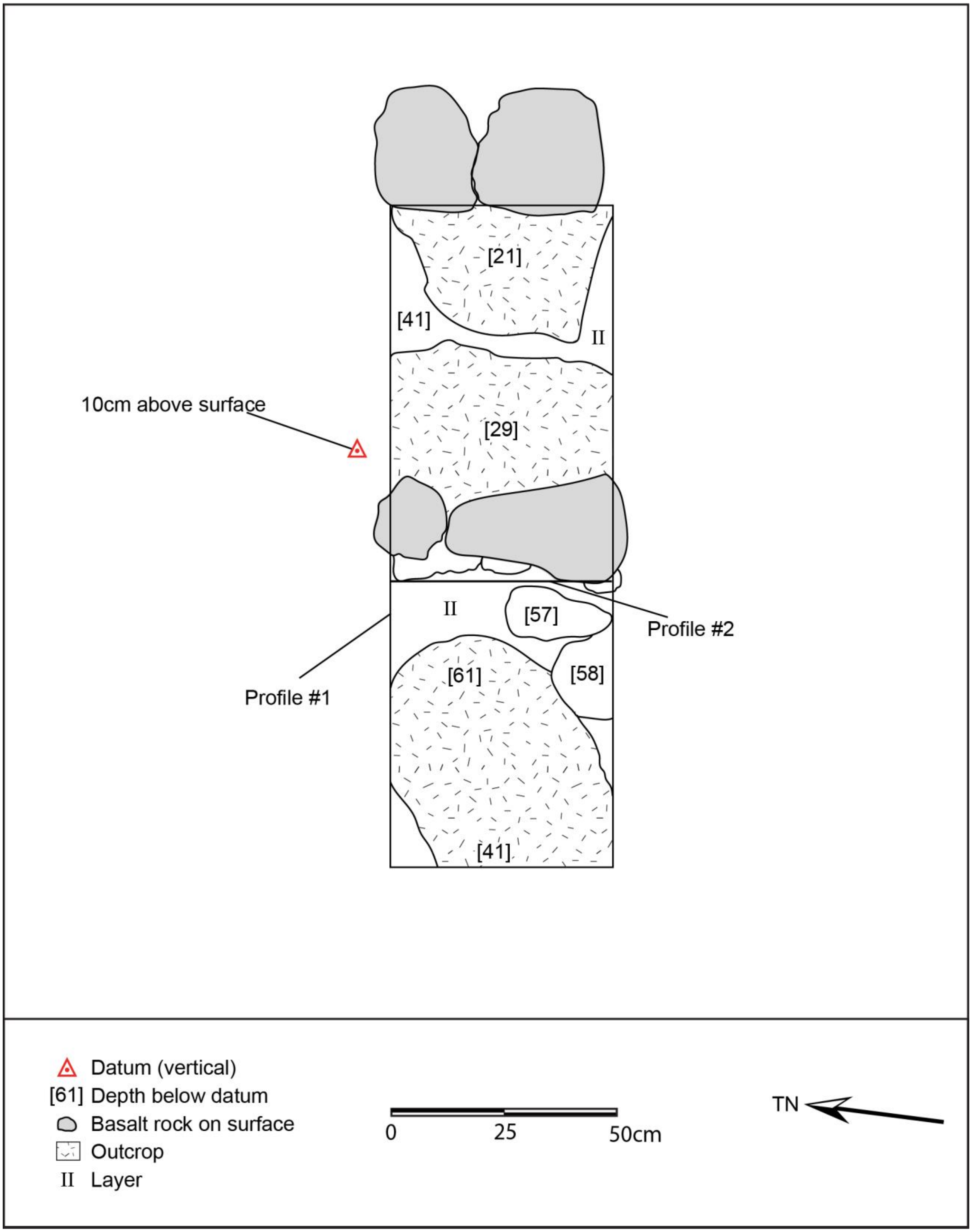

Figure 28. Plan-view map of SIHP 50-80-12-01975, Feature 1, TU-2 base of excavation.

Figure 29. SIHP 50-80-12-01975, Feature 1, north wall profile of TU-2, after excavation (view to north).

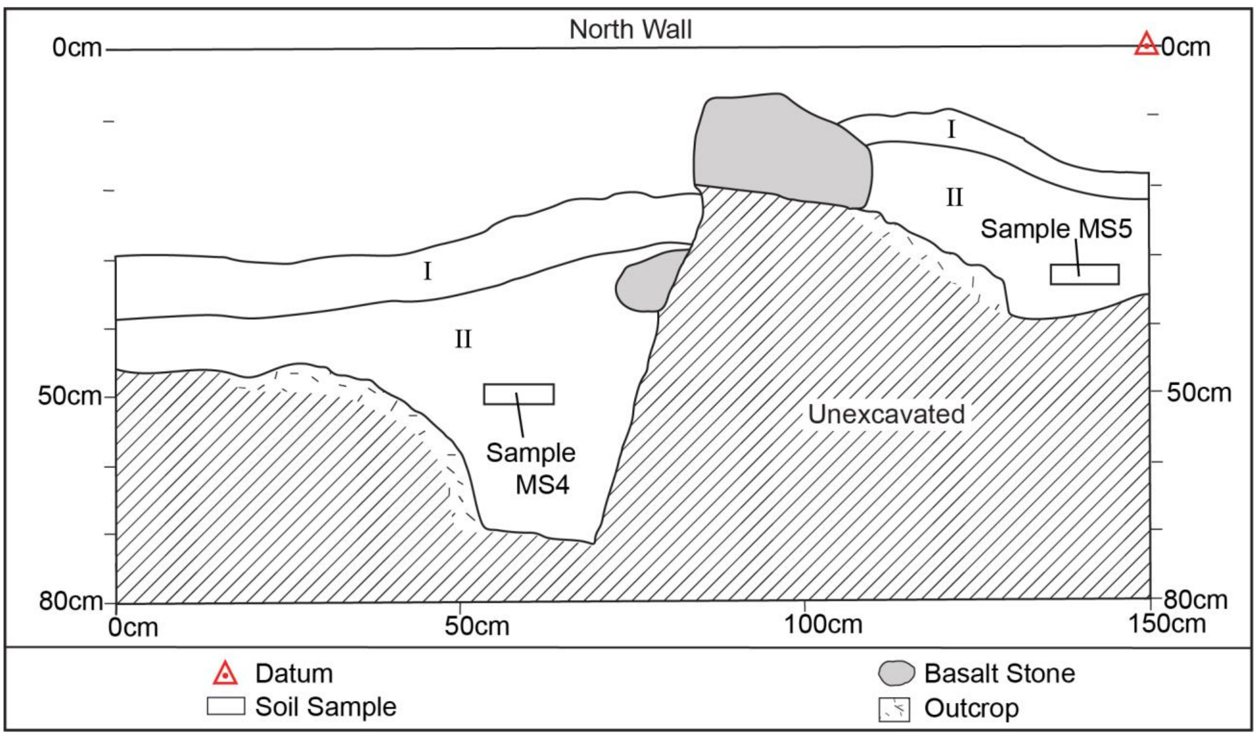

Figure 30. SIHP 50-80-12-01975, Feature 1, TU-2 north wall profile.

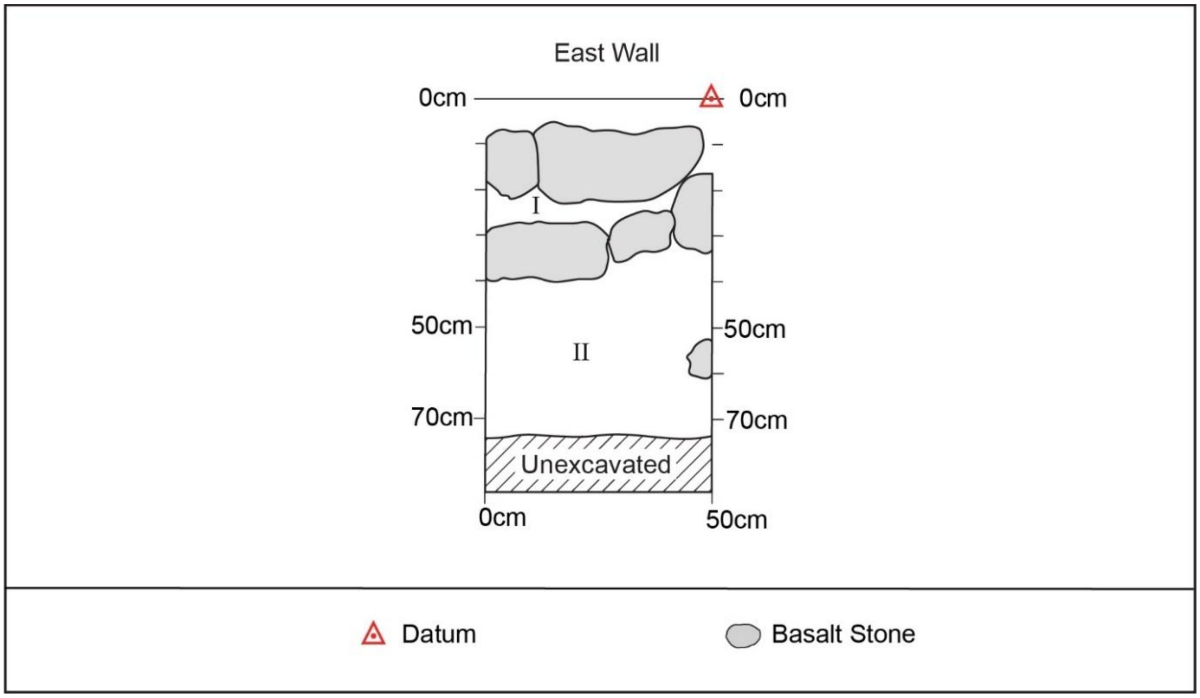

Figure 31. SIHP 50-80-12-01975, Feature 1, TU-2 east wall profile.

Figure 32. SIHP 50-80-12-01975, Feature 1, TU-2 east wall profile showing western face of bi-faced wall section of Feature 1 (view to east).

Table 3. SIHP 50-80-12-01975, Feature 1, TU-2 Soil Descriptions

Layer	Depth (cm below datum)	Description
Layer I	10–40 cmbd	Dark reddish-brown (Munsell No. 2.5YR 3/3) silty clay; weak, medium crumb; slightly hard, friable, sticky, plastic; abrupt smooth boundary. Terrigenous deposit. No cultural material.
Layer II	14–72 cmbd	Dark reddish-brown (Munsell No. 2.5YR 3/4) silty clay; moderate, fine crumb; slightly hard, friable, sticky, moderate plastic. Terrigenous deposit. No cultural material.

Feature 2 Description

Feature 2 is a stone-retained soil terrace consisting of a retaining wall oriented roughly north to south on the east side of a level soil area (Figure 33 and Figure 34). The terrace feature is oriented across a 6-m wide erosional channel. It is upslope and 11.2 m west of Feature 3, a similar terrace feature, which is situated in the same erosional channel.

Overall, the feature measures 4.8 m long (N/S) by 1.0 to 4.5 m wide (E/W) and has a maximum height of 0.90 m. The retaining wall of Feature 2 is 0.5 m wide and constructed of a 3 to 6 course facing of subangular and angular basalt large cobbles and small to medium boulders. Feature 2 is in good condition.

Figure 33. Oblique view of SIHP 50-80-12-01975, Feature 2 terrace, showing construction of east wall face (view to southwest).

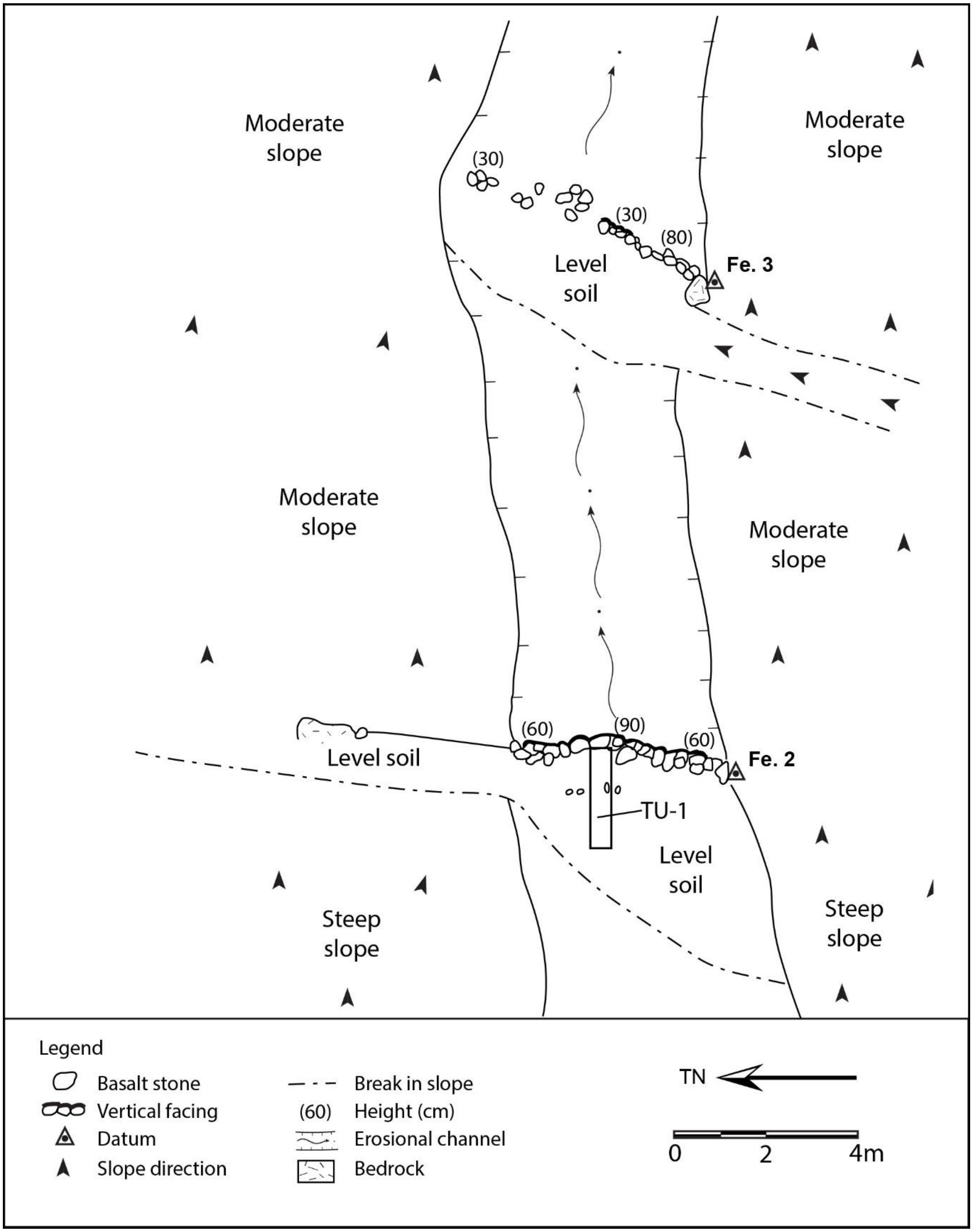

Figure 34. Plan-view map of SIHP 50-80-12-01975, Features 2 and 3, with location of TU-1.

SIHP 50-80-12-01975, Feature 2, Test Unit 1 Results

Test Unit 1 (TU-1) consisted of a 2.0 by 0.5 m excavation unit which was placed on the west side of the main retaining wall of Feature 2 and overlapped a portion of a possible buried alignment that was exposed roughly 3 cm above the ground surface prior to excavation (Figure 35). The unit was placed across these stones to investigate whether they represented a potential secondary interior stone wall, which would be similar to the bi-faced section of the wall of Feature 1. The excavation began with a 1.5 by 0.5 m unit that was later expanded into a 2.0 m by 0.5 m unit (extending 0.5 m to the west) due to the presence of many large basalt boulders uncovered during excavation, which rendered further excavation impossible without expansion (Figure 36). TU-1 was excavated using a vertical datum situated 10 cm above the ground surface on the southern side of the test unit.

A single, homogenous soil layer was identified within the test unit (Layer I). Layer I consisted of silty clay (Figure 37, Figure 38, Table 4). Excavation of TU-1 confirmed the presence of a second stone alignment which runs parallel to, and roughly 1 m to the west (upslope) of the Feature 2 retaining wall that is fully visible from the surface. The western alignment consists of small basalt boulders stacked 2 to 3 courses high and 70 cm in height (Figure 39 and Figure 40). The mostly buried alignment appears to have been more expediently constructed than the eastern retaining wall.

The excavation of TU-1 was terminated upon reaching the base of the feature architecture at a maximum depth of 96 cmbd. Based on the deep and highly weathered soil deposits observed in the active quarry area, Layer I likely extends much further before encountering bedrock. No cultural material was identified within the excavation unit.

With the exposure of the second partially buried parallel alignment, Feature 2 now bears a close resemblance to Feature 1, which also contains a section of parallel walls, noted as a bi-faced wall on the surface with a soil fill rather than an anticipated stone fill based on the previous observation of Sinoto (1988) at Feature 1. It is possible that the parallel walls at both features are the former edges of a constructed drainage ditch that has been naturally filled in with soil.

No cultural materials were identified within the excavation. Three soil samples (samples MS1 through MS3) were collected from the south wall of the test unit (see Figure 37). All three samples were submitted to Microfossil Research, Ltd. for microfossil analysis (see Appendix B). Results of microfossil analysis of the three samples provide evidence for previously disturbed, open vegetation, with identification of a single pollen grain of coconut (*Cocos nucifera*) in Sample MS2 and a tentative identification of *kalo* (taro; cf. *Colocasia esculenta*) starch observed in all three soil samples. Section 5.0 of this report provides a detailed analysis of the microfossil analysis and examines the context of the single coconut pollen grain and tentative identification of *kalo* in all three samples.

Figure 35. SIHP 50-80-12-01975, Feature 2, TU-1 prior to excavation (view to east).

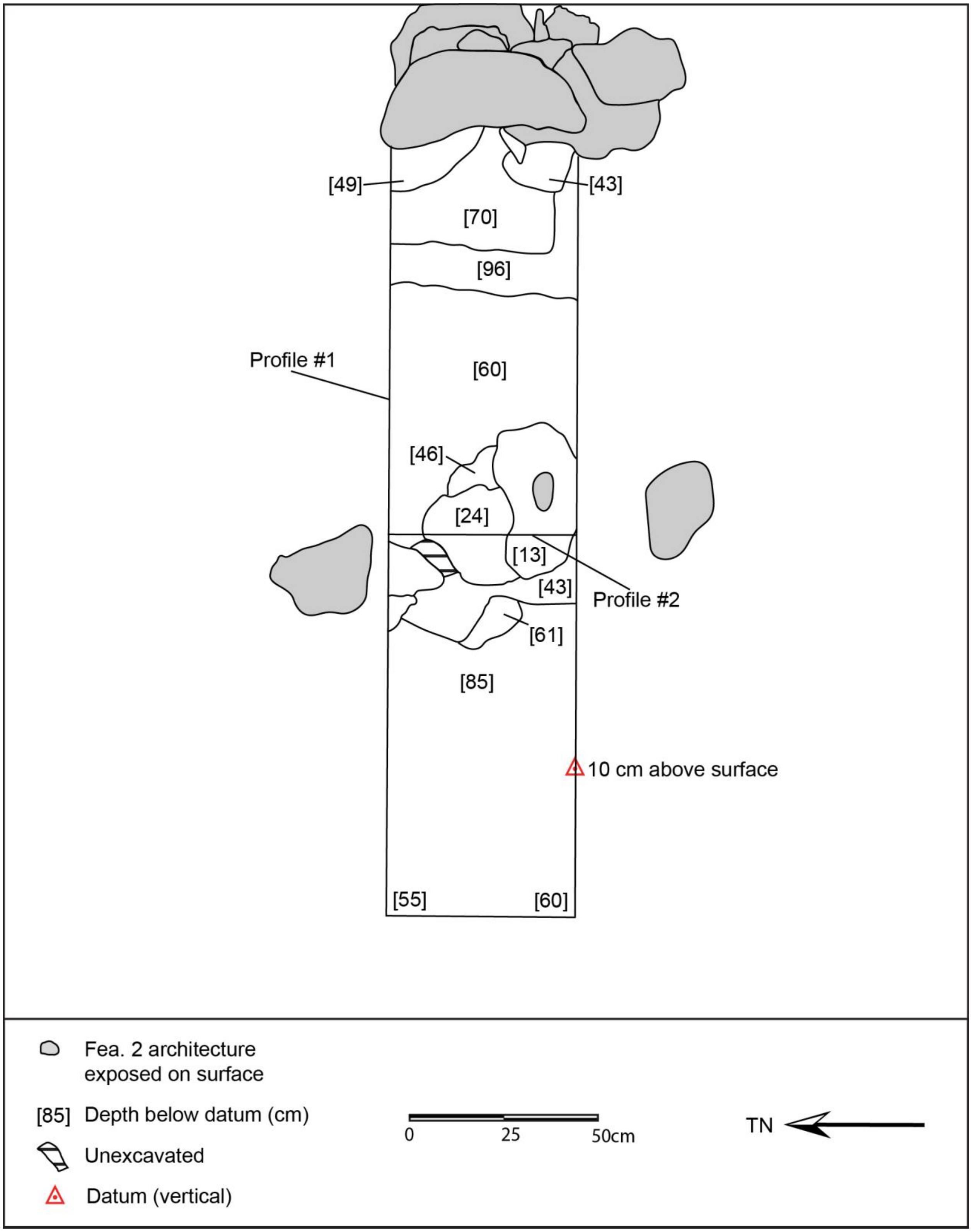

Figure 36. Plan-view map of SIHP 50-80-12-01975, Feature 2, TU-1 base of excavation.

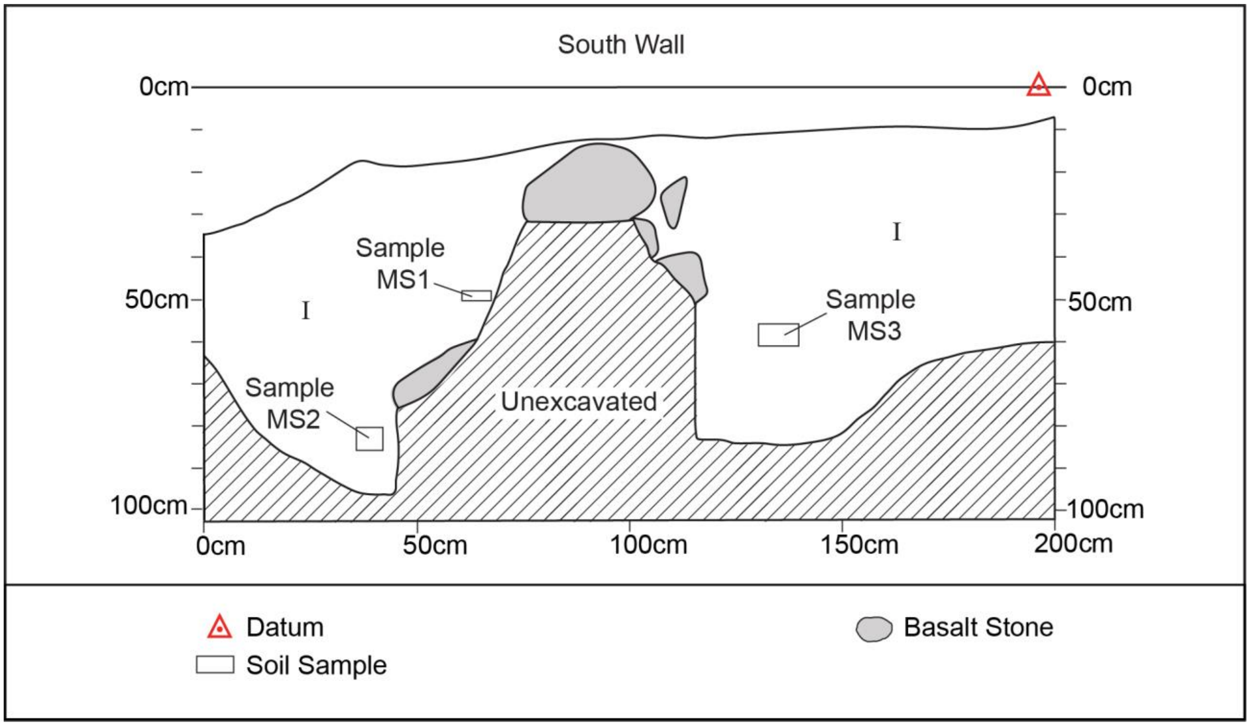

Figure 37. SIHP 50-80-12-01975, Feature 2, TU-1, profile of south wall.

Figure 38. SIHP 50-80-12-01975, Feature 2, TU-1, profile of south wall (view to south).

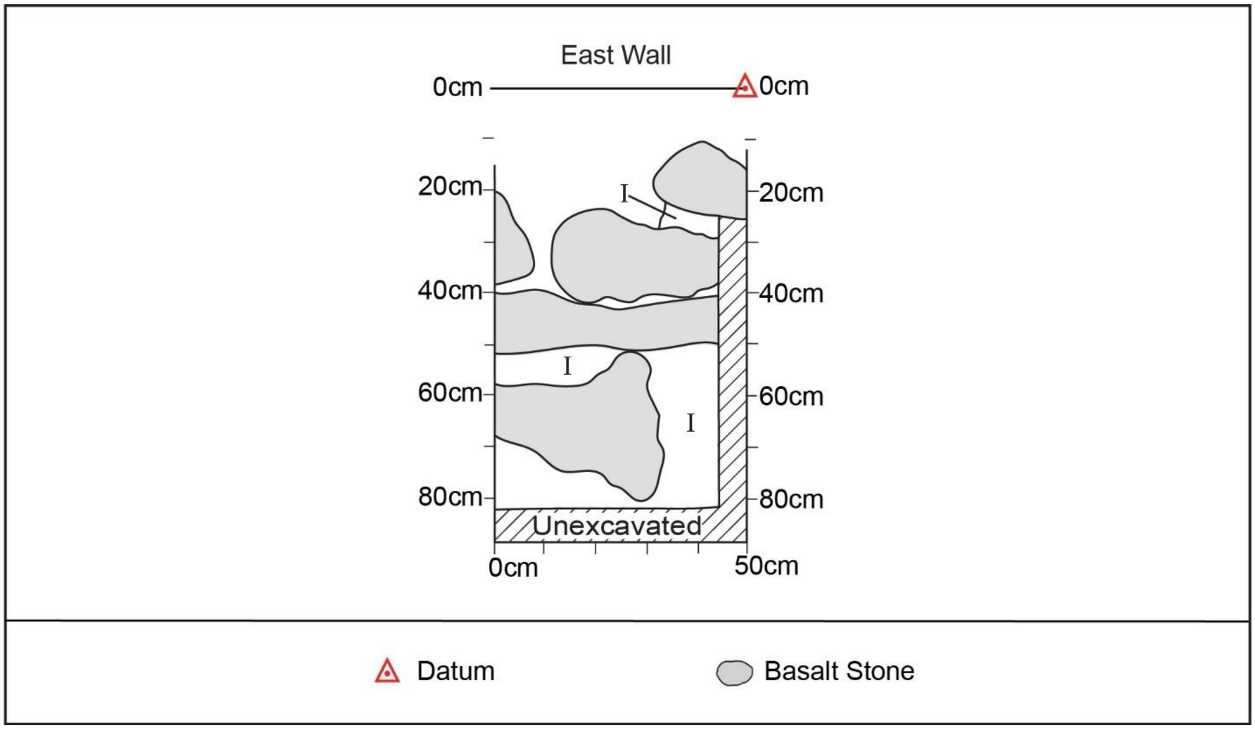

Figure 39. SIHP 50-80-12-01975, Feature 2, TU-1, profile of east wall showing west side of buried stone wall.

Figure 40. SIHP 50-80-12-01975, Feature 2, TU-1, east wall, showing west side of buried stone wall (view to east).

Table 4. SIHP 50-80-12-01975, Feature 2, TU-1 Soil Descriptions

Layer	Depth (cm below datum)	Description
Layer I	10–96 cmbd	Dusky Red (Munsell No. 10R 3/4) silty clay; weak, fine crumb; slightly hard, friable, sticky, moderately plastic. Contains few roots and no cultural material. Colluvial soil.

Feature 3
Feature 3 is a stone-retained soil terrace situated in the same erosional channel as Feature 2, 11.2 m east of Feature 2 (Figure 41). A possible natural water channel or constructed ditch ascends from the southwest into the south end soil area of Feature 3 (see Figure 23).

Overall, the terrace measures 11.3 m long (N/S) by 6 m wide (E/W) and has a maximum height of 0.8 m (Figure 41). The terrace wall is constructed of stacked and faced angular and subangular basalt large cobbles and small to large boulders 2 to 3 courses high. The north side of the terrace wall was likely faced at one time but is now covered with soil. A level soil area on the west or upslope side of the retaining wall is 6 m long (NE/SW) by 2 m wide (NW/SE). Overall, Feature 3 is in fair condition.

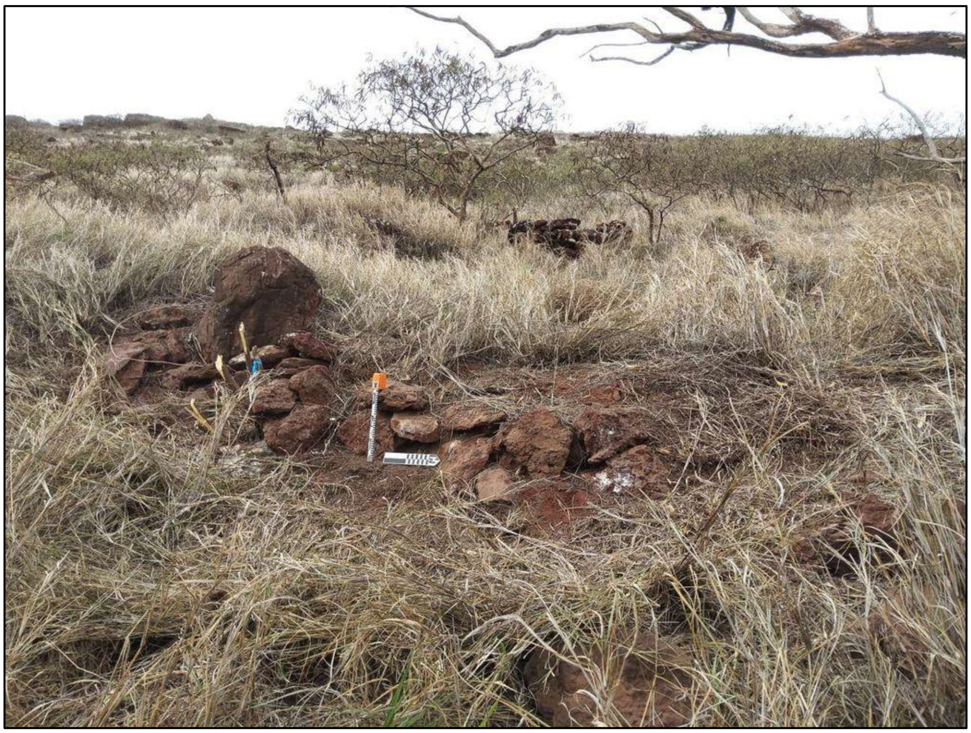

Figure 41. Photo of southern portion of SIHP 50-80-12-01975, Feature 3, terrace (view to west). Note Feature 2 terrace in background.

Feature 4 Description

Feature 4 is a stone-retained soil terrace located at the base of Pu‘u Makakilo’s slope, roughly 24 m southeast of Feature 3 (Figure 42 through Figure 44). The terrace retaining wall contains a level soil area on the upslope or northwest side. Feature 4 was impacted by recent grading in the area, as indicated by a mound of pushed soil mixed with stones on the terrace’s north side. See Figure 42 and Figure 44 for the extent of disturbance in proximity to Feature 4.

Overall, the feature measures 3 m wide (E/W) by 3 m long (N/S) and has a maximum height of 0.5 m. The terrace’s retaining wall is constructed of a 2 to 3 course facing of medium and large cobbles and small basalt boulders. Feature 4 is in fair condition due to recent disturbance.

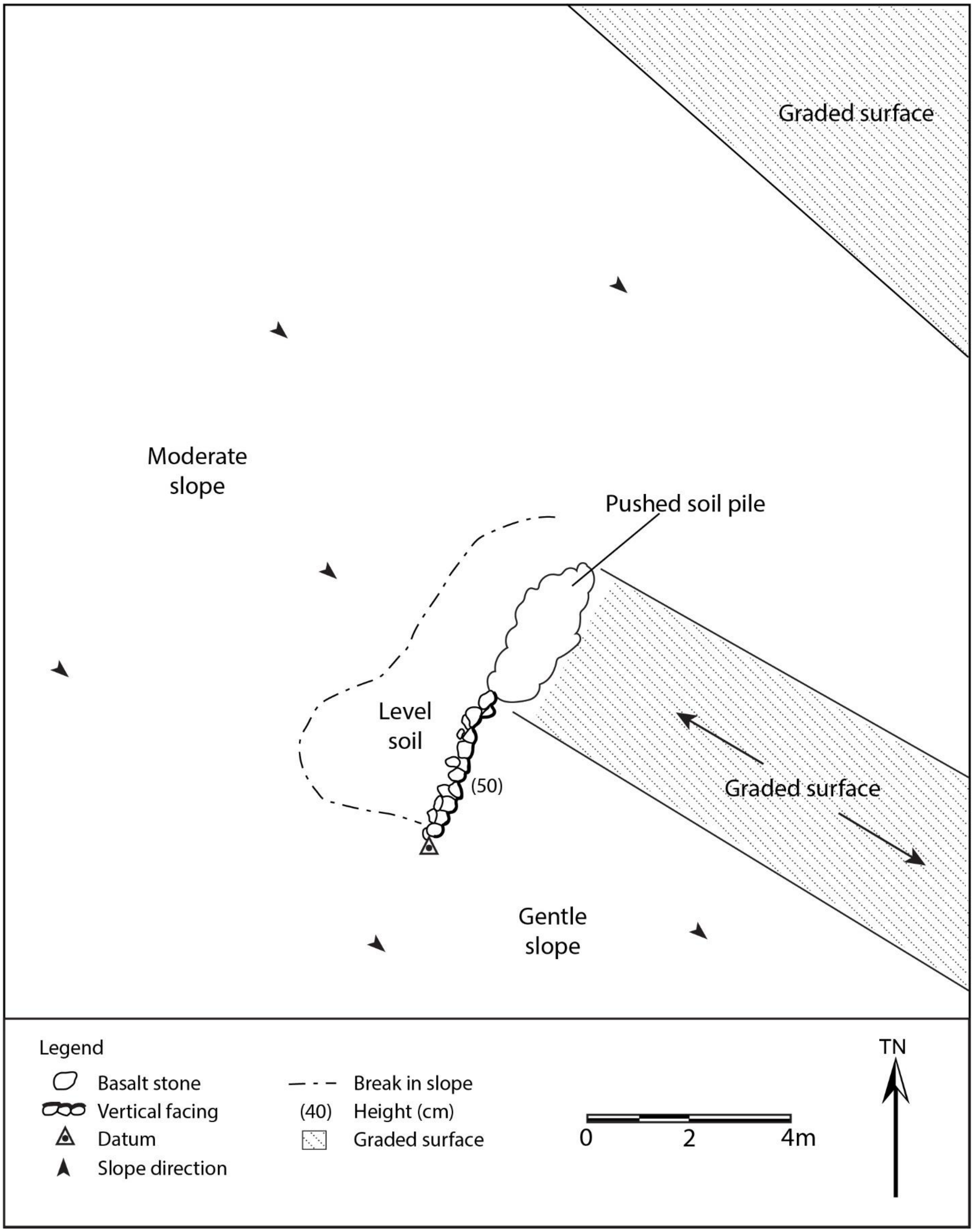

Figure 42. Plan-view map of SIHP 50-80-12-01975, Feature 4.

Figure 43. SIHP 50-80-12-01975, Feature 4, retaining wall (view to south).

Figure 44. Overview of SIHP 50-80-12-01975, Feature 4 showing recent graded surface and push pile in foreground (view to southwest).

Feature 5 Description
Feature 5 is a stone-retained soil terrace located approximately 42 m northwest of Feature 2. The terrace is built across an erosional channel and measures 12 m long (N/S) by 1.5 to 3.0 m wide (E/W) by a maximum 0.7 m high. The wall is in fair to good condition with the northern portion being the most intact (Figure 45 and Figure 46). The intact portion of the retaining wall is constructed of a facing of 2 to 4 courses of medium to large cobbles and small boulders of subangular and angular basalt. The middle section of the wall is poorly defined and possibly eroded or covered in soil, and the southern end is roughly stacked with subangular basalt cobbles.

Figure 45. North portion of SIHP 50-80-12-01975, Feature 5 terrace, showing the intact portion of the feature (view to east).

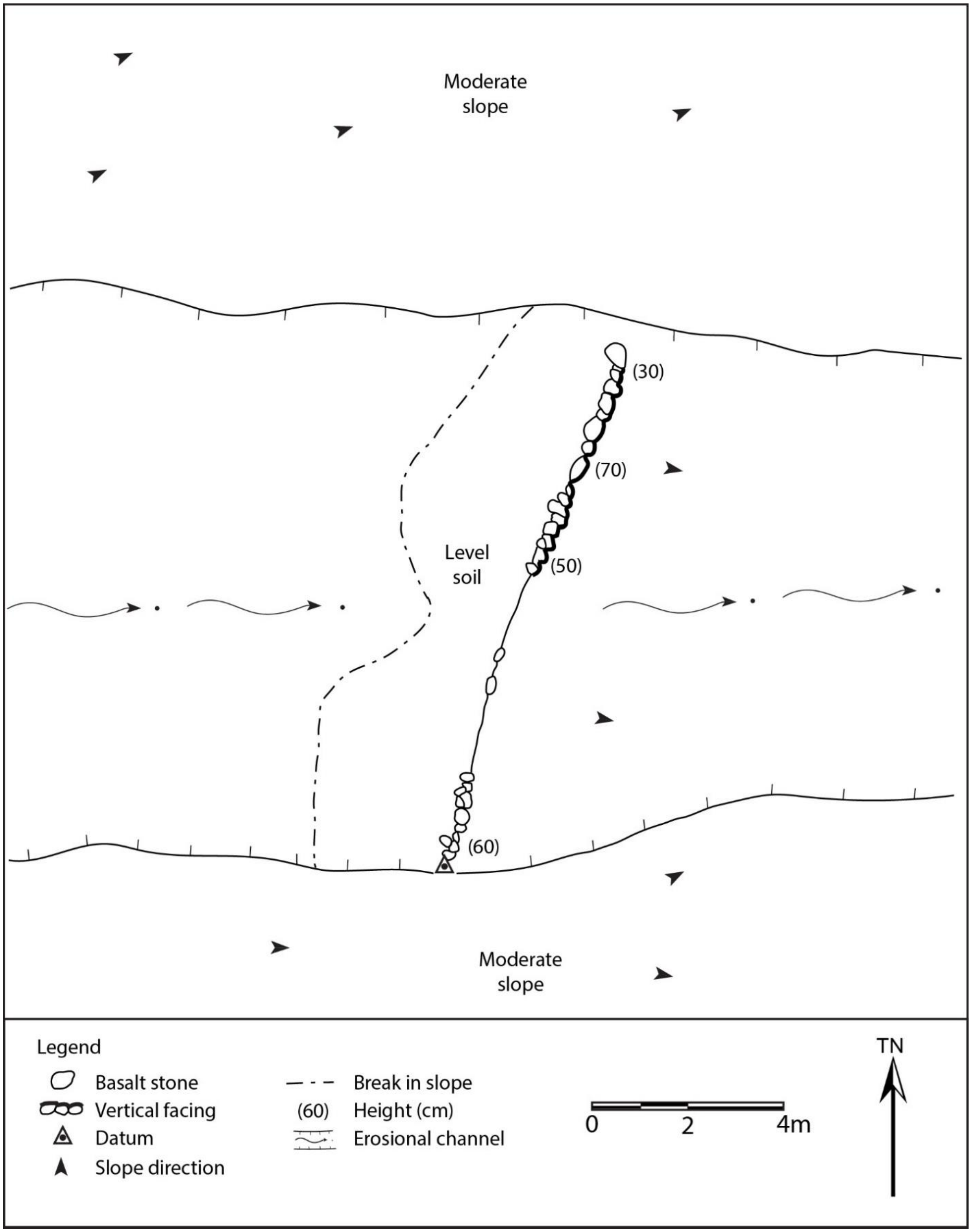

Figure 46. Plan-view map of SIHP 50-80-12-01975, Feature 5 terrace.

5.0 RESULTS OF LABORATORY ANALYSES

All materials collected during the course of test excavations conducted within the project area were transported to Pacific Legacy's Oʻahu Laboratory for processing, identification, and detailed analysis. Analysis of recovered materials included identification, labeling, and temporary curation.

5.1 ARTIFACT ANALYSIS AND FINDINGS

No artifacts were recovered from test excavations within the Makakilo Quarry Proposed Expansion Project Area, and no suitable materials for AMS radiocarbon dating were recovered from either test unit.

5.2 PALEOBOTANICAL ANALYSIS OF SOILS

Three sediment samples (MS1, MS2, and MS3) were collected from the south wall of TU-1, and two sediment samples (MS4 and MS5) from the north wall of TU-2. All three samples from TU-1 were submitted to Dr. Mark Horrocks at Microfossil Research, Ltd. for identification and interpretation of microfossils and other plant materials (e.g., phytolith, starch, and pollen) to help determine whether the five features of SIHP 50-80-12-01975 may have previously functioned as agricultural terraces. Sediment samples from TU-2 were not submitted and are temporarily housed in Pacific Legacy, Inc.'s laboratory.

Given their formal similarities and close spatial association, it was assumed that Features 1–5 likely all had the same function. As such, intensive soil testing at a single feature (Feature 2) within SIHP -01975 was determined to be the most appropriate sampling strategy for investigating the past function of these features.

Results of microfossil analysis provide evidence for previously disturbed, open vegetation, with identification of a single pollen grain of coconut (*Cocos nucifera*) in MS2 and a tentative identification of *kalo* (taro; cf. *Colocasia esculenta*) starch observed in all three samples (MS1, MS2, and MS3). Dr. Horrocks advised that the tentative *kalo* identification should be treated cautiously (see Appendix B). This microfossil evidence suggests that there may have been agricultural activity in the vicinity of the sampled deposits, though it cannot confirm that the microfossils identified were deposited as a result of *in situ* cultivation. It is possible that soil containing these microfossils was deposited later, during an erosional event or other soil transport activities. The concentrations of microscopic plant materials observed within the test units were lower than might be expected for agricultural soils. While the microfossil evidence for agricultural activities at SIHP -01975 is tenuous at best, the possibility cannot be entirely ruled out based on these results.

Table 5. Sediment Samples collected from Test Excavations for Further Analysis. Highlighted Samples were Submitted to Dr. Mark Horrocks for Microfossil Analysis

Lab No.	Site	Test Unit	Depth
MS1	Feature 2	Test Unit 1	48–50 cmbd
MS2	Feature 2	Test Unit 1	80–85 cmbd
MS3	Feature 2	Test Unit 1	55–60 cmbd
MS4	Feature 1	Test Unit 2	50–55 cmbd
MS5	Feature 1	Test Unit 2	30–35 cmbd

6.0 SUMMARY AND INTERPRETATION

The AIS for the Makakilo Quarry Proposed Expansion Project Area identified and recorded one previously identified historic property (SIHP 50-80-12-01975) and added four newly identified features to the site. SIHP -01975 is a complex of five soil-filled terraces with linear, basalt rock walls aligned roughly north-south across shallow, natural erosional drainages with level soil areas on their west (*mauka*) sides. The function of these features is not entirely clear, though the two most likely possibilities are either for agricultural use or for controlling the flow of water and sediments across the slope of Puʻu Makakilo. These two functions are also not mutually exclusive; a former agricultural terrace could easily be adapted into an erosional ditch feature. Agricultural use of SIHP -01975 is most likely to have occurred during the pre-Contact era, but may have continued during the early post-Contact period, prior to extensive land disturbance associated with ranching and commercial agriculture in the region. Stone ditch features may have been constructed at any time, though this practice was likely more relevant to commercial agricultural and ranching land use during the post-Contact period, as vegetation clearance likely accelerated erosional processes.

6.1 PRE-CONTACT SETTLEMENT AND LAND USE

If the five terrace features of SIHP -01975 were used to retain soil for agricultural purposes, this would likely have been a pre-Contact activity. Evidence in favor of this interpretation includes the overall terraced form of the features, test excavations at two of the features uncovering relatively loose sediment with few stone inclusions, and tentative identifications of coconut and taro microfossils in recovered sediment samples from Feature 2. However, it is unclear whether the level soil was deliberately created for the purposes of cultivation, or if it was incidentally created through soil retention caused by the placement of stone walls in the middle of erosional channels. Although the sediment within the test units was relatively loose and contained few stone inclusions, the reddish-brown color and high clay content of the soils are not necessarily conducive to agriculture. Further, one might expect to see a darker color in soils that had been under cultivation as a result of increased organic deposits. Finally, although starch grains recovered from all test units were tentatively identified as belonging to taro (*Colocasia esculenta*), these starches were highly degraded and their identification must be treated with caution. It is also possible that the identified microfossil remains were not deposited as a result of *in situ* cultivation, but rather carried in later by an erosional event (or other soil depositional process).

Taken together the evidence suggests the possibility of past agricultural activities that, while tenuous, cannot be ruled out entirely.

6.2 POST-CONTACT SETTLEMENT AND LAND USE

During the post-Contact period, the most common use of the lands inside and around the project area was for ranching. Historic maps and aerial photographs do not offer evidence for industrial agricultural activities, though large-scale commercial sugarcane agriculture was taking place on the nearby Ewa Plantation lands. The post-Contact features most likely to occur in the project area are those related to ranching activities, or infrastructure to protect the agricultural parcels located downslope from the project area. Post-Contact disturbance and removal of vegetation on the slopes of Honouliuli would likely have facilitated increased soil erosion. Deliberate management of the slopes in order to direct this sedimentation into favorable areas has also been observed (e.g., Frierson 1972). While these stone walls are currently observed as fronting soil-filled terraces, it is also possible that they were built as drainage ditches to direct the flow of water and/or sediment to desired areas. The level soil areas located immediately upslope of each feature may be incidental to their erosional control functions. In addition, Features 1 and 2 of SIHP -01975 both contain a set of two parallel alignments, roughly 1 m apart from each other, which may have served as a former drainage channel. It is also worth noting that the high levels of disturbance within the project area may have destroyed additional components of a post-Contact drainage system within and around the project area.

7.0 SIGNIFICANCE ASSESSMENTS

7.1 INTEGRITY

There are seven aspects of integrity. **Location** is the place where historic properties were constructed and **association** speaks to their relationship to one another and the physical environment, or **setting**. **Design, materials,** and **workmanship** refer to the built structures that comprise historic properties. **Feeling** is the historic properties' historic sense of a particular period of time.

7.2 SIGNIFICANCE

In accordance with Hawai'i State historic preservation rules governing private (non-governmental) projects, as outlined in Hawai'i Revised Statutes (HRS) 6E-42, archaeological historic properties which have been identified and inventoried within a project area must be evaluated for significance. Per Hawai'i Administrative Rules (HAR) Title 13 Chapter 284-6:

> To be significant, a historic property shall possess integrity of location, design, setting, materials, workmanship, feeling, and association and shall meet one or more of the following criteria:
>
> Criterion "a" Be associated with events that have made an important contribution to the broad patterns of our history;
>
> Criterion "b" Be associated with the lives of persons important in our past;
>
> Criterion "c" Embody the distinctive characteristics of a type, period, or method of construction; represent the work of a master; or possess high artistic value;
>
> Criterion "d" Have yielded, or is likely to yield, information important for research on prehistory or history; or
>
> Criterion "e" Have an important value to the native Hawaiian people or to another ethnic group of the state due to associations with cultural practices once carried out, or still carried out, at the property or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group's history and cultural identity.

7.3 ASSESSED SIGNIFICANCE OF HISTORIC PROPERTIES IN THE PROJECT AREA

The historic property that was identified during the AIS has been assessed for significance based upon one or more of the listing criteria as defined in Hawai'i Revised Statute §13-284-6. SIHP 50-80-12-01975 and its component features possess integrity in location, association, materials, and setting. SIHP -01975 is assessed as significant under Criterion "d", as it has yielded information about the use of Pu'u Makakilo in the past. This historic property is recommended for no further work.

8.0 PROJECT EFFECT AND MITIGATION RECOMMENDATIONS

8.1 PROJECT EFFECT

HAR §13-284-7 identifies two possible effect determinations, “no historic properties affected” and “Effect, with agreed upon mitigation commitments.” The purpose of this Archaeological Inventory Survey (AIS) is to identify and document all historic properties and assess their integrity and significance. Further, it identifies potential for the project to impact significant historic properties and provides agreed-upon mitigation commitments to address the identified adverse impacts. It provides detailed information on the location, character, and relative significance of the archaeological remains present within the survey area. Based on the findings of this AIS, the project effect is determined to be “effect, with agreed upon mitigation commitments.”

The present program of site recording was undertaken to gather information about historic properties in the project area, not to mitigate any adverse impacts to these archaeological remains. Significance assessments and mitigation commitments have been made to meet AIS requirements and are based on the integrity and significance of each property. SIHP 50-80-12-01975, which was re-identified during the AIS of the Makakilo Quarry Proposed Expansion Project Area, has been recommended for treatment. The category of treatment recommended is:

No Further Work
When a site is determined significant solely for its informational content, and that information has been adequately documented during the present archaeological inventory survey, no further work is suggested.

8.2 MITIGATION RECOMMENDATIONS

Through the present AIS, SIHP 50-80-12-01975 was documented as containing a total of five features within the project study area.

All five component features of SIHP -01975 will potentially be impacted by this project. This historic property is recommended for no further work, as all five of the features that make up this site have been thoroughly documented through the current AIS and further archaeological testing does not have potential to reveal additional information about the past at this historic property.

8.3 DISPOSITION OF MATERIALS

All field records (descriptions, notes, and photographs) resulting from the AIS have been temporarily housed in the Pacific Legacy Kailua, Oʻahu office. These will be provided to the landowner once all analysis and write-up has been completed. Long-term curation specifics will be determined by the landowner, per HAR 13-276-6(a).

9.0 CONCLUSION

The archaeological inventory survey (AIS) of the Makakilo Quarry Proposed Expansion Project Area, Honouliuli Ahupuaʻa, ʻEwa Moku, Island of Oʻahu, resulted in the re-identification and detailed recording of one previously identified historic property (SIHP 50-80-12-01975), and the addition of four newly identified features at this site, for a total of five features. These five features are soil-filled terraces that contain linear, basalt rock walls aligned roughly north-south across shallow, natural erosional drainages on the slopes of Puʻu Makakilo. The features are in fair to good condition and their functions are most likely associated with pre-Contact agricultural activities and/or post-Contact drainage and erosion control. Test units were excavated at two of the five features (TU-1, Feature 2 and TU-2, Feature 1). These test excavations determined that both Feature 1 and Feature 2 were composed of a set of two parallel rock walls spaced roughly 1 m apart. No suitable materials for AMS radiocarbon dating were recovered from TU-1 or TU-2. Three sediment samples from TU-1 were submitted for microfossil analysis. The results of microfossil analysis were largely inconclusive, though did offer some tentative evidence for taro cultivation and the presence of coconut palms in the soils recovered from the project area. Based on the findings of the AIS, the project effect is determined to be "effect, with agreed upon mitigation commitments." SIHP -01975 has been assessed as significant under Criterion d and recommended for no further work.

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APPENDIX A

Correspondence from SHPD regarding the Project

DAVID Y. IGE
GOVERNOR OF
HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
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DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESERVATION DIVISION
KAKUHIHEWA BUILDING
601 KAMOKILA BLVD., STE 555
KAPOLEI, HI 96707

October 17, 2022

IN REPLY REFER TO:
Project No.: 2022PR01199
Doc. No.: 2210LS20
Archaeology

Ms. Dawn Takeuchi-Apuna, Acting Director
Department of Planning and Permitting
City and County of Honolulu
Planning Division
Community Planning Branch
650 S. King Street
Honolulu, HI 96813
c/o Brandon Soo, brandon.soo@honolulu.gov

Dear Ms. Takeuchi-Apuna:

SUBJECT: **Chapter 6E-42 Historic Preservation Review –**
Conditional Use Permit (CUP) – 2007/CUP-91
Special Use Permit (SUP) – SP73-147
Makakilo Quarry, Makakilo – Expansion
Honouliuli Ahupuaʻa, Ewa District, Island of Oʻahu
TMK: (1) 9-2-003:074

This letter provides the State Historic Preservation Division's (SHPD's) HRS 6E-42 review of the proposed modifications to the current Conditional Use Permit (CUP) and Special Use Permit (SUP) to allow for expansion of the quarrying area of Makakilo Quarry located on Puʻu Makakilo. The SHPD received the project submittal via HICRIS on September 22, 2022, which included an HRS 6E Submittal Form, a summary of proposed modifications, a Pacific Legacy letter summarizing the project, an archaeological literature review and field inspection report (LRFI) (Swift et al., June 2022), construction plans, and photos of the project area. The project area comprises of a 15.6-acre portion of the 312-acre subject parcel.

According to the submittal, Grace Pacific, LLC is requesting modifications to their existing CUP and SUP to expand the quarry by approximately 15.6 acres on the northwest side of the current Makakilo Quarry footprint. The proposed expansion will provide Grace Pacific, LLC with access to high-quality rock for use in concrete and asphalt paving. The modifications to the current quarry permit would extend the permit 15 years beyond its current expiration of December 21, 2032 to December 21, 2047, modification of the existing operating hours from 6 a.m. to 6 p.m. for hot mix asphalt production and sales in the pit of the quarry 24 hours per day, 7 days per week. However, mining would continue to be restricted to daytime use only. In addition, Grace Pacific, LLC plans to expand the footprint of the Hot Mix Asphalt Plant within the existing quarry and install a new recycle sub-feed plant on the Quarry floor, adjacent to the B-Rock Finishing Plant.

A review of SHPD records indicates that an archaeological inventory survey (Mooney and Cleghorn, May 2008) for the Makakilo Quarry Expansion (TMK: (1) 9-2-003:018) was reviewed and accepted in a letter dated November 17, 2009. Due to the negative findings, the final report was submitted as an archaeological assessment (AA) report.

Pacific Legacy's LRFI report (Swift et al., June 2022) submitted in support of the expansion project identified five archaeological historic properties which included a concrete ditch running northeast to southwest located in a cleared area at the northwest corner of the project area (Temporary Site T-01), a terrace/retaining wall (Temporary Site T-02), a modified outcrop consisting of a few small boulders placed on top of natural basalt outcrop (Temporary Site T-03), a modified outcrop consisting of a few small boulders placed on top of natural basalt outcrop (Temporary Site T-04), and a retaining wall running north to south (Temporary Site T-05) which may represent a previously recorded

Ms Takeuchi-Apuna
October 17, 2022
Page 2

historic property (Site 50-80-12-01795). Swift et al. (June 2022) recommends that an archaeological inventory survey be completed to identify and document all historic properties prior to the expansion of the quarry.

At this time, SHPD has insufficient information to make a determination regarding the potential for the subject project to impact historic properties. **SHPD requests the following**:

1. Formally request an SIHP number for all significant historic properties within the project area.
2. Convert the archaeological LRFI report (Swift et al., June 2022) to an AIS report and revise the report to meet the requirements of HAR §13-276-5 and submit it to the SHPD for review and acceptance.

SHPD shall notify the City and County of Honolulu when the AIS report and any required mitigation plans are accepted, and the permit issuance process may proceed.

When completed, please submit the draft AIS report and associated submittal review fee ($450) to our office via HICRIS to Project No. 2022PR01199 using the Project Supplement option.

Please contact Susan A. Lebo, Archaeology Branch Chief, at Susan.A.Lebo@hawaii.gov for any matters regarding archaeological resources or this letter.

Aloha, *Alan Downer*

Alan S. Downer, PhD
Administrator, State Historic Preservation Division
Deputy State Historic Preservation Officer

cc: Jodie Cordero, jcordero@gracepacific.com
Krickette Pacubas, pacubas@pacificlegacy.com
Mara Mulrooney, mulrooney@pacificlegacy.com

APPENDIX B

Report from Microfossil Research, Ltd.

Microfossil Research

Dr Mark Horrocks
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7 March 2023

Plant microfossil analysis of archaeological samples from Makakilo Quarry, Oahu

Summary

The microfossils provide evidence of disturbed, open vegetation, and of Polynesian introduced *Cocos nucifera* (coconut) and possible cf. *Colocasia esculenta* (taro). Although the microfossil evidence suggests agricultural activity in the vicinity of the sampled deposits, it does not prove or disprove direct association with the deposits.

Methods

Three samples (1-3) were analysed for pollen, phytoliths, and starch to provide a record of past vegetation, environments, and human activity. Sample 3 had a different sampling location to the other two samples. Detailed methods of analysis are described in the Appendix.

Results and discussion

Pollen and spores

The samples contained very low concentrations of organic material, including charred plant remains. Sufficient pollen was preserved to allow meaningful counting. The assemblages were dominated by variable amounts of pollen of Cheno-Am and Poaceae (grasses) (Fig. 1). The former pollen type is from the Chenopodiaceae and Amaranthaceae, both comprising small trees, shrubs, and herbs, pollen of which is difficult to differentiate. These dominant pollen types suggest disturbed, open vegetation.

A single pollen grain of Polynesian introduced *Cocos nucifera* was identified in Sample 2 (Whistler 2009) (Fig. 1). Another introduction observed in a very small amount in this sample was Cichorieae, an herbaceous plant tribe. As the Hawaiian Islands have no indigenous members of the Cichorieae, this pollen type is presumably of the *Sonchus* genus, a probable accidental Polynesian introduction, or European-introduced *Taraxacum officinale* (dandelion) (Arthur Whistler, pers. comm.). Some of the Cheno-Am and Poaceae pollen could also be from modern introductions.

Phytoliths

Sufficient phytoliths were preserved in the sampled deposits to allow meaningful counting. The assemblages were dominated by bilobate and bulliform/elongate grass leaf phytoliths, with Samples 1 and 2 also having large amounts of saddle grass leaf phytoliths (Fig. 2). A paucity of saddle phytoliths in Sample 3 presumably reflects its different sampling location.

Starch and other plant material

One type of starch, observed in all samples, was tentatively identified in this study (in the pollen preparations). This type comprised small amounts of possible, degraded amyloplast (sub-cellular units specialised for starch grain synthesis and storage) fragments of the corm of Polynesian introduced cf. *Colocasia esculenta* (Fig. 2). Starch grain decay involves progressive loss of visibility in cross-polarised light, discoloration, expansion, distortion, and disintegration (Horrocks and Weisler 2006, Horrocks et al. 2007). Given the highly degraded nature of this possible starch material, the starch evidence should be treated cautiously.

Possible local agricultural and other human activity

Although microfossils of two Polynesian cultigens, namely *Cocos nucifera* and possible *Colocasia esculenta*, were identified in this study, the results do not necessarily prove that the sampled deposits had been directly subjected to agricultural activity or other disturbance-type human activity such as water reticulation (Fig. 1, 2). If the sampled deposits had previously undergone such activity, a higher concentration of microscopic plant material than observed could perhaps be expected. In addition, the microfossils observed could have been mixed with older material by erosion, percolation, bioturbation, or mechanical disturbance. Regarding specific human activity, the microfossil evidence thus suggests agricultural activity in the vicinity of the sampled deposits but does not prove or disprove direct association with the deposits.

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Appendix

Plant microfossil methods

Pollen analysis

Pollen analysis includes pollen grains of seed plants and spores of ferns and other plants. It provides insight into past vegetation and environments and in Polynesia can allow the differentiation of sediments deposited in pre-settlement, and pre- and post-contact times (Horrocks et al. 2012a, 2013). Pollen can also provide evidence for Polynesian introduced plants, for example *Aleurites moluccana* (candlenut tree), *Colocasia esculenta* (taro), *Cordyline fruticosa* (ti), *Cyrtosperma merkusii* (giant swamp taro), *Ipomoea batatas* (sweet potato), *Lagenaria siceraria* (bottle gourd), and *Morinda citrifolia* (Athens and Ward 1997; Horrocks et al. 2012a, 2012b, 2022, 2023, in press; Kahn et al. 2014; McCoy et al. 2016; Prebble et al. 2019; Handley et al. 2020; Horrocks and Thomas 2022; Flexner et al. in press).

The samples were prepared for pollen analysis by the standard acetolysis method (Moore et al. 1991, Horrocks 2020). For Samples 1 and 2, at least 100 pollen grains and spores were counted for each sample, and slides were scanned for types not found during the counts. Pollen was very sparse in Sample 3, with 34 pollen grains and spores counted.

Starch and other plant remains can sometimes be found in pollen preparations. Microscopic fragments of charred plant material are also extracted during pollen preparation, providing evidence of fire.

Phytolith analysis

Phytoliths are particles of silica formed in inflorescences, stems, leaves, and roots of many plants (Piperno 2006). Phytolith analysis compliments pollen analysis and can provide evidence for Polynesian introduced crops, such as *Musa* (banana) and *Broussonetia papyrifera* (paper mulberry) (Horrocks 2004; Horrocks and Rechtman 2009; Horrocks et al. 2012a, 2012b, 2013, 2023, in press; Kahn et al. 2014). Other types of microscopic biosilicates, notably diatoms, radiolarians, and sponge spicules, are extracted along with phytoliths during preparation. Diatoms are unicellular algae and have cell walls composed of silica; radiolarians are a type of amoeboid protozoa with siliceous skeletons; sponges are multi-cellular animals with skeletons often composed of siliceous spicules. Diatoms are found in aquatic and sub-aquatic environments; radiolarians and sponges are exclusively aquatic. Diatoms and sponges are found in both marine and freshwater environments; radiolarians are exclusively of marine origin.

The samples were prepared for phytolith analysis by density separation (Piperno 2006, Horrocks 2020). At least 100 phytoliths were counted for each sample, and slides was scanned for types not found during the counts.

Analysis of starch and other plant material

This analysis includes starch grains and other plant material such as calcium oxalate crystals and xylem (Pearsall 2015). Starch is the main substance of food storage for plants and is mostly found in high concentrations of microscopic grains in underground stems (e.g., tubers and corms), roots, and seeds. The grains are synthesised and stored in amyloplasts; sub-cellular units specialised for this function. Calcium oxalate crystals, comprising raphides which are needle-like and druses which are compound, are found in both the aerial and underground parts of many plant taxa. Xylem is a vascular tissue comprising elongated cells through which most of the water and minerals of a plant are conducted. Starch analysis can provide evidence from archaeological sites for Polynesian introduced starch crops, such as *Ipomoea batatas*, *Colocasia esculenta*, and *Dioscorea* spp. (yams), and European introduced plants such as *Solanum tuberosum* (potato) (Horrocks and Weisler 2006; Horrocks et al. 2007, 2012a, 2012b; Kahn et al. 2014, 2023, in press; Flexner et al. in press). As well as at archaeological sites, *I. batatas* and *C. esculenta* starch and associated material have also been identified in an offshore marine sediment core (Handley et al. 2020).

Advances in this method include the use of Fourier Transform InfraRed spectroscopy to positively identify degraded starch, often uncertain due to loss of distinguishing features, and the discovery of non-starch *Colocasia* microfossil types, namely shoot epidermal tissue and phenolic inclusions from the skin of the corm (Horrocks and Barber 2005; Horrocks et al. 2012a, 2012b, 2014, 2016, 2017; Kahn et al. 2014).

Starch and other remains were prepared for analysis by density separation and presence/absence noted (Pearsall 2015, Horrocks 2020). These remains can sometimes be found in pollen preparations, despite the harsh chemicals used in that procedure.

Fig. 1. Pollen percentage diagram from Makakilo Quarry, Oahu (+ = found after count).

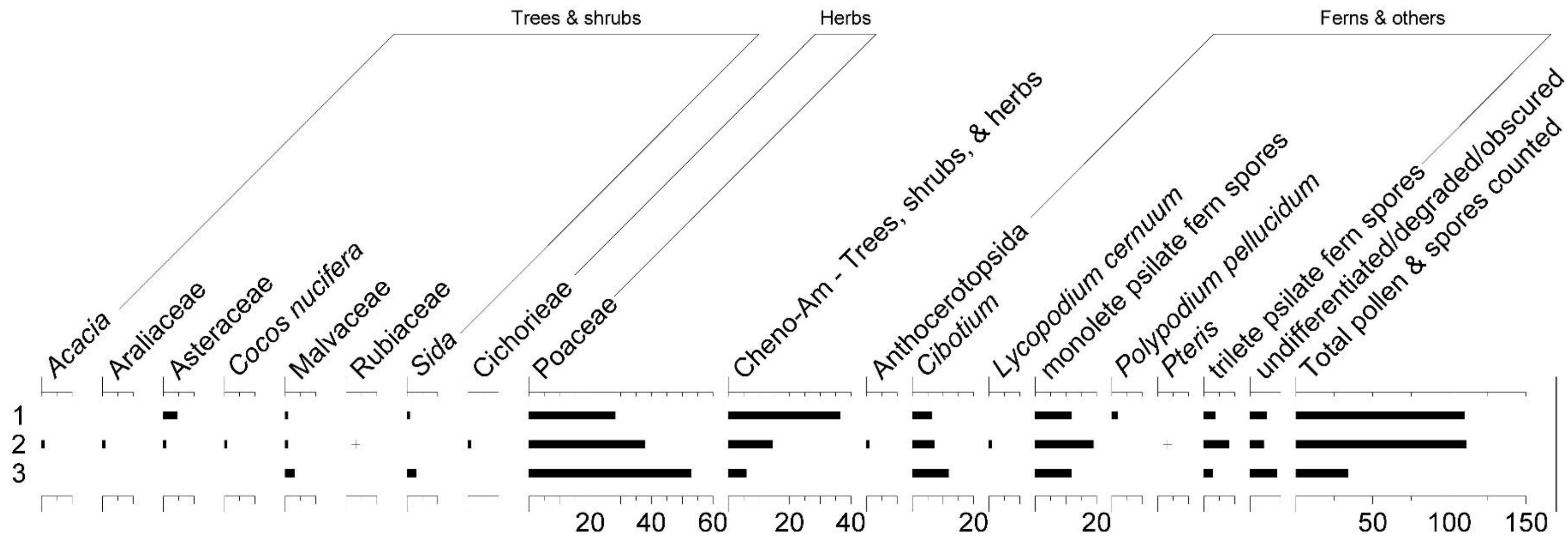

Fig. 2. Phytolith percentage and starch diagram from Makakilo Quarry, Oahu (++ = present).