DRAFT

Hāʻena State Park Master Plan

Appendices

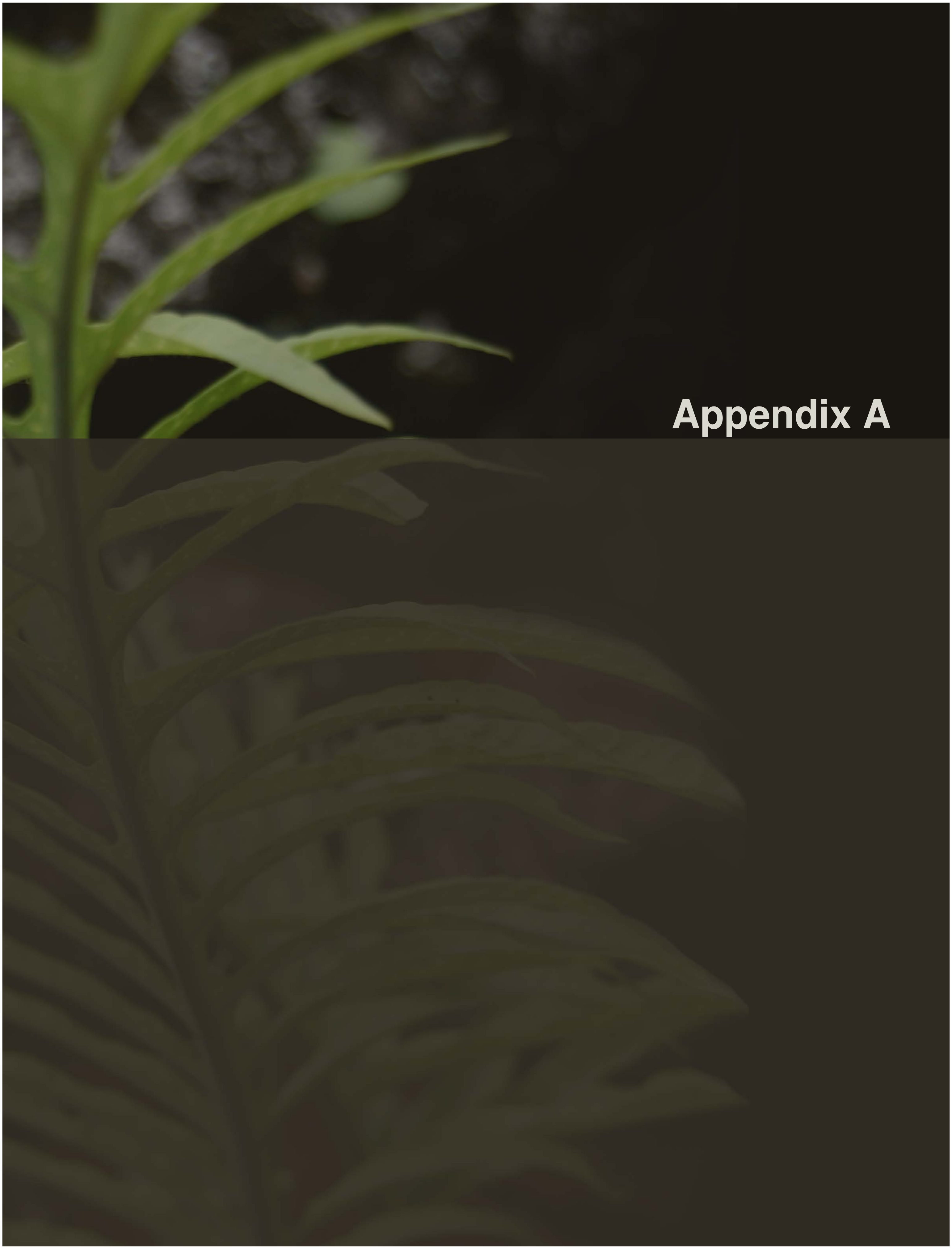
Prepared for

Department of Land & Natural Resources
Division of State Parks

Prepared by

PBR HAWAII
& ASSOCIATES, INC.

MAY 2018



Appendix A

STATE OF HAWAIʻI
Department of Land and Natural Resources

<u>Hāʻena State Park Master Plan Advisory Committee Members 2008-2015</u>

1., 2.	Thomas & Annie Hashimoto	Kupuna & Hāʻena ʻOhana
3.	Cathy Ham Young Pfeffer	Kupuna & Hāʻena ʻOhana
4.	Henrietta Phillips	Kupuna & Hāʻena ʻOhana
5.	Lono Brede	Hāʻena ʻOhana
6.	Presley Wann	Hāʻena ʻOhana
7.	Kehaulani Kekua	Kumu for Halau Palaihiwa O Kaipuwai
8.	ʻAikane Alapaʻi	Cultural Practitioner, Halau Palaihiwa O Kaipuwai
9.	Sabra Kauka/Victoria Wichman	Garden Island RC&D, Inc./Nā Pali Coast ʻOhana
10., 11.	Chipper and Hauʻoli Wichman	National Tropical Botanical Garden, Director and CEO, Executive Assistant to the CEO
12.	Jeff Chandler	Hui Makaʻāinana o Makana, President
13.	Kaimi Hermosura	Hui Makaʻāinana o Makana, VP
14.	Keliʻi Alapaʻi	Hui Makaʻāinana o Makana, ʻOhana Council Chair
15..	Naomi Yokotake	Hanalei Hawaiian Civic Club
16.	Carlos Andrade	UH Center for Hawaiian Studies
17.	Makaʻala Kaʻaumoana	Hanalei Watershed Hui, Exec. Director
18.	Kawika Winter	Limahuli Garden and Preserve, Director
19.	Barbara Robeson	Hanalei Roads Committee
20.	Caren Diamond	Protect Our Neighborhoods ʻOhana
21.	Carl Berg	Surfrider Foundation
22.	Carl Imparato	Hanalei - Hāʻena Community Association
23.	Sue Kanoho	Kauaʻi Visitors Bureau
24.	Julie Schuller	Princeville Community Association
25.	Joel Guy	Kauaʻi North Shore Business Council
26.	Mehana Vaughn	Doctorate Student
27.	Chino or Micco Godinez	Kayaks Kauaʻi
28.	Kathryn Keala	Office of Hawaiian Affairs, Oʻahu Office
29.	D. Kaliko Santos	Office of Hawaiian Affairs, Kauaʻi Ofice
30.	Michael Dahilig	County of Kauaʻi, Planning Dept., Director
31.	Atta Forrest	Makai Watch Coordinator

Hāʻena State Park Community Advisory Committee
Charter and Guiding Principles

HSPCAC Overview

Purpose

The Hāʻena State Park Community Advisory Committee (HSPCAC), is a self-directed, voluntary alliance of individuals representing ʻohana, agencies, organizations, and businesses desiring to protect and perpetuate the natural and cultural resources of Hāʻena State Park, and to serve as an advisory body to the DLNR as the State develops and then implements a Master Plan for this sacred area that is of utmost importance to the community of Kauaʻi.

Vision

The HSPCAC envisions Hāʻena State Park as a place where a diverse community leads management of the land and resources in a pono manner that honors the community's ancestors and the Hawaiian values that they passed down to us.

Mission Statement

The mission of the HSPCAC is to advise the DLNR and engage with the larger community in the process of developing the Master Plan for HSP, and to be the lead group that will assist the DLNR with a community-based adaptive management process that will be essential to the long-term implementation of the Master Plan.

Scope & Functions

The HSPCAC will fulfill its mission by taking the following actions:

- Recruiting an appropriate number of community members who are committed to the Vision and Mission and who pledge to be active and responsible members of the Committee.
- Conduct regular HSPCAC meetings to review and amend the Draft Master Plan (DMP).
- Conduct a community consultation process to review the proposed changes to the DMP.
- Monitor the effectiveness of the MP as it is being implemented and recommend changes as needed to ensure a proper balance is maintained in the Park (things are pono).
- Effectively share what is discussed and decided at HSPCAC meetings with members of their extended ʻohana and the larger community.
- Enable collaborative projects and efficient resource use with DLNR.

HSPCAC Organization

HSPCAC Membership
Membership is voluntary and non-binding and does not create legal or financial obligation on behalf of any individual or the ʻohana, agency, organization, or business they may represent. New members may be invited to join the HSPCAC only after a vote of existing members.

Member Eligibility
Membership is open by invitation to any individual representing any ʻohana, agency, organization, or business committed to fulfilling the Vision and Mission of the HSPCAC.

Member Expectations
- Support the mission, vision and activities of the HSPCAC.
- Commit to working collaboratively and with respect for differing views.
- Participate in meetings with aloha, and maintain aloha through disagreements.
- Strive to achieve consensus.
- Attend meetings regularly.
- Communicate effectively via email or phone when needed.
- Sign a copy of this Charter as an indication of commitment to the HSPCAC.

Relationship of Past Members to the HSPCAC
In the event an individual chooses to leave the HSPCAC, or is removed for nonparticipation, that person's name and association with the HSPCAC and Hāʻena State Park Master Plan will be reflected historically, but shall not be used by either the HSPCAC or the State in the context of endorsing any current or ongoing work of the HSPCAC.

Network Governance
A Coordinator will provide leadership, set meeting dates, develop agendas, and document attendance and participation of HSPCAC members.

Terms
HSPCAC members will serve with no term limits.

Sub-Committees and Working Groups
The HSPCAC may establish Sub-Committees and/or Working Groups to accomplish the HSPCAC goals and complete projects as needed.

Staff
The HSPCAC does not have any staff or financial resources. It will not be staffed by DLNR, but will strive to use its volunteers to conduct HSPCAC business.

HSPCAC Operations

Meetings and Attendance

- During the DMP review and amendment phase, the HSPCAC expects to hold meetings at least twice monthly and more often as needed.
- During the community consultation phase, the HSPCAC expects to hold small group or large group meetings as needed but likely 2-3 per month.
- During the long-term monitoring and MP implementation phase (ongoing) the HSPCAC expects to hold regular member meetings at least twice yearly or as often as needed.
- CAC members may be removed from the HSPCAC if they are not active. Any member who does not attend three consecutive meetings and does not provide communication as to why he/she can't participate will be removed from the active roster.
- Any member who does not attend four consecutive meetings, regardless of whether or not an excuse was provided, may be dropped from the active roster.
- Members who are to be dropped from the active roster for non-participation will first be contacted by the HSPCAC leadership to advise them of the action. Dropped members may reapply.

Decision Making

HSPCAC members will make decisions by consensus whenever possible. There is no required quorum, but decision-making will be as inclusive as possible. If unable to attend, Members should be consulted and accommodated as is reasonable. When the HSPCAC is unable to reach consensus, a summary of the supporting and opposing sentiments / concerns will be compiled and approved by the HSPCAC so as to communicate the breadth of community opinion.

Evolution of the Charter

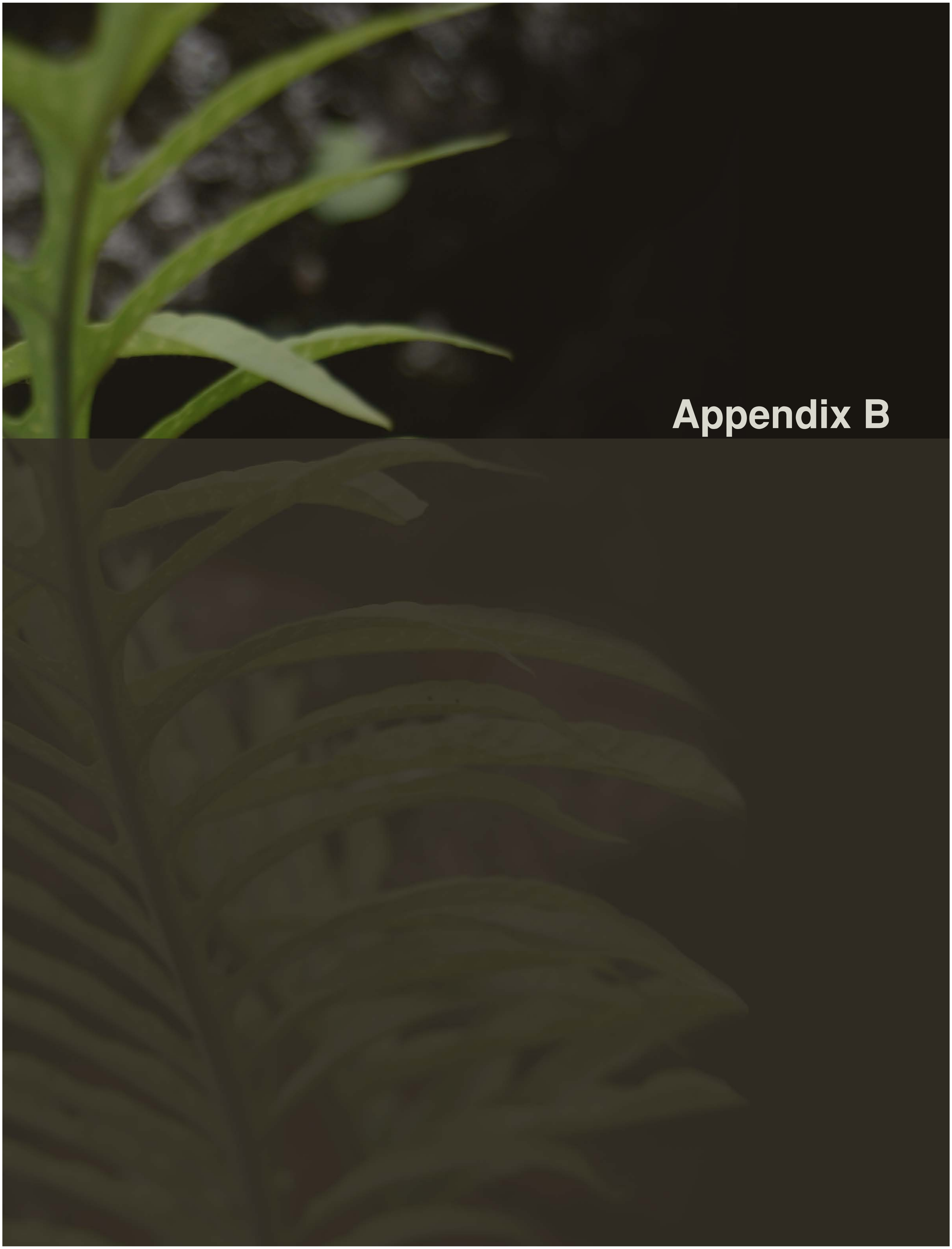
HSPCAC members may determine that this charter needs revising as the HSPCAC evolves.

Language approved by HSPCAC on November 22, 2015 and formally affirmed by the following members:

HSPCAC Members on 22 November 2015

1. Keliʻi Alapaʻi	Hāʼena ʻohana, Hui MoM
2. Carlos Andrade	Hui MoM
3. Carl Berg	Surfrider Foundation
4. Lono Brede	Hāʼena ʻohana
5. Laverne Brede	Hāʼena ʻohana
6. Hoku Cabebe	Hāʼena ʻohana
7. Caren Diamond	Protect Our Neighborhoods ʻOhana
8. Atta Forrest	Hāʼena ʻohana, Hui MoM
9. Devin Kamealoha Forrest	Hāʼena ʻohana
10. Hayley Ham-Young Giorgio	Hāʼena ʻohana
11. Chino Godinez	Kayaks Kauaʻi
12. Micco Godinez	Kayaks Kauaʻi
13. Joel Guy	Kauaʻi North Shore Business Council
14. Anne Hashimoto	Kupuna, Hāʼena ʻohana, Hui MoM
15. Tom Hashimoto	Kupuna, Hāʼena ʻohana, Hui MoM
16. Carl Imparato	Hanalei - Hāʻena Community Association
17. Makaʻala Kaʻaumoana	Hanalei Watershed Hui
18. Noah Kaaumoana-Texeira	Hāʼena ʻohana, Hui MoM
19. Sue Kanoho	Kauaʻi Visitors Bureau
20. Sabra Kauka	Nā Pali Coast ʻOhana
21. Kehaulani Kekua	Kumu for Halau Palaihiwa O Kaipuwai
22. Koral McCarthy	Hāʻena ʻohana
23. Henrietta (Etta) Phillips	Kupuna, Hāʼena ʻohana, Hui MoM
24. Kaliko Santos	OHA - Kauai Community Outreach Coordinator
25. Julie Schuller	Princeville Community Association
26. Mehana Vaughn	UH Professor, Hui MoM
27. Presley Wann	Hāʼena ʻohana, Hui MoM
28. Lei Wann	Hāʼena ʻohana, Hui MoM
29. Chipper Wichman	Hāʼena ʻohana, Hui MoM
30. Hauʻoli Wichman	Hāʼena ʻohana, Hui MoM
31. Kawika Winter	Limahuli Garden, Hui MoM
32. Naomi Yokotake	Hāʼena ʻohana, Kumu Hula
• Johanna Ventura	Waipa, community facilitator

Appendix B



I. INTRODUCTION

A. Project Location and Description

Haena State Park is located on the north shore of Kauai, at the end of Kuhio Highway. It is bounded by the Na Pali Cliffs to the west, the base of Makana to the south, Limahuli Stream to the east and the Pacific Ocean to the north.

There are three (3) TMK parcels within the Park boundary. The parcel north of Kuhio Highway is identified by TMK 5-9-008:001 and encompasses approximately 52 acres. South of Kuhio Highway, parcels TMK 5-9-001:022 and 025 encompass approximately 180 acres.

The parcels identified by TMK 5-9-008:001 and 5-9-001:022, are owned by the State of Hawaii. The third parcel, TMK 5-9-001:025 contains the Kauluapaoa Heiau and Keahualaka hula platform, is owned by the County of Kauai and managed by the State Historic Preservation Division (SHPD), Department of Land and Natural Resources (DLNR). Haena State Park utilizes approximately 65.7 acres of the coastal area for recreational uses.

The Park experiences heavy usage throughout the week and is considered one of the highest utilized parks in the State. It is used by the public for picnics, snorkeling, swimming and hiking. It is estimated approximately 708,400 visitors experienced the many geological and cultural features of this unique park in 2007.

II. EXISTING SITE CONDITIONS

A. Soils

Based on Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii, five soil classes are present at Haena State Park. Its western coastline consists of Mokuleia fine sandy loam (Mr), while its northern coast is defined as Beach (BS). Marsh (MZ), Hanalei silty clay (HnA) and Hanalei silty clay with deep water table (HrB) are present further inland.

Beach soil extends up to 150 feet inland from the northern coast. This soil consists of light-colored sands resulting from the breakdown of coral and seashells.

Mokuleia fine sandy loam extends up to 800 feet inland from the western coast. Its surface layer contains 16 inches of fine sandy loam and its subsurface contains 34 to 48 inches of single-grain and loamy sand. This soil exhibits moderately rapid permeability in its surface layer and rapid permeability in its subsurface.

Marsh soil is present approximately 800 feet inland from the western coast of Haena State park. This soil type covers small, low-elevation areas where water

stands at the ground surface. Grasses, bulrushes and other herbaceous plants thrive in these areas.

Hanalei silty clay (HnA) soil is present in the western and inland portions of the Park. Its surface layer contains 13 inches of dark-gray, silty clay, of which the top 10 inches contain brown and red mottles. Its subsoil contains 13 inches of dark-gray and dark grayish-brown silty clay loam. The water table in this soil type is typically less than 3 feet below the ground surface. This soil experiences moderate permeability and is strongly acidic in its surface layer.

Hanalei silty clay with deep water table is present in the eastern and inland portions of the Park. This soil is similar to Hanalei silty clay; however it contains fewer mottles and is located in areas where the water table is greater than 3 feet below the ground surface.

Soil test borings and percolation tests were not performed specifically for this preliminary engineering report. Instead, the previously performed percolation test results at the existing comfort station are referenced to preliminarily size the disposal fields. A percolation rate of 4.14 minutes/inch was obtained in December 2009 for the constructed wetland project at the existing Ke'e comfort station.

B. Topography

The ground elevation in the area north of Kuhio Highway ranges from approximately 70.0 feet above mean sea level (MSL) at the entrance to the Park to sea level at the coast line. This area is where the majority of recreational and cultural activity and usage is currently occurring as the area is relatively level.

The ground elevation south of the Kuhio Highway rises sharply with steep slopes and forms the cliffs of Na Pali, beyond the shoulder of the roadway.

The 100-year base flood elevation ranges from sea level to elevation 24.0 feet above MSL.

C. Site Access, Roadways, Parking and Safety

Kuhio Highway is owned by the State of Hawaii, Department of Transportation (DOT) and provides the only access to and through Haena State Park. Prior to entering the Park, Kuhio Highway is a two lane roadway with gravel and AC pavement shoulders. Entry to the park requires crossing Limahuli Stream over a single lane, 10-foot wide x 12-foot long x 12-inch thick concrete bridge. Past the bridge, Kuhio Highway again becomes a two lane road, measuring approximately 24 feet wide, and continues approximately 0.5 miles to the end of the park at Ke'e Beach. The actual pavement structure within the roadway is not known, but is assumed to be a minimum of 2-1/2 inches of AC pavement over 8 inches of base course. It is in fair condition with some cracking and potholes in concentrated areas.

The paved shoulder lanes were added in 1985 under DOT Project No. 560A-01-86M, which resurfaced approximately 1.43 miles of Kuhio Highway. The guardrails were added in 2002 under DOT Project No. 560A-03-99 because the steep slopes on either side of Kuhio Highway and winding roads posed a threat to driver's safety. Kuhio Highway continues in an east-west direction through the southern portion of the Park until its termination at Ke'e Beach. The 2.0 foot shoulder pavement structure consists of a minimum of 1.5 inches of AC pavement over 6 inches of base course.

Figure 1: Haena State Park Entrance Crossing Limahuli Stream

Currently, pedestrian access to Haena State Park is limited. Within the Park, there are no pedestrian walkways along Kuhio Highway. Pedestrians typically walk on the side of the road or in the paved shoulder lane. However, there are many areas where rock slopes, vegetation, and/or guard rails force pedestrians to walk in the paved vehicular lanes.

Although a few hiking trails are scattered around the south areas of the site, there is only one marked pedestrian trail along the coast area traversing within the Park. It is an approximately 10-foot wide dirt trail beginning at the end of Kuhio Highway. The path is delineated with logs. The trail was intended to lead to other areas of the Park along the shoreline, but overgrown vegetation and fallen trees have blocked the path beyond the existing comfort station. Observations reveal visitors tend to walk in a direct path between the end of the paved road and the beach, in lieu of the dirt trail and do not venture into the overgrown areas.

Bicyclists encounter the same dangers as pedestrians due to similar reasons. There are currently no designated biking lanes or pathways in Haena State Park.

There are two authorized parking areas within Haena State Park, one approximately 800 feet from the entrance to the Park and one at the end of Kuhio

Highway. The parking lot near the entrance to the Park consists of a dirt and gravel clearing, approximately 30,000 square feet (sf) in area with a 12-foot wide driveway entrance from Kuhio Highway. The parking area is approximately 3.0 to 4.0 feet below the highway. Parking stall markings are non-existent and their absence causes inefficient usage of the designated parking areas. The parking area near Ke'e Beach is off-street parking, consisting of an approximately 10-foot wide cleared dirt strip to the north and south of Kuhio Highway. Although two parking areas are available, there is a shortage of parking stalls during high usage. Limited parking exacerbates the pedestrian and bicyclist safety problem. Currently, "No Parking" signs are present throughout Haena State Park along Kuhio Highway. However as parking fills up within the designated areas, visitors disregard posted signs and park in "No Parking" zones along the shoulder lanes. These vehicles force pedestrians to walk in vehicular lanes.

A helicopter landing area is currently located to the east of the gravel parking lot. The area is grassed, fenced and well maintained. Typically, it is used for emergency rescues and fires.

D. Drainage and Stormwater Management

The coastal areas of Haena State Park are located within the 100 year flood plain. Also, most of the Park is classified as estuarine and marine wetlands.

The only perennial stream within the Park is Limahuli Stream, but during periods of heavy rainfall, there are several intermittent streams flowing north through natural swales in the Park. During these times, storm water runoff is typically full of sediment, soil, stream fish, logs, plants and other debris material. The runoff creates a muddy plume at the stream outfall, but is part of the naturally occurring drain pattern in Haena State Park.

Drainage improvements on the site consist of five 18-inch RCP drain culverts that allow storm water to cross beneath Kuhio Highway from south to north. It is estimated approximately 56.8 cubic feet per second (cfs) and 37.9 cfs of runoff from approximately 14.2 acres above Kuhio Highway flows down Maunahou into the five culverts, during the 10-year and 2-year storm, respectively. See Appendix A for drainage calculations. Three 3'x4' drain inlets are located on the south edge of the roadway to collect runoff originating from the south and discharge through endwalls located along the north edge of Kuhio Highway. The other two culverts have concrete headwalls located on the south edge of the road and discharge through endwalls located immediately north of Kuhio Highway. The drain culverts satisfy the requirements set forth in the County of Kauai Department of Public Works Storm Drainage Standard.

The remainder of the site discharges stormwater runoff directly into the Pacific Ocean. It is estimated that approximately 7,300 cfs of runoff flows directly to the ocean during a 50-year storm. This includes the runoff from the west end of Maunahou that flows over Kuhio Highway and the entire area of the Park below Kuhio Highway. During heavy rain storms the entire Park is inundated with rushing waters from this surge of rainwater. The existing drainage improvements do not have the capacity and were not designed to handle the larger storm events.


Figure 2: Typical Existing Drain Inlet along Kuhio Highway
Figure 3: Typical Existing Drain Outlet along Kuhio Highway with 3" Water Line and ¾" Telephone Lines

E. Water System

1. Potable Water

The Kauai Department of Water provides potable water to the site through a 4-inch PVC water line that terminates at the entrance to the Park with a 1-inch water meter (Water Meter No. 083000140). Water is gravity fed from a 0.1 million gallon (MG) reservoir 1.1 miles away, located at ground elevation 126.5 feet above MSL. The spillway elevation is at 144 feet above MSL. In 1996, a standpipe pressure test was conducted by the Kauai Department of Water near Limahuli Stream. The test revealed a static pressure of 27 pounds per square inch (psi) and a 6 psi residual pressure at 103 gallons per minute (gpm) on the 4-inch pipe.

Within Haena State Park, a 3-inch galvanized iron pipe runs along the edge of Kuhio Highway in an east-west direction until its terminus at the Ke'e beach comfort station. Most of the 3-inch galvanized iron pipe within the Park is installed above ground. Buried pipe depths are unknown, but assumed to have a minimum cover of 3.0 feet. Existing 2-inch and 1-inch water laterals are assumed to have 1.5 feet of cover. At the parking lot entrance, the 3-inch water line is embedded under 1-inch of AC pavement.

Recorded water usage from October 2003 to November 2006 is documented to average 2,125 gallons per day (gpd).

At the comfort station, the existing water fixtures are currently being replaced under DLNR Job No. H10C663A with the following:

1. 2" PVC water lateral serving 3 water closets, 1 urinal, 2 lavatories, 1 drinking fountain with a drywell, and 2 hose bibs

2. 1" PVC water lateral serving an outdoor shower

These improvements were under construction in September 2008, but have since been completed. It is anticipated these new fixtures will decrease water demands by 4 gpm.

Figure 4: Ke'e Beach Comfort Station and Existing Leach Field Location

There is no fire protection water system within the Park. If needed, bucketing seawater is used. The last fire hydrant/standpipe on the potable water system is outside of the Park, 75 feet away.

2. Non-Potable Water

A non-potable, irrigation, gravity fed HDPE pipe diverts an average of 760,000 gpd of water from Limahuli Stream. The diversion was installed south of Kuhio Highway and discharges into the taro patches north of Kuhio Highway and west of the parking lot. The irrigation water line begins as an 8-inch HDPE line at elevation 95.9 feet above MSL and transitions to a 6-inch HDPE line at elevation 57.5 feet above MSL. It crosses Kuhio Highway through one of the 18-inch RCP drain pipes.

F. Wastewater System

The original comfort station at Ke'e Beach was constructed in 1979 under DLNR Job No. 54-KP-11. It consisted of 3 water closets, 1 urinal and 2 lavatories. These fixtures drained into a 6.0 to 8.0 foot diameter cesspool, approved by DOH.

In 2001, the cesspool was replaced by a 2,500 gallon septic tank and approximately 2,700 square foot (sf) leach field located to the north and east of the comfort station. Record drawings for the construction of the individual wastewater system replacement were not available.

In 2008, the existing comfort station was demolished and replaced, under DLNR Project No. H10C663A. The new comfort station retains the same fixture count as its predecessor; 3 water closets, 1 urinal and 2 lavatories, which is estimated to generate 2,016 gpd.

The outdoor shower is located to the south of the comfort station. Greywater from the showers is allowed to drain and infiltrate into the surrounding soils.

In the Fall of 2010, the wastewater system for Ke'e Beach comfort station will be modified and upgraded to add a subsurface constructed wetland to further treat and improve water quality of the wastewater before discharging into the ground, at the request of the community. The planned system consists of 4-inch diversion valves and piping; 2-1,500 gallon primary treatment fiberglass tanks with battery-operated alarm control and panel; 968 sf of constructed wetland and 1,358 sf of infiltration field and appurtenances. The existing septic tank and leach field will continue to serve as an emergency backup system in the event the constructed wetlands system goes down.

Electric power is currently not available anywhere within Haena State Park and has been a limiting factor in the development of other wastewater treatment options.

In addition to the existing wastewater system for the comfort station, an abandoned cesspool was found at the old house site near Limahuli Stream. The existing Allerton House and Caretaker's cottage should also have abandoned cesspool(s). If any of these facilities are renovated the wastewater systems should also be upgraded or abandoned completely.

The comfort station renovation drawings call for the installation of a 30-inch diameter drywell to service a relocated drinking fountain near Ke'e beach. This drywell was not constructed as of September 2008.

G. Electrical and Communication

There is no electrical service currently available on-site. Service stops at the entry to the Park.

A ¾-inch telephone line runs along the same alignment as the 3-inch water line. It services a payphone and an emergency phone at the end of the Park, near the existing comfort station.

H. Solid Waste

Trash receptacles and recycle bins are available and maintained in the Ke'e beach area.

III. MASTER PLAN IMPROVEMENTS

A. Site Access, Roadways, Parking and Safety

The Master Plan greatly improves the safety and experience of the Park for visitors by closing down Kuhio Highway beyond the existing parking lot. By allowing only emergency and maintenance vehicles beyond this point, pedestrians and bicycles can safely navigate the Park and enjoy its beauty without having to co-exist with vehicular traffic.

The proposed Plan also provided for a delineated parking areas and controlled access. The existing parking lot should be raised, leveled, stabilized and resurfaced with a pervious, geogrid surface to allow for drainage while not increasing runoff. It should be striped to maximize parking spaces and control traffic flow.

Well marked, stabilized pedestrian trails are proposed throughout the Park to provide access and visual appreciation to cultural sites, while protecting these significant sites from being disturbed. These trails, like the parking lot should be stabilized with a geogrid base.

The helicopter pad will remain where currently sited. No planned improvements are anticipated.

B. Recommended Areas for Development

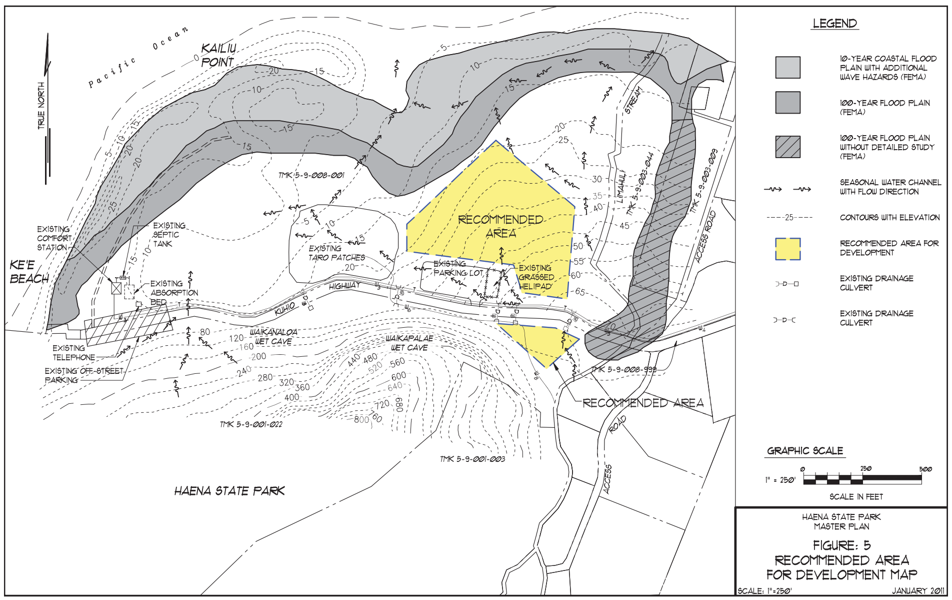
Areas recommended for development are based on avoiding existing low-lying and coastal areas subject to flooding and utilizing areas where the terrain is sloped less than 10% to avoid massive excavation. These areas include:

1.) The 100-year flood zone, which reaches elevations of 18 feet along the coastline, and
2.) The coastal 10-year flood zone with wave velocity hazards, which reaches elevations of 21 feet.

In addition, interior areas with elevations less than 15 feet above mean sea level and areas adjacent to stream flood plain zones were eliminated.

However, the location of Limahuli stream within the previous Master plan and on TMK maps differs from the location shown on FEMA maps, the Kauai Online Hazard Assessment (KOHA) database, and the Hawaii National Flood Insurance Program (NFIP) database. The Department of Land and Natural Resources (DLNR) is currently working out this issue with the Environmental Protection Agency (EPA) Region 9. Until this issue is resolved, it is not recommended that development be considered in the vicinity of Limahuli Stream.

Figure 5 shows the limited area where these conditions apply and development can occur.



C. Drainage and Stormwater Management

Due to the minimal land disturbances recommended within the Park, the drainage systems will not be significantly affected. However, drainage discussions with the community included:

1. Restoration of the auwai (natural drainage patterns) where possible, including the one that flowed alongside Kuhio Highway, through the existing parking lot. This system is shown to be relocated north of the parking lot on the Master Plan;

2. Utilizing bioswales to define drainage courses and direct runoff away from proposed improvements and cultural sites; and

3. Reconfiguration of existing drainage inlets to a more natural state as done by the old Hawaiians. A natural state can be created by lowering the grates and lining it with stones. This should not create a traffic hazard because traffic along the interior roadway will decrease after implementation of the master plan. Pipe bollards should be placed around depressed inlets to warn pedestrians and maintenance traffic.

During moderate to heavy rainfall, stormwater management becomes very difficult. The wetland and lois typically serve as natural retention basins, but during surges of runoff, there is no way to protect coastal waters from sediment and debris. Constructed green spaces, native plants, bio-retention cells and bio-swales can be used to help minimize the amount of stormwater and sediment leaving the site.

Haena State Park contains many ephemeral streams that flow only after moderate rainfall. The courses of these streams vary and are not delineated on available maps. If the addition of impervious area is minimized, diversion of stormwater around buildings should have a minimal effect on ephemeral streams.

D. Water System

1. Potable Water

The existing 3-inch water main with the Park should be sufficient for the proposed Master Plan as the population and activities within the Park will not increase. Relocation and maintenance of the water system may be required during the design phase, including adding backflow preventers.

2. Non-Potable Water

The use of non-potable water for irrigation and other possible alternatives is highly recommended. Beside the use of stream water, water reclamation from treated wastewater and greywater as well as rainwater catchment systems could support non-potable water needs. These alternatives should be explored during design.

E. Wastewater System

The proposed wastewater system is discussed under a separate cover, Wastewater Preliminary Engineering Report for Haena State Park Master Plan, dated November 2010. Recommendations are summarized as follows:

During the community meetings, it was agreed that any proposed wastewater system should treat the wastewater effluent for potential reuse, to protect the grounds and surrounding environment of the Park from any on-site disposal. It is believed by being good stewards of the Park, the environment will be preserved for future generations.

Therefore, at a minimum, aerobic treatment units with absorption beds should be considered. Beyond this, water resource management and reuse options should be seriously taken into consideration during design.

Also discussed at the community meeting were the following to be considered in the design:

1. Providing R-2 water quality effluent at the Orientation and Cultural Center, with additional treatment for reuse.
2. Placing the absorption bed under the parking lot to provide separation of effluent from ground water and avoid contamination of the loi patches.
3. Providing aeration to the existing constructed wetlands primary treatment tanks through the use of a photovoltaic system.
4. Considering compost toilets only for low usage areas, if at all.

F. Electrical and Communication

Electrical service currently terminates at the entrance to Haena State Park. In order to provide electrical service to the new Orientation and Cultural Center, approximately 1,000 feet of overhead electrical line must be installed. Kauai Island Utility Cooperative (KIUC) provided a budgetary construction cost of $33,000 to install 1,000 feet of 1-phase, 2-wire primary conductor that will service the Orientation and Cultural Center (cost is KIUC cost only and does not include connections to the building). 3-phase service terminates at Hanalei and is not feasible for this project.

Due to the winding nature of Kuhio Highway, overhead electrical poles will require anchoring at all corners. Easements will need to be granted to KIUC before the line extension can be executed.

We recommend overhead electrical power be extended from the Park entrance to the Orientation and Cultural Center. Beyond that point, photovoltaic systems and other sustainable power sources should be utilized.

APPENDIX A

CALCULATIONS

Kennedy/Jenks Consultants

By Michael Bungcayao Date 11/16/10 Project Haena State Park MP Project No. 1000711*00

Checked By Ramon Sera Date 11/17/10 Sheet 1 3

Find:

Flow entering the five (5) existing culverts, crossing Kuhio Highway within Haena State Park (2-year, 1-hour storm and 10-year, 1-hour storm)

References:

1. County of Kauai – Department of Public Works – Storm Drainage Standard, February 1972
2. County of Kauai – Department of Public Works – Storm Drainage Standard, July 2001*

*Section references within calculations refer to the July 2001 edition unless otherwise noted.

Assumptions:

1. Run-Off coefficients (Attachment 2) were calculated from the February 1972 version for a conservative, representative estimate.
2. Assume watercourse slope = 50%
3. Intensity of the 10-year storm was calculated from the February 1972 version. Intensity of the 10-year storm not provided in Reference 2.

Calculation:

Drainage Area = 14.17 Acres (Local Drainage System) [§ 1.7(m)]
Although Tm = 2 years per Reference 2, [§ 3.3(c)(1)]
Q will be calculated for both Tm = 2 years and Tm = 10 years
Also, Rational Method shall be used (Q = CIA) [§ 3.3(d)(1)]
Where:
Q = Flow Rate, in cubic feet per second
C = Runoff Coefficient
I = Rainfall Intensity, in inches per hour for a duration equal to time of concentration
A = Drainage Area, in acres

Run-Off Coefficient, C (Attachment 2): [See Assumption 1]
For all zones –

Moderate Infiltration	0.07
Extreme Relief	0.08
Good Vegetal Cover	0.03
Agricultural	0.15

Total C = 0.07 + 0.08 + 0.03 + 0.15
= 0.33

Area, A (Attachment 1 and 1A):
Zone 1 Area = 3.43 Acres
Zone 2 Area = 4.05 Acres
Zone 3 Area = 2.55 Acres
Zone 4 Area = 1.76 Acres
Zone 5 Area = 2.38 Acres
Total Area = 3.43+4.05+2.55+1.76+2.38
= 14.17 Acres

Intensity, I: [§ 4.4.3]
Strip Length –

Zone 1 Strip Length = 1,251	Feet
Zone 2 Strip Length = 1,405	Feet
Zone 3 Strip Length = 824	Feet
Zone 4 Strip Length = 1,066	Feet
Zone 5 Strip Length = 742	Feet

Kennedy/Jenks Consultants

By Michael Bungcayao Date 11/16/10 Project Haena State Park MP Project No. 1000711*00

Checked By Ramon Sera Date 11/17/10 Sheet 2 3

For All Zones –
Using Plate 1, (Attachment 3) –
First 300 feet of strip length, use *Forest with Heavy Ground Litter and Meadow*
Remaining Length, use *Grassed Waterway*
Velocity for first 300 feet = 1.8 feet per second
Velocity for remaining length = 11 feet per second

Time of Concentration, Tc:

Zone 1 Tc = $\frac{300\,ft}{1.8\,fps} + \frac{1{,}251\,ft - 300\,ft}{11\,fps} =$ 253 seconds

Zone 2 Tc = $\frac{300\,ft}{1.8\,fps} + \frac{1{,}405\,ft - 300\,ft}{11\,fps} =$ 267 seconds

Zone 3 Tc = $\frac{300\,ft}{1.8\,fps} + \frac{824\,ft - 300\,ft}{11\,fps} =$ 214 seconds

Zone 4 Tc = $\frac{300\,ft}{1.8\,fps} + \frac{1{,}066\,ft - 300\,ft}{11\,fps} =$ 236 seconds

Zone 5 Tc = $\frac{300\,ft}{1.8\,fps} + \frac{742\,ft - 300\,ft}{11\,fps} =$ 207 seconds

*Minimum Tc = 300 seconds (5 minutes)
Therefore for all zones, Tc = 5 minutes

For All Zones –
Using Plate 2, (Attachment 3)
Intensity correction factor = 2.7

Intensity, I –
From Plate 3, (Attachment 4)
Intensity of 1-hr Rainfall for a 2 year storm = 3 inches
2-year storm corrected intensity = 3 inches * 2.7
= 8.1 inches

From Plate 1, (Attachment 4A)
Intensity of 1-hr Rainfall for a 10 year storm = 4.5 inches
10-year storm corrected intensity = 4.5 inches * 2.7
= 12.2 inches

Flow Rate, Q = CIA
Zone 1, 2-year storm flow rate = 0.33 * 8.1 * 3.43
= 9.2 cubic feet per second
Zone 2, 2-year storm flow rate = 0.33 * 8.1 * 4.05
= 10.8 cubic feet per second
Zone 3, 2-year storm flow rate = 0.33 * 8.1 * 2.55
= 6.8 cubic feet per second
Zone 4, 2-year storm flow rate = 0.33 * 8.1 * 1.76
= 4.7 cubic feet per second
Zone 5, 2-year storm flow rate = 0.33 * 8.1 * 2.38
= 6.4 cubic feet per second

2-year, 1 hour storm – Total Flow in all 5 Zones = 9.2 + 10.8 + 6.8 + 4.7 + 6.4 cubic feet per second
= 37.9 cubic feet per second

Kennedy/Jenks Consultants

By Michael Bungcayao Date 11/16/10 Project Haena State Park MP Project No. 1000711*00

Checked By Ramon Sera Date 11/17/10 Sheet 3 3

Zone 1, 10-year flow rate = 0.33 * 12.15 * 3.43
= 13.8 cubic feet per second

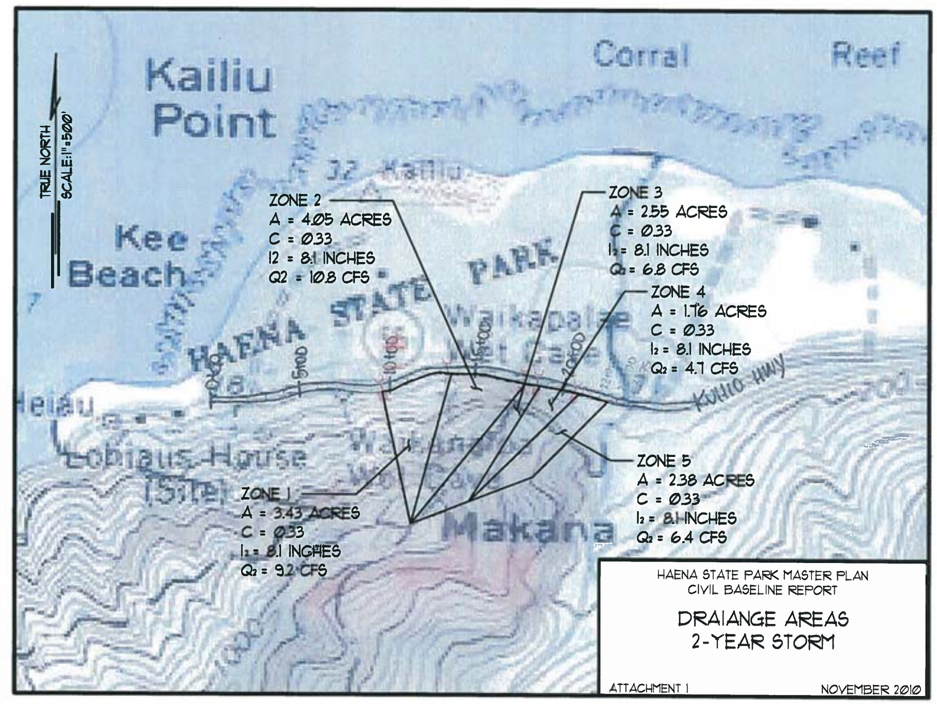
Zone 2, 10-year flow rate = 0.33 * 12.15 * 4.05
= 16.2 cubic feet per second

Zone 3, 10-year flow rate = 0.33 * 12.15 * 2.55
= 10.2 cubic feet per second

Zone 4, 10-year flow rate = 0.33 * 12.15 * 1.76
= 7.1 cubic feet per second

Zone 5, 10-year flow rate = 0.33 * 12.15 * 2.38
= 9.5 cubic feet per second

10-year, 1 hour storm – Total Flow in all 5 Zones = 13.8 + 16.2 + 10.2 + 7.1 + 9.5 cubic feet per second
= 56.8 cubic feet per second



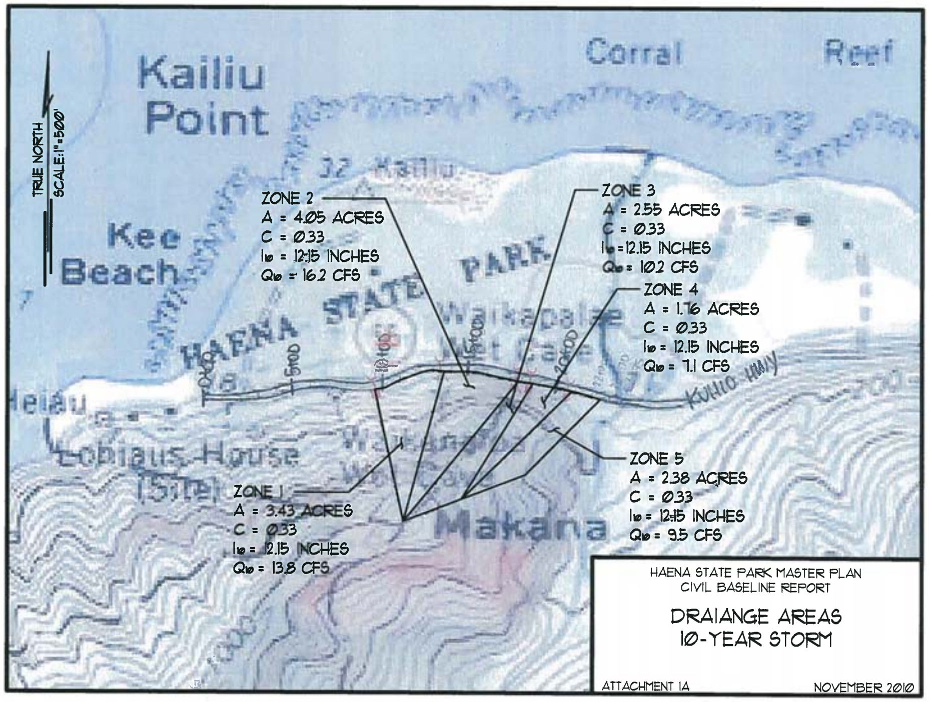


Table 1

GUIDE FOR THE DETERMINATION OF RUNOFF COEFFICIENTS FOR BUILT-UP AREAS*

WATERSHED CHARACTERISTICS	EXTREME	HIGH	MODERATE	LOW
INFILTRATION	NEGLIGIBLE 0.20	SLOW 0.14	MEDIUM 0.07	HIGH 0.0
RELIEF	STEEP (> 25%) 0.08	HILLY (15-25%) 0.06	ROLLING (5-15%) 0.03	FLAT (0-5%) 0.0
VEGETAL COVER	NONE 0.07	POOR (< 10%) 0.05	GOOD (10-50%) 0.03	HIGH (50-90%) 0.0
DEVELOPMENT TYPE	INDUSTRIAL & BUSINESS 0.55	HOTEL-APARTMENT 0.45	RESIDENTIAL 0.40	AGRICULTURAL 0.15

*NOTE: The design coefficient "c" must result from a total of the values for all four watershed characteristics of the site.

Table 2

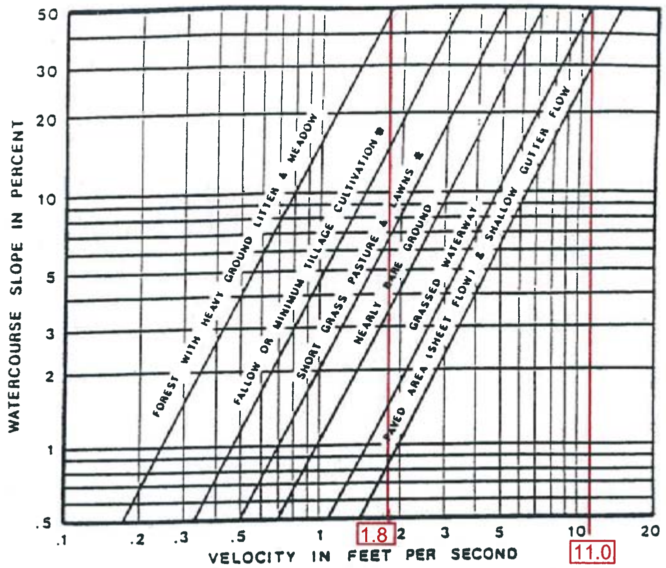
APPROXIMATE AVERAGE VELOCITIES OF RUNOFF FOR CALCULATING TIME OF CONCENTRATION

TYPE OF FLOW	VELOCITY IN FPS FOR SLOPES (in percent) INDICATED			
	0-3%	4-7%	8-11%	12-15%
OVERLAND FLOW:				
Woodlands	1.0	2.0	3.0	3.5
Pastures	1.5	3.0	4.0	4.5
Cultivated	2.0	4.0	5.0	6.0
Pavements	5.0	12.0	15.0	18.0
OPEN CHANNEL FLOW:				
Improved Channels	Determine Velocity by Manning's Formula			
Natural Channel* (not well defined)	1.0	3.0	5.0	8.0

*These values vary with the channel size and other conditions so that the ones given are the averages of a wide range. Wherever possible, more accurate determinations should be made for particular conditions by Manning's formula.

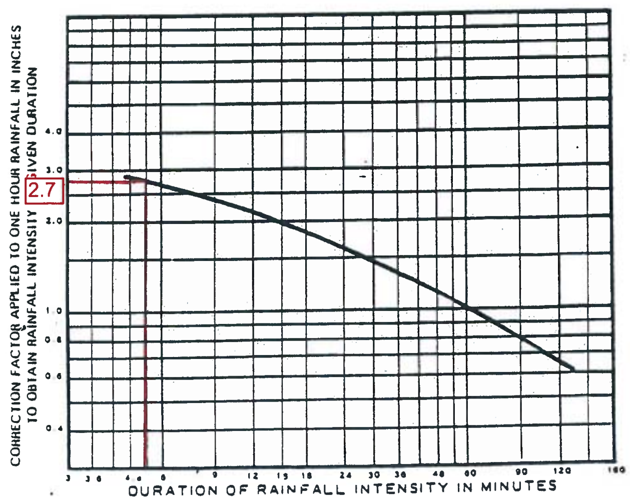
ATTACHMENT 2

PLATE 1



ESTIMATE OF AVERAGE FLOW VELOCITY FOR USE WITH THE RATIONAL FORMULA.

PLATE 2

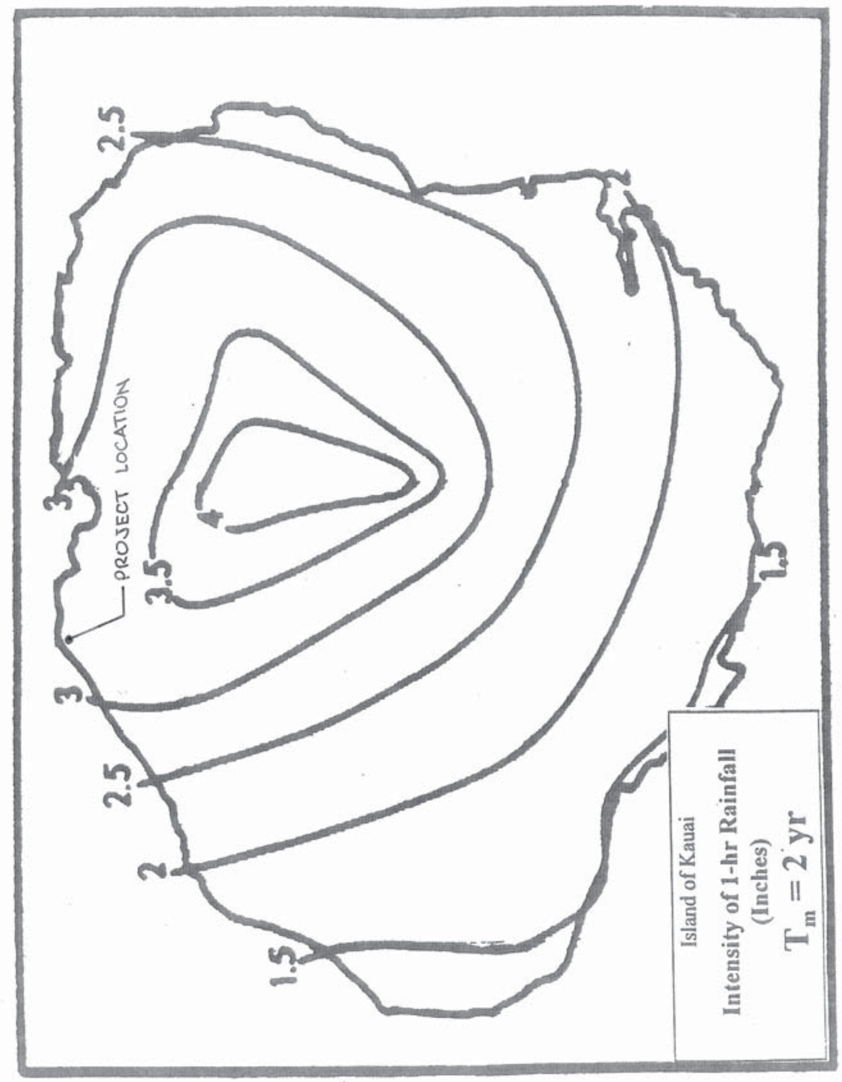


CORRECTION FACTOR
FOR CONVERTING 1 HR. RAINFALL TO RAINFALL INTENSITY OF VARIOUS DURATIONS

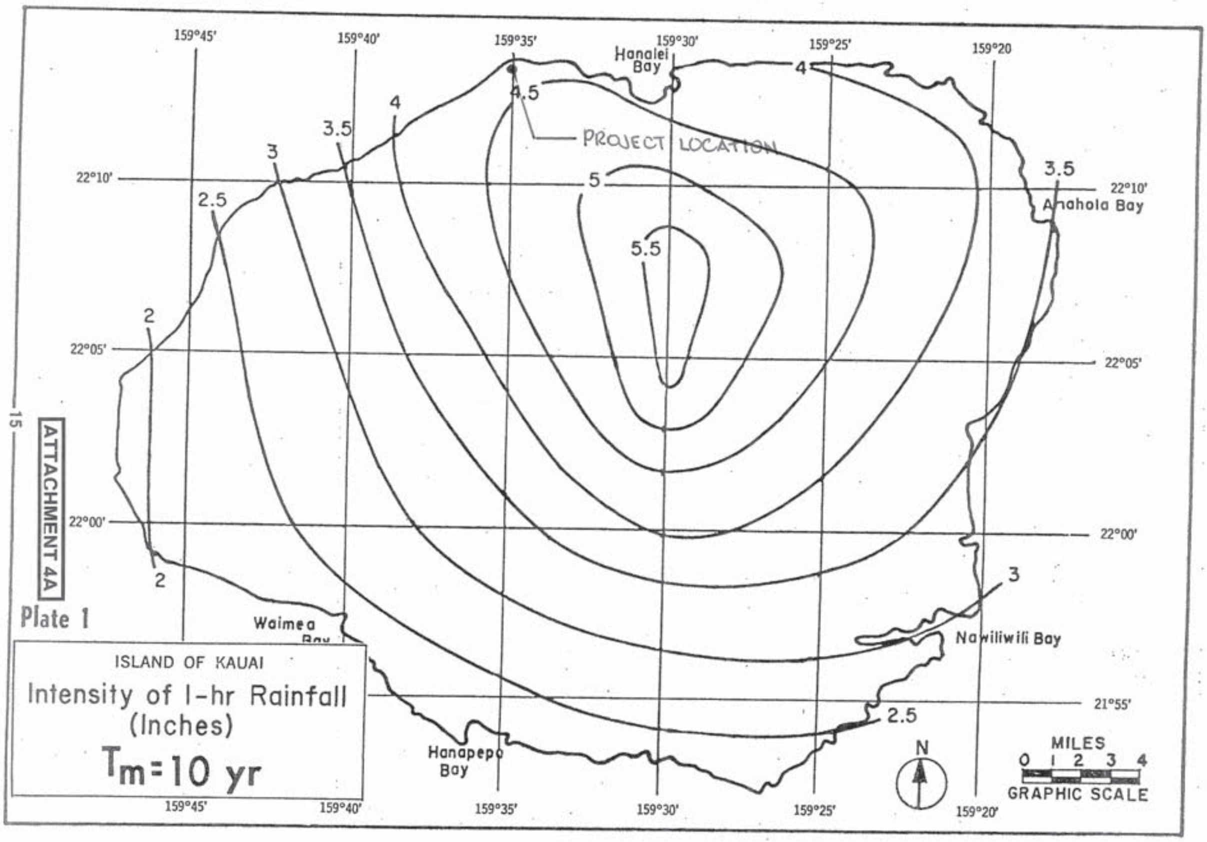
TO BE USED FOR AREA LESS THAN 100 ACRES

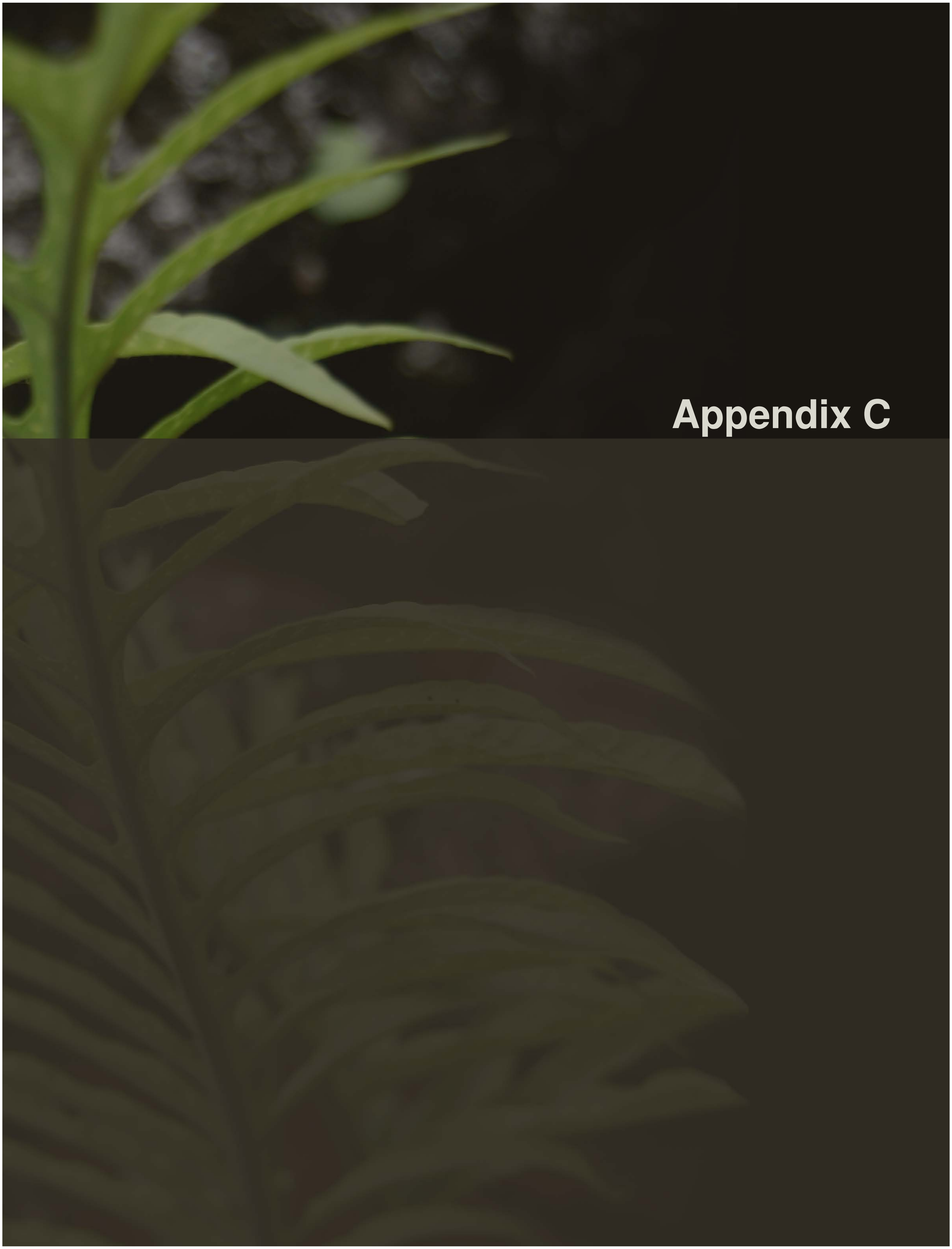
ATTACHMENT 3

PLATE 3



ATTACHMENT 4


ATTACHMENT 4A
Plate 1
ISLAND OF KAUAI
Intensity of 1-hr Rainfall
(Inches)
Tm=10 yr
159°45'
159°40'
159°35'
159°30'
159°25'
159°20
22°10'
22°05'
22°00'
21°55'
Hanalei Bay
Anahola Bay
Nawiliwili Bay
Hanapepo Bay
Waimea Bay
PROJECT LOCATION
2
2.5
3
3.5
4
4.5
5
5.5
N
MILES
0 1 2 3 4
GRAPHIC SCALE



Appendix C

Appendix C – Preliminary Shuttle Study

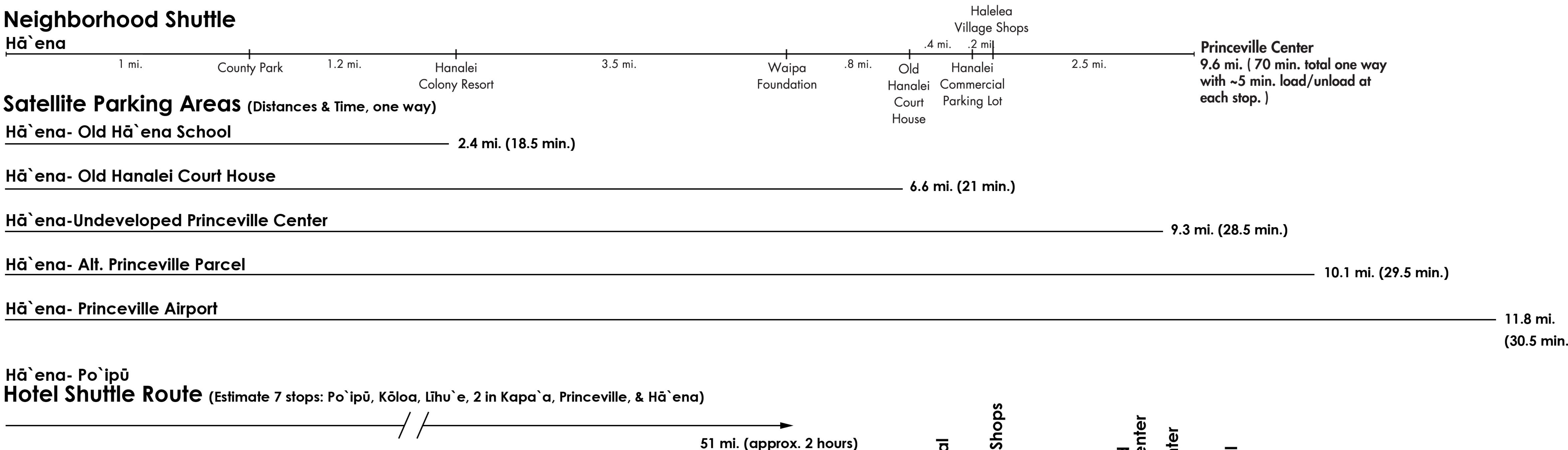
A preliminary shuttle study was prepared to support discussions held with the MPAC and community to determine potential scenarios and feasibility. Three route types were presented as examples: a single-stop shuttle service between the park and an offsite parking area, a North Shore neighborhood shuttle that would serve the local community as well as park visitors, and a hotel shuttle that would run between Po‘ipū and Hā‘ena State Park. A driving tour to investigate potential offsite parking areas between Princeville and Hā‘ena was conducted with members of the MPAC comprising the Transportation Workgroup. Also participating in a special Transportation Workgroup meeting were ATA, the Kaua‘i District Engineer from the State Department of Transportation-Highways, the Executive on Transportation for the County of Kaua‘i, and representatives from the Governor’s office and Kaua‘i Planning Department. The information gathered is compiled in Figure 31 and Table 9 through Table 11. Estimated travel times and distances between the stops are provided as calculated by ATA.

For the offsite parking options, four potential locations are compared in Table 11. However, not all existing zoning and State Land Use designations are appropriate. The Princeville Airport and Alternative Princeville Parcel are in the Agriculture zoning district and the Agricultural State Land Use Districts. Two of the sites are also zoned Open which limits permitted lot coverage to ten percent, reducing the amount of stalls that could be developed without a variance. The 2010 study included additional sites that have since been eliminated from consideration due to other uses being developed at the site or lack of MPAC support.

There were also some community concerns in using the old Hanalei Courthouse site as an offsite parking area as there may be higher and better community uses for that site. However, it could be added to the neighborhood shuttle as it is a historic and focal point in the community. In addition, many community members felt it would be safer if an offsite parking area were located outside the special flood and tsunami evacuation zones, which would be one of the two Princeville locations.

Initial discussions with CBRE, Princeville Center’s management entity, indicated their support of having an offsite parking area for Hā‘ena State Park at the shopping center. It is an ideal location due to the variety of retail establishments and restaurants, convenience for local residents, parking potential, willing management, and its location outside of the special flood and tsunami evacuation zones. The site, however, will soon be developed as affordable housing and will no longer be available.

The Princeville Airport was also studied due to its currently underutilized parking lot. Initial discussions with a representative from the Princeville at Hanalei/The Resort Group indicated some hesitation on tying up the area in a long-term agreement due to future development plans and the potential for attracting other tenants. However, they were open to further discussion and negotiation on a short-term arrangement.



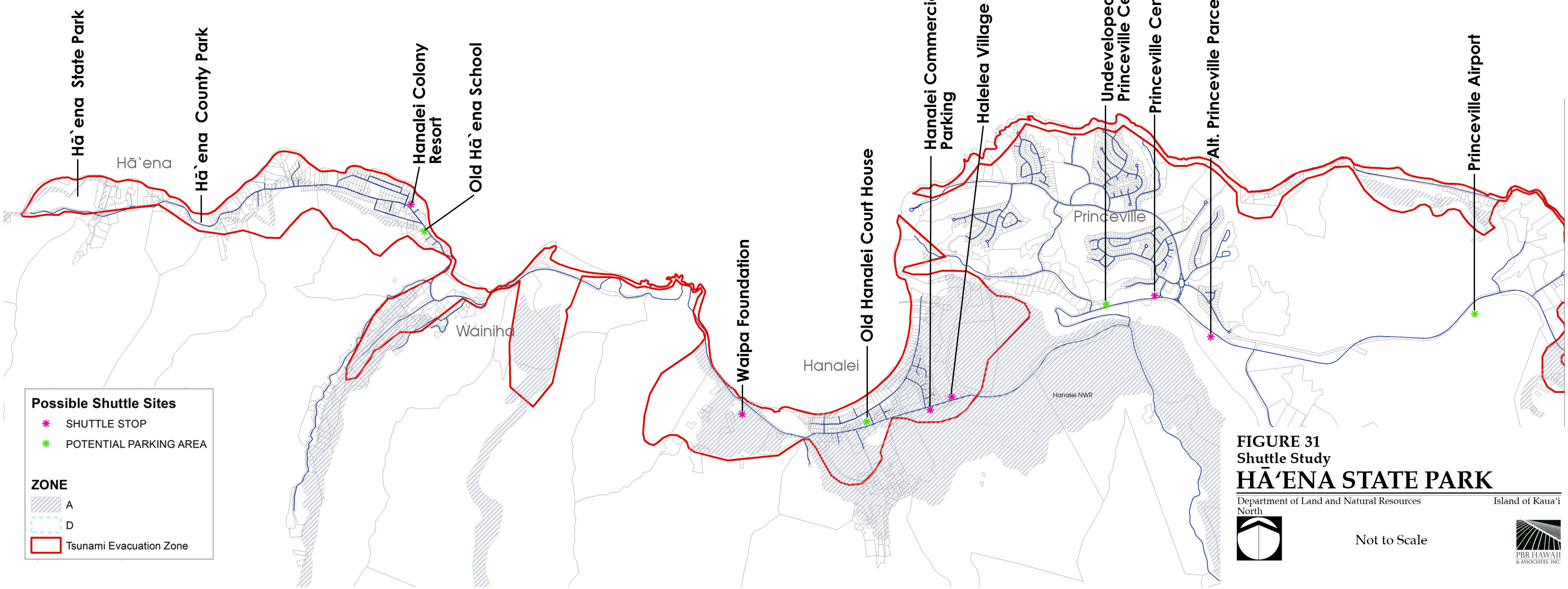


FIGURE 31
Shuttle Study
HĀʻENA STATE PARK
Department of Land and Natural Resources
Island of Kauaʻi

Table 9 – Shuttle Service Comparison Matrix

SERVICE TYPE	NEIGHBORHOOD SHUTTLE	OFFSITE PARKING LOT		HYBRID	SOUTH SHORE TO NORTH SHORE
CONCEPT	STOPS ONLY, NO DESIGNATED PARKING	SINGLE PARKING AREA	MULTIPLE PARKING AREAS	OFFSITE LOTS COMBINED WITH CONVENIENCE STOPS	HOTEL SHUTTLE
DESCRIPTION	Utilize existing commercial areas and access other points of interest.	Locate all parking or overflow parking in a single offsite lot and shuttle people between the lot and park.	Locate overflow parking in multiple parking lots and shuttle people between them and the park.	Combine provision of offsite parking area(s) and draw from/support existing commercial areas.	Reduce tourist demand for parking and reduce regional traffic by providing direct shuttle from hotels to North Shore.
MILES*	9.7 miles total between Hāʻena and Princeville Center	Ranges from 2.4 miles (Old Hāʻena School) to 11.8 miles (Princeville Airport)	Ranges from 2.4 miles (Old Hāʻena School) to 11.8 miles (Princeville Airport)	Varies	51 miles between Hāʻena and Poʻipū
MINUTES (ONE-WAY)	70 minutes (5 min. at each stop) or 46 minutes (2 min. at each stop)	Ranges from 18.5 minutes (Old Hāʻena School) to 30.5 minutes (Princeville Airport)	Varies depending on number and combination of stops	Varies depending on number and combination of stops	Approx. 2 hours (5 min. at each stop)
LAND DEMAND*	None to minimal. Use existing facilities.	One large lot to accommodate all parking or overflow parking.	Multiple smaller lots to accommodate overflow parking.	Varies. Mix of offsite lots and existing commercial areas.	None. Use existing facilities.
NEW FACILITIES REQUIRED*	None to minimal. Signage and potentially bus pull outs.	Depends on site.	Depends on sites.	Varies. Mix of offsite lots and existing commercial areas.	No
EXISTING ZONING/ STATE LAND USE	County Park: --/C; Hanalei Colony: Resort/U; Waipā Foundation: Open/A; Hanalei Courthouse: O/ST-P/U; Hanalei Commercial: Open/U; Haleleʻa Village Shops: C-N/U; Alternative Princeville Parcel: A/A; Princeville Center: C-G/U	Hāʻena School: Open/U; Hanalei Courthouse: O/ST-P/U; Undeveloped Princeville Lot (Princeville Center would develop parking lot): C-G/U; Alternative Princeville Parcel: Ag/A Princeville Airport: Ag/A	Hāʻena School: Open/U; Hanalei Courthouse: O/ST-P/U; Undeveloped Princeville Lot (Princeville Center would develop parking lot): C-G/U; Alternative Princeville Parcel: Ag/A Princeville Airport: Ag/A	See previous columns.	Find locations within Commercial or Resort Zoning/Urban.
OPERATOR OPTIONS	Independent, Non-Profit, County	Independent, Non-Profit, State	Independent, Non-Profit, State	Independent, Non-Profit, State, County	Independent, Hotels, Non-Profit, Visitor industry
PROS	Little new infrastructure required. Retail/service opportunities for surrounding businesses. Service local North Shore community including residents.	Operationally most simple.	Flexibility for visitor parking locations. May reduce congestion/overflow at a single location. May better integrate into community fabric better than one large lot.	May eliminate some parking lot demand as shuttle users may walk to stops from various locations.	Reduce number of single occupancy vehicles on North Shore roads.
CONS	Users may take up spaces at commercial parking areas for long periods of the day.	All except Princeville Airport will require new facilities for park and ride lot. Depending on location, may or may not be appropriate land use.	All except Princeville Airport will require new facilities. Depending on location, may or may not be appropriate land use.	Users may take up spaces at commercial parking areas for long periods of the day.	May not capture resident community or those staying at smaller properties.

*See Table 10 and Table 11 which compare the possible convenience stops and offsite parking areas.

Table 10 – Neighborhood Shuttle Stops

	HĀʻENA COUNTY PARK	HANALEI COLONY RESORT	WAIPĀ FOUNDATION	HANALEI COURTHOUSE	HANALEI COMMERCIAL	HALELEʻA VILLAGE SHOPS	PRINCEVILLE CENTER
OWNERSHIP	County	Private	Kamehameha Sch.	State	Private	Private	Private
SURROUNDING USES	Residential	Residential	Rural residential/ agriculture	Cultural center, churches, parks, residential	Commercial	Commercial	Commercial, resort, civic
STATE LAND USE	C	U	A	U	U	U	U
ZONING	-	RR	O	O/ST-P	O	C-N	C-G
HAZARDS	Flood zone VE (EL 35), tsunami evacuation	Flood zone VE (EL 24), tsunami evacuation	Flood zones VE (EL 11), AEF, AE and tsunami evacuation	Flood zones X, X500, AE (EL 13), tsunami evacuation	Flood zone AE, tsunami evacuation	Flood zone AEF, tsunami evacuation	Flood zone X (outside the .2% annual chance floodplain)
EXISTING PULL-OUT OR TURN-AROUND	Y, parking lot	Y, parking lot	Y, gravel driveway loop	Y, parking lot	Y, loop parking lot	Planned bus pull out	Y, existing parking with maneuvering areas
MILES FROM PARK	1.0	2.4	5.8	6.6	7.0	7.1	9.6

Table 11 – Offsite Parking Areas

	OLD HĀʻENA SCHOOL	OLD HANALEI COURTHOUSE/COUNTY BASEYARD	ALTERNATIVE PRINCEVILLE PARCEL	PRINCEVILLE AIRPORT
OWNERSHIP	State	State	Private	Private
SIZE / # STALLS	2.76 acres/30-40 stalls	2.50 acres/30-40 stalls (if allowed to exceed 10% lot coverage)	4.6 acres/200+ stalls	~60-70 stalls
SURROUNDING USES	Residential	Residential/Commercial/historic sites	Cultural Uses (church, heiau)	Rural residential/ agriculture
STATE LAND USE	U	U	A	A
ZONING	O	O/ST-P (Open/Special Treatment-Public)	A	A
HAZARDS	Flood zones VE (EL 24), AE (EL 24), X and tsunami evacuation	Flood zone X, X500, AE (EL 13), tsunami evacuation	Flood zone X (outside the .2% annual chance floodplain	Flood zone X (outside the .2% annual chance floodplain)
EXISTING PARKING FACILITIES	None	Cleared lot, driveway accesses	None	Established parking lot, highway access
EXISTING VEHICLE STORAGE/REPAIR FACILITIES	None	None	None	None
MILES FROM PARK	2.4	6.6	10.0	11.8

The Alternate Princeville Parcel site was not evaluated in 2010, but added to the potential list of sites due to community knowledge of this vacant parcel and a landowner that has indicated an interest in selling the property. Its ample land area and location outside flood hazard zones makes this parcel an ideal candidate for offsite parking.

Additional stops could be added between the park and offsite parking areas such as Hanalei town. However, this will lengthen the travel time between the two areas and potentially reduce the number of shuttle runs to the park without adding additional shuttles.

For the neighborhood shuttle, stops were chosen for their location near or in commercial uses or important community centers such as the Waipā Foundation. Parking availability was not a necessity as the neighborhood shuttle was envisioned to serve a broader group of people who would not be driving and not just visitors to Hāʻena State Park. This would help supplement ridership and serve the greater North Shore community, including seniors, children, and others who are not able to drive, potentially further reducing traffic on the highway between Princeville and Hāʻena.

The hotel shuttle route was proposed to serve mainly visitors to Kauaʻi, with seven stops between Poʻipū and Hāʻena. With 51 miles between the two areas, the one-way trip was estimated to take approximately two hours (including stopping time for picking up passengers). This service was envisioned to run less frequently, but could also serve the greater visitor industry and reduce traffic on the roadways by providing shuttle service between the North and South Shores.

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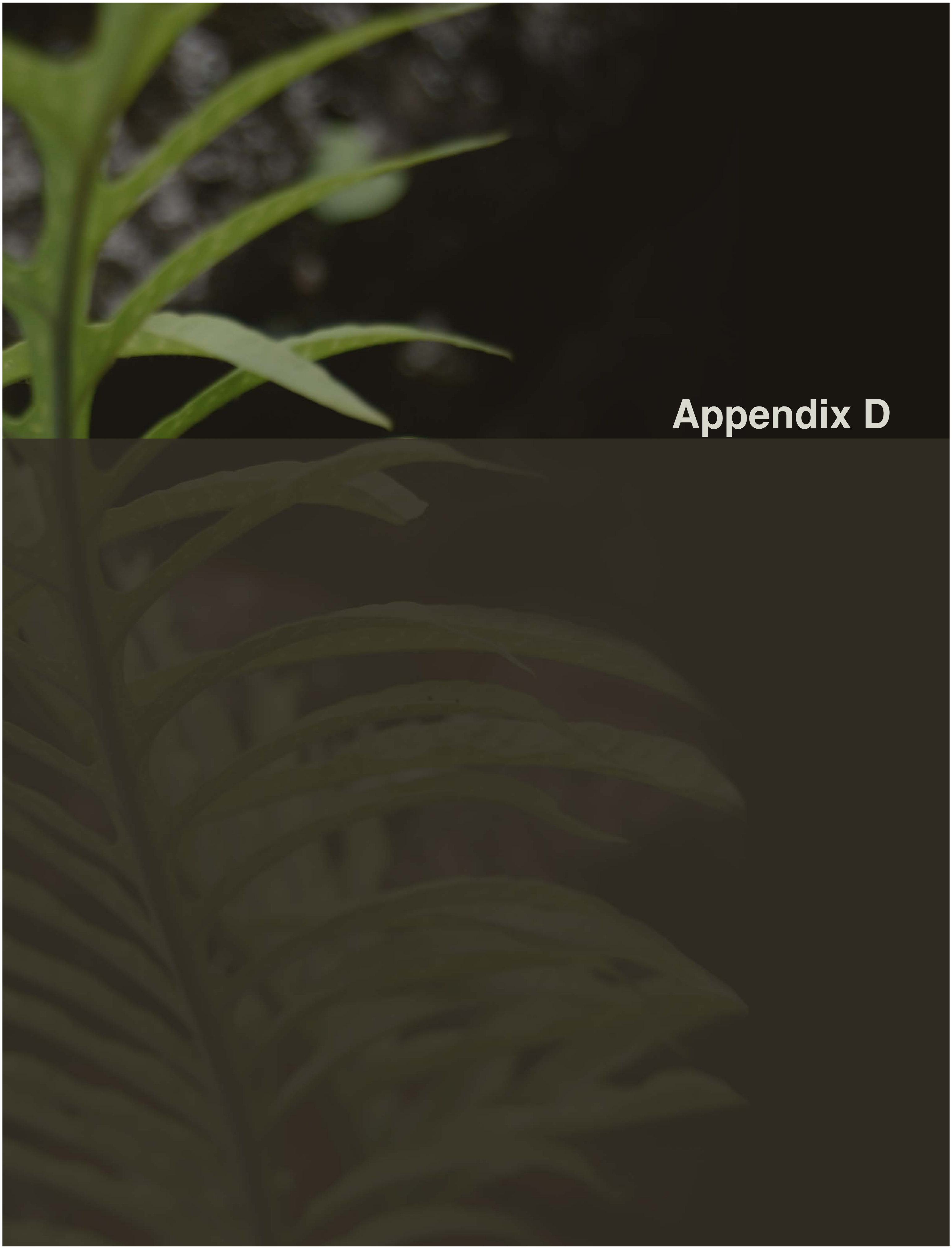

Appendix D

TRAFFIC IMPACT ANALYSIS REPORT
HĀʻENA STATE PARK MASTER PLAN
Hāʻena, Kauaʻi, Hawaiʻi

September 14, 2011
Revised June 17, 2013

Prepared for:

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TRAFFIC IMPACT ANALYSIS REPORT
HĀʻENA STATE PARK

Hāʻena, Kauaʻi, Hawaiʻi

Prepared for:

PBR Hawaii, Inc.

Prepared by
Austin, Tsutsumi & Associates, Inc.
Civil Engineers • Surveyors
Honolulu • Wailuku • Hilo, Hawaii

September 14, 2011

Revised June 17, 2013

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AUSTIN, TSUTSUMI & ASSOCIATES, INC. CIVIL ENGINEERS • SURVEYORS
CONTINUING THE ENGINEERING PRACTICE FOUNDED BY H. A. R. AUSTIN IN 1934

TERRANCE S. ARASHIRO, P.E.
STANLEY T. WATANABE
IVAN K. NAKATSUKA, P.E.
ADRIENNE W. L. H. WONG, P.E., LEED AP
KEITH K. NIIYA, P.E.
DEANNA HAYASHI, P.E.
PAUL K. ARITA, P.E.

TRAFFIC IMACT ANALYSIS REPORT
HĀʻENA STATE PARK
Kauaʻi, Hawaiʻi

I. INTRODUCTION

This report documents the findings of a traffic study conducted by Austin, Tsutsumi & Associates, Inc. (ATA) to evaluate the potential traffic impacts resulting from the proposed Hāʻena State Park Master Plan (Project).

A. Background

The proposed Master Plan will be limiting the number of visitors and the amount of vehicular traffic into Hāʻena State Park to help improve safety, mitigate impacts to the unique cultural and natural resources, and enrich visitor experience at the park. The initial proposed visitor limit is 900 people per day but this number could be adjusted over time based on the impacts to the park. This daily visitor limit does not include the 60 overnight camping permits for the Kalalau Trail. This would represent a significant reduction from the park's current number of visitors, estimated at 2,000 visitors per day.

Similar to the previous Draft Master Plan, the proposed plan will have roughly 100 parking stalls in the main parking lot and an additional 13 special parking stalls at Kēʻē Beach. This report will also investigate the requirements for a shuttle service between Hāʻena State Park and a satellite parking area in Princeville that could be considered to support access to the park. The satellite parking area would be outside of the special flood hazard area as designated by the Federal Emergency Management Agency. This report will investigate existing

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WAILUKU, MAUI, HAWAII
HILO, HAWAII

federal precedent, examples of similar applications, and estimate the cost of the proposed shuttle system (Shuttle).

This study will also analyze the traffic impacts of the proposed project and potential management options.

B. Location

Hāʻena State Park is situated on approximately 65.7 acres of land located on the north shore of the island of Kauaʻi. The park is bordered to the east by the Limahuli Stream, to the south by cliffs and by the Pacific Ocean to the north and west.

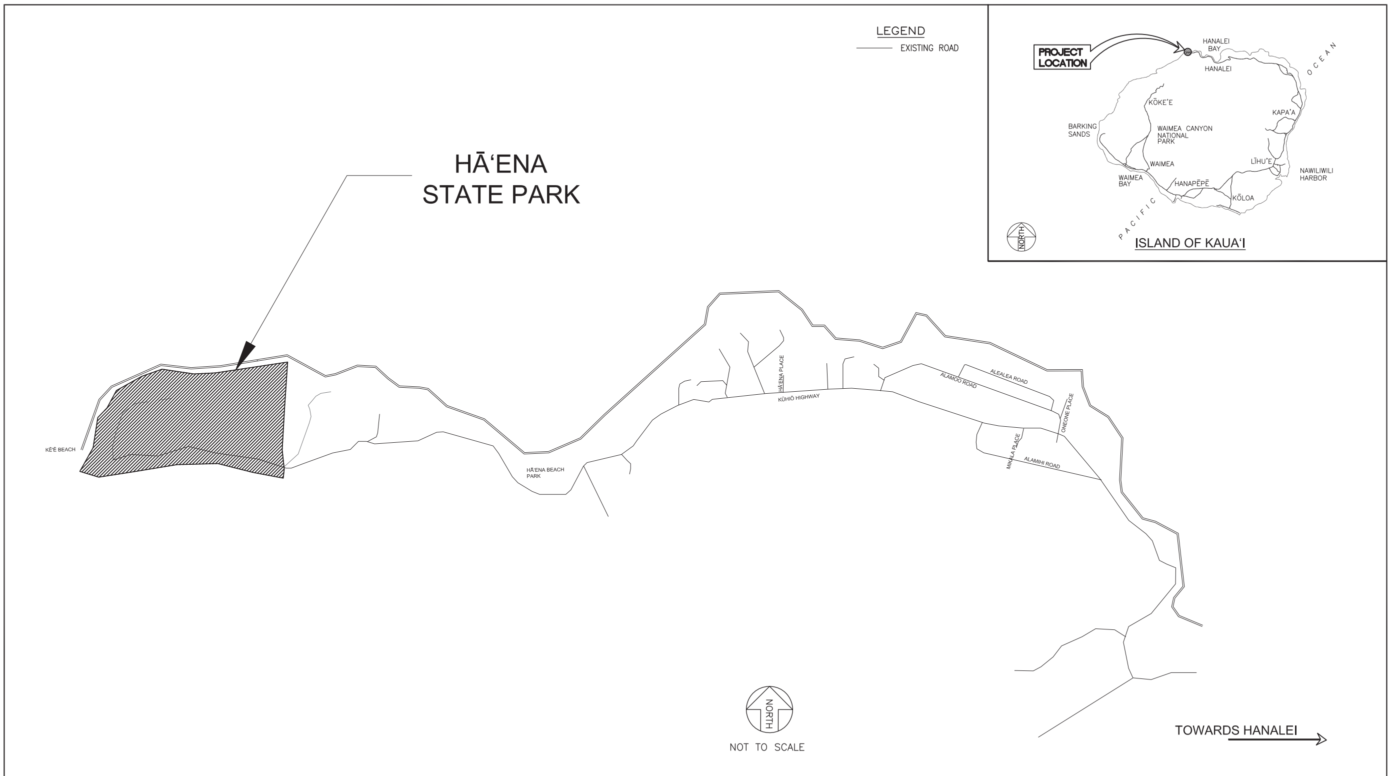
Sole access to Hāʻena State Park is provided via Kūhiō Highway, which terminates at Kēʻē Beach.

See Figure 1 for the location of the Hāʻena State Park. See Figure 2 for the Project Site Plan. See Figure 3 for the proposed parking lot.

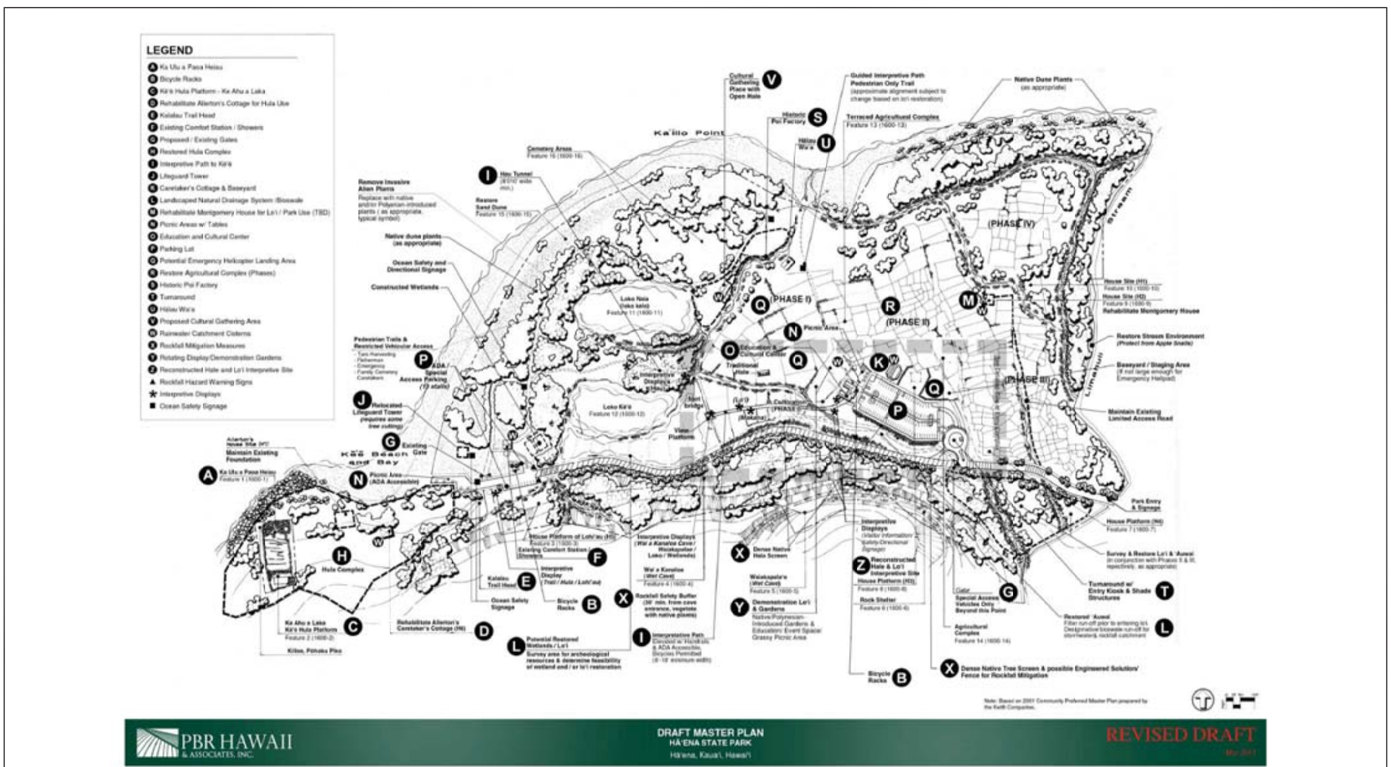
C. Study Methodology

This study will address the following:

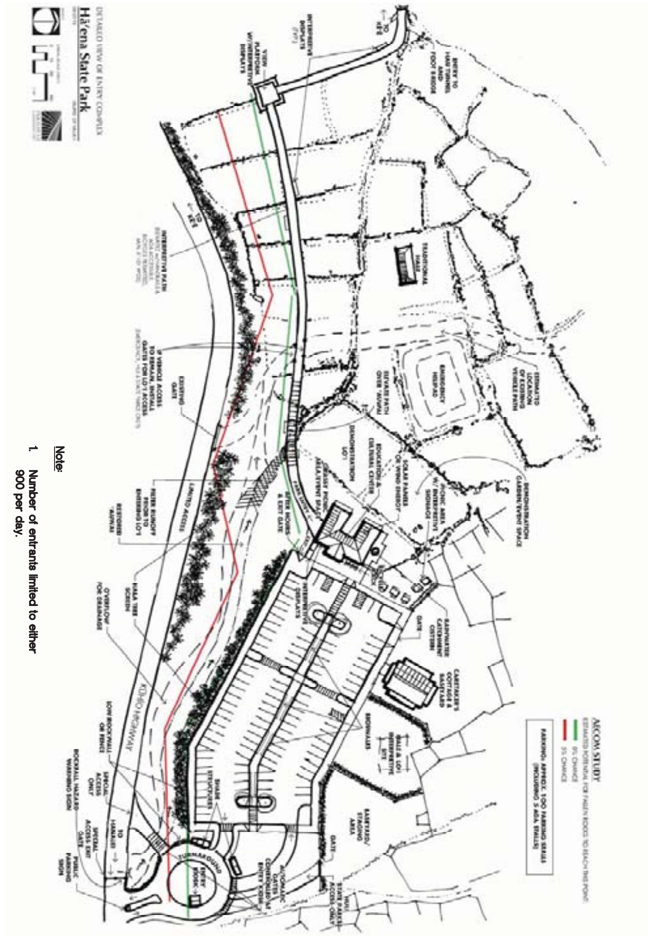
1. Existing traffic operating conditions at key locations within the study area.
2. Existing precedent for shuttle services in state and/or national parks.
3. Estimation of shuttle operation costs.
4. Recommendations for shuttle operations.
5. Projected traffic impacts for the proposed master plan and management options.



HĀʻENA STATE PARK	AUSTIN, TSUTSUMI & ASSOCIATES, INC. ENGINEERS, SURVEYORS • HONOLULU, HAWAII	FIGURE
	LOCATION MAP	1



HĀʻENA STATE PARK	AUSTIN, TSUTSUMI & ASSOCIATES, INC. ENGINEERS, SURVEYORS • HONOLULU, HAWAII	FIGURE
	SITE PLAN	2



HĀ'ENA STATE PARK

AUSTIN, TSUTSUMI & ASSOCIATES, INC.
ENGINEERS,SURVEYORS • HONOLULU,HAWAII

PARKING PLAN

FIGURE 3

II. EXISTING CONDITIONS

A. Roadway System

Sole ingress and egress to Hā'ena State Park is provided via Kūhiō Highway, which in the vicinity of the park is a winding two-lane roadway that runs east-west and terminates near Kē'ē Beach. Ten (10) one-lane bridges slow traffic between Princeville and Hā'ena State Park. The Kaua'i County General Plan (2000) stated the county's intent to maintain them; the bridges are valued for their historic significance and "traffic slowing" effect. [1]

Hā'ena State Park currently provides two parking lots. The first is approximately 750 feet west of the Hā'ena State Park entrance, and the second is where Kūhiō Highway terminates near Kē'ē beach. Due to the limited number of stalls, vehicles park along the road leading up to the beach. No sidewalks are provided for pedestrians.

B. Existing Traffic Conditions Analysis and Observations

Along Kūhiō Highway and leading up to the park, no significant congestion was observed. However, in the areas between Princeville and Hā'ena State Park, a maximum of 4-vehicle queues were observed to form as they waited to traverse the numerous narrow 1-lane bridges. Otherwise, traffic flowed smoothly, though cautiously, due to the relatively low volume.

It is estimated that Kuhio Highway operates at approximately 39 percent of capacity at the Waipa bridge based upon a bi-directional capacity of 1,250 vehicles per hour and a bi-directional volume of 487 vehicles per hour[2]. Refer to Appendix B for derivation.

Upon entering the Hā'ena State Park driveway (Kūhiō Highway), vehicles generally travel slowly to avoid pedestrians and oncoming vehicles. An incoming driver will first encounter an unpaved and un-striped parking lot on the right (makai), approximately 750 from the entrance. Visitors that use this parking lot must walk approximately 1,500 feet along the roadway to reach the beach, as no

[1] County of Kaua'i Planning Department, *Kaua'i General Plan*. (2000). 2-11.

[2] Field observations indicate that capacity might be lower than 1,400 – however, traffic was observed to flow smoothly.

sidewalk is provided. At the end of the road, there is a turnaround area wherein a limited number of parking stalls are provided. Due to the stalls' comparatively favorable location, congestion occurs as vehicles wait for them to be vacated. Some visitors were observed waiting for over five (5) minutes for a stall.

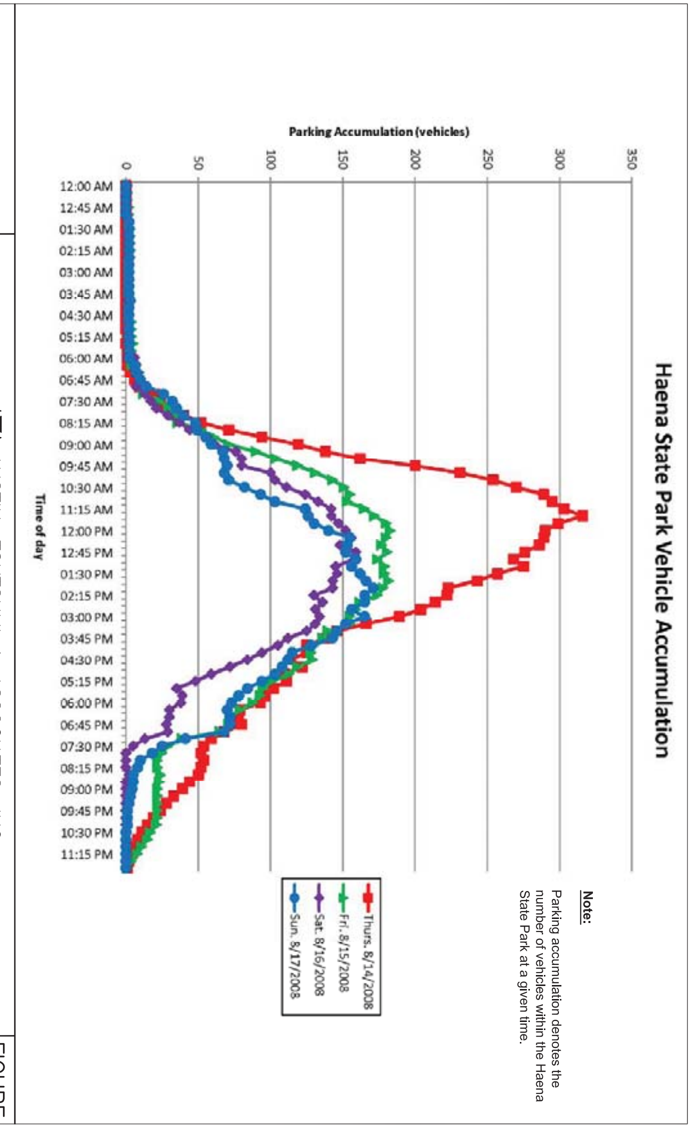
The 24-hr traffic count data was collected via pneumatic tubes laid at the Hāʻena State Park entrance between August 14, 2008 and August 18, 2008; this included a long weekend for Statehood Day. According to 1993 data from County of Kauaʻi Lifeguards, Hāʻena State Park experiences its highest attendance during month of August.[4]

Approximately 1,550 vehicles per day were counted entering and exiting Hāʻena State Park (775 entering, 775 exiting). The heaviest hourly flow of traffic occurred on Thursday, August 14 between 1:15 and 2:15 PM, where 75 vehicles entered and 120 vehicles exited.

At the Hāʻena State Park entrance, the peak hours occurred towards the middle of the day. Near the Princeville Center, more typical commuter peak hours were observed. The traffic count data and respective peak hours are shown in Figure 5.

See Figure 4 for daily parking accumulation over a 5-day period.

[4] The Keith Companies. V-5.



HAENA STATE PARK
MASTER PLAN

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VEHICLE ACCUMULATION CHART

FIGURE 4

III. SHUTTLE RESEARCH

A. Background

Alternative Transportation in Parks and Public Lands (ATTPL)

In 1997, the Department of the Interior and Department of Transportation signed a Memorandum of Understanding (MOU) to "develop a plan for a comprehensive effort to improve public transportation in the National Parks."

Pursuant to this goal, the "Alternative Transportation in Parks and Public Lands" program has been initiated in 2005 – with the stated purpose "to enhance the protection of national parks and public lands and to increase the enjoyment of those visiting parks and public lands." The program authorized $97 million dollars in funding for Alternative Transportation Systems (ATS) projects between fiscal years 2006 and 2009.

The program – while primarily geared towards National and Tribal parks, also states that "also eligible to apply are state, tribal, or local governmental authorities with jurisdiction over land in the vicinity of an eligible area, acting with the consent of the FLMA, alone or in partnership with an FLMA or governmental or nongovernmental participant."

Funding is directed only towards either planning (studies to identify the best alternative) or implementation (capital improvements, i.e. equipment purchases) projects.

According to its 2007 program manual the demand for funding is "highly competitive," with only half of the 2006 applicants having been funded.

Federal Lands Alternative Transportation Systems Study (2001)

This report identified prospective sites for either new or improved ATS at 207 locations throughout the country, including those listed in Table 1 below:

Table 1: Hawai'i ATS Parks Information

	Annual Visitation (2001)	Annual Visitation (2010)	Current ATS	ATS improvements or new ATS proposed?
Haleakalā National Park	1.1 Mil.	1.1 Mil.	None	Yes
Hawai'i Volcanoes National Park	1.5 Mil.	1.3 Mil.	None	Yes
Kalaupapa National Historic Park	75,000	28,546	Plane	Yes
Pohakuloa Heiau National Park	200,000	124,061	None	Yes

It should be noted that ATS measures were recommended for all of the Hawai'i National Parks studied, though none have been implemented to-date for all but Kalaupapa National Historic Park.

The report identified that the following parks offered small or medium busses for use in shuttles as of 2001:

Table 2: Nationwide Shuttle Use at National Parks

Park	Annual Visitation	Existing ATS
Red Rock Canyon National Conservation Area	1,100,000	Small/medium bus
Kenai National Wildlife Refuge	400,000	Small/medium bus
Merritt Island National Wildlife Refuge	500,000	Small/medium bus
Adams National Historic Park	65,000	Historic trolley
Aztec Ruins National Monument	72,000	Small/medium bus
Cabrillo National Monument	1,200,000	Small/medium bus
Chiricahua National Monument	195,000	Small/medium bus
Devil's Postpile National Monument	125,000	Small/medium bus
Eugene O'Neill National Historic Site	5,000	Small/medium bus
Glacier National Park	1,800,000	Small/medium bus
Great Smoky Mountains National Park	10,000,000	Historic trolley
Hot Springs National Park	1,500,000	Historic trolley

Jefferson National Expansion Memorial	1,000,000	Small/medium bus
Kalaupapa National Historic Park	75,000	Small/medium bus
Lyndon B. Johnson National Historic Park	125,000	Small/medium bus
Natchez National Historic Park	41,000	Historic trolley
Organ Pipe Cactus National Park	300,000	Small/medium bus
Pinnacles National Monument	95,000	Small/medium bus
San Juan Island National Historical Park	250,000	Small/medium bus
Scotts Bluff National Monument	150,000	Small/medium bus
Sequoia and Kings Canyon National Parks	1,500,000	Small/medium bus
Shenandoah National Park	1,750,000	Small/medium bus
Tallgrass Prairie National Preserve	100,000	Small/medium bus
Tumacacori National Historic Park	62,500	Small/medium bus
Wolf Trap Farm Park for the Performing Arts	500,000	Small/medium bus

Budgetary and ridership information was not readily available for most of these sites.

B. Case Studies

Zion National Park (Utah)

Zion National Park served 2.7 million visitors in 2010, and implemented a mandatory shuttle system in 2000. In the year 2000, the shuttle transported 2,994 passengers per day. The annual operating costs of the system are estimated to be $2.5 million, or $1 per visitor. Capital improvements to initiate the program were $27.4 million.

Source: http://www.nps.gov/zion/planyourvisit/shuttle-system.htm

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Kalaeloa Homeless Shelter

Established in June, 2008, this program utilizes 2 full-sized busses and 1 van. The bus provides transit between Kalaeloa and the Kapolei Transit Station and is operational during the following hours:

- Monday-Friday: 7:00 AM-4:30 PM, with a headway of 60 minutes.
- Saturday & Sunday: 8:30 AM-4:00 PM, with a headway of 90 minutes.

The program operates on an annual budget of approximately $152,000, but is also supplemented by the Hawai'i Helping the Hungry Have Hope (H-5) Program.

Kaua'i Bus System

The Kaua'i Bus system provides six (6) routes – with headways generally at 60 minutes between arrivals. Notable statistics[5]:

- Ridership for March 2011: 51,894 trips
- Annual Budget (2012): $5,550,482
- Salaries and Wages (2012): $2,500,464
- Bus Driver Wage: $19.22/hour
- Hourly costs: $69/service hour/bus

Speedishuttle

During this investigation, Speedishuttle was found to be the only shuttle operator on Kaua'i providing service between the Airport and hotel destinations. According to its website, the lowest one-way fare was $9 per passenger.

[5] County of Kaua'i Transportation Agency, 2012 Budget Presentation (2011). 3,7,9.

<u>TheBus (Honolulu)</u>

Honolulu's TheBus system operates with a $125 Million subsidy and charges its approximately 73 Million riders $2.50 each way, with special pricing for monthly, annual, senior, child, and student passes. Its busses carry between 63 and 103 passengers per bus.

The annual subsidy, divided by the number of passengers, equates to approximately $3.40 for each round-trip ride. Added to the standard bus fare of $5.00/round trip, the total cost for each round trip is approximately $8.40, despite the fact that the carrying capacity is at least three times as great as the proposed Shuttle system.

IV. ALTERNATIVES ANALYSIS

As mentioned in the introduction, the proposed Master Plan will be limiting the number of visitors to 900 per day. The following scenarios were considered:

<u>Scenario 1</u> – Limit the number of visitors to 900 persons per day and reduce the number of parking stalls to 100.

<u>Scenario 2</u> – Limit the number of visitors to 900 persons per day, and reduce the number of parking stalls to 50. Provide a shuttle service between Princeville and Hāʻena State Park.

<u>Scenario 3</u> – Limit the number of visitors to 900 persons per day, and eliminate the parking lot. Provide a shuttle service between Princeville and Hāʻena State Park.

<u>Scenario 4</u> – Do not limit the number of visitors to Hāʻena State Park; reduce the number of parking stalls to 50. Provide a shuttle service between Princeville and Hāʻena State Park.

<u>Scenario 5</u> – Do not limit the number of visitors to Hāʻena State Park; eliminate the parking lot. Provide a shuttle service between Princeville and Hāʻena State Park.

A. Traffic Analysis

Although some congestion currently occurs within the Hāʻena State Park site, traffic along the roadways leading up to Hāʻena State Park is relatively light. The proposed shuttle system would serve to significantly reduce the number of vehicles destined towards Hāʻena State Park. This impact would improve queuing while reducing the amount of traffic at all of the historic one-lane bridges between the Princeville Center (proposed shuttle terminus) and Hāʻena State Park to below the current 39 percent of capacity. See Table 3 for a comparative analysis of the scenarios during the critical PM peak hour of traffic. The Waipa bridge was analyzed as the measure of capacity because it is the longest one-lane span between Princeville and Hāʻena State Park, and is close to the HDOT count location used in this study.

Table 3: Capacity Analysis of Waipa Bridge During the Critical PM Peak Hour.

Scenario	Bi-directional Flow @ Waipa Bridge (veh./hr.)	Estimated Bridge Capacity (veh./hr.)	Volume-to-Capacity Ratio
Existing	487	1250	39%
Scenario 1	388	1250	31%
Scenario 1 w/carpooling (4 pers./veh.)	358	1250	29%
Scenario 2	323	1250	26%
Scenario 3	319	1250	26%
Scenario 4	337	1250	27%
Scenario 5	333	1250	27%

Note: Bridge capacity estimated based upon Simtraffic Analysis of existing conditions.

While vehicle occupancy rates are estimated to be approximately 2.5 persons/vehicle, "Scenario 1 w/carpooling" assesses the impact of increasing the occupancy to 4 persons per vehicle.

See Figure 5 for traffic volumes with and without the proposed shuttle system (scenario 1).

The shuttle system would also reduce traffic throughout the Hanalei and Princeville Area. However, the access point to the shuttle pick-up/drop-off terminus is anticipated to generate a maximum of 60, 70, 140, and 150 vehicles per hour entering/exiting the site, respectively for shuttle scenarios 2, 3, 4, and 5 (refer to section IV.D. for description). The arrivals are assumed to be relatively uniform as a result of the reservation system.

B. Shuttle (Scenarios 2-5)

It is proposed that the shuttle run between Hāʻena State Park and the Princeville Center with no stops in-between. The number of busses and proposed headways will be scenario-based and discussed in section III.C below.

It is anticipated that if the number of entrants into the park are limited, some form of communication or a reservation system will be needed to ensure against backlogs and long wait times at the shuttle's entrance point. This could be accomplished through any combination of the following methods:

- **Online reservation system** – Tickets would have to be presented to ride the shuttle; walk-in's would be accepted, but given last priority.

Ideally, the departure time would be reserved as well to ensure that long delays are prevented while leaving the park as well. The implementation cost of such a system is currently unknown, and will require further study.

- **Bus Driver Fare Collection Method** – Given that an online ticket reservation system might be costly to implement, it is possible that bus drivers could collect the money themselves. However, this would slightly increase the time required at stops. This method is not recommended where entry restrictions are enacted for Hāʻena State Park due to the potential for wasted trips and long wait times at the shuttle terminus.
- **Kiosk Fare Collection Method** – Would require a manned kiosk where ride fares could be collected and tickets distributed. The kiosk's operator could perform other tasks, such as:
  - Gather and disseminate information regarding current shuttle wait times; the information could be provided to hotels, or be managed via a website.
  - Serve as the hub of communication in the event of an emergency or compromised road conditions.

It is assumed that handicapped park entrants will be allowed to park in the parking lot at Hāʻena State Park.

It is recommended that a roadside sign be installed along Kūhiō Highway ahead of the Park and Ride to inform visitors that shuttle service to the park is required and that vehicles will not be allowed to park unless passes are purchased.

This will encourage visitors to plan their trips ahead of arrival and prevent visitors from parking throughout the surrounding neighborhoods and walking in.

C. Engineering Considerations

Due to the narrow and winding roadways between Hāʻena State Park and Princeville, it is recommended that as a maximum, only 15- or 20-passenger vehicles be used as shuttles, as vehicles of this size were reported to have been used along these routes during five days of filming of the Pirates of the Caribbean: On Stranger Tides movie in 2010. Parking was also available to the east of the County's Hāʻena Park. See Figure 5.

The following information was gleaned from the experience:

1. Flagmen and road signage were used to help the vehicles in areas streets were narrow and/or curvy. This could denote that there were issues with sight distance and or traversal of narrow segments.
2. Two 15-passenger and one wheelchair-ready 20-passenger van were used to shuttle beachgoers.

It should be noted that topographical survey data was not available at the time of this report, and therefore vehicle navigability was not explicitly considered. Further study and/or test runs may be necessary prior to implementation and could affect vehicle size/model selection.

The 12 bridges along the proposed Shuttle route appear to offer sufficient theoretical carrying capacity to accommodate 15-20 passenger shuttles. See Table 4.

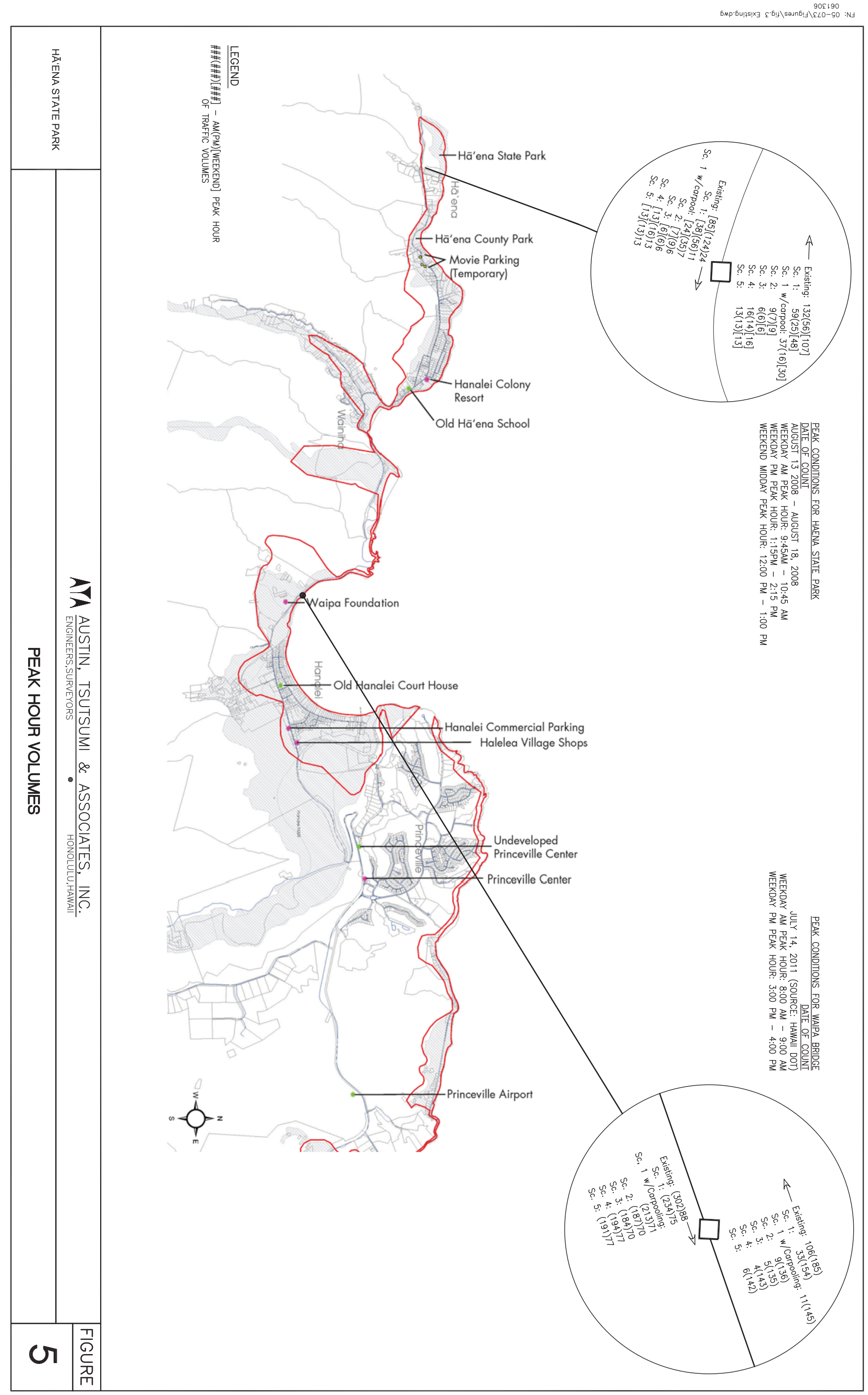

Table 4: Existing Bridge Capacity

Bridge Name	MP	Type	Year Constructed	Length (ft.)	Load Rating	Load Restriction (lbs.)*
Kaua'i Route 560						
Hanalei River Bridge	1.2	Steel Pratt Truss	1912	113	H-10	30,000
Wai'oli Bridge	3.39	R.C. Flat Slab	1912	90	H-15	16,000
Waipā Bridge	3.91	R.C. Flat Slab	1912	188	H-15	16,000
Waikoko Bridge	4.21	R.C. Flat Slab	1913	45	H-10	16,000
Lumaha'i Bridge	5.88	Cont. Concrete	1968	538	HS 20	32,000
Wainiha Bridge #1	6.4	Steel Truss Deck	1969	42	H10	16,000
Wainiha Bridge #2	6.86	Seel Truss Deck	1973	78	H15	16,000
Wainiha Bridge #3	6.7	Steel Truss Deck	1975	146	H15	16,000
Kaua'i Route 56						
Waiakalua Bridge	20.29	PrSt. Conc. Gdr	1967	39	HS20	40,000
Kīlauea Bridge	22.92	Presetressed Beam	1973	258	HS20	40,000
Structure #4	24.9	RC SlabBr.	1963	50	CHN	40,000
Kalihiwai Bridge	25.01	Prestressed Concrete	1963	798	RW	50,000

*Information provided by the Hawai'i Department of Transportation.

Typical 15- and 20- passenger vans have gross vehicle weights (includes passengers and load) of approximately 10,000 lbs.

D. Shuttle Cost Estimate

Assumptions

- Based on information collected in 2011.
- Per-van cost $920/day
  - Driver cost: $600/day
  - Van O&M: $300/day
  - Van cost (amortized over 5 years): $20/day
- Administrative costs:
  - Assume 2 positions (1 full-time, and 1 part-time) in addition to a web startup fee (not based upon any research). $610/day with amortized web startup fee.
    - $577/8 hours = $72.12/hour for Administrator (incl. overhead cost).
    - $33*365 days*5 years = $60,000 for web startup fee.
- Round trip duration: 70 minutes
- ADA accessibility: It was assumed that an ADA-accessible van would render approximately 4-5 seats unusable. This will vary depending upon the make and model of the van.
- Van capacity: 15 persons (20-person van with reductions for wheelchair capability and partial occupancy).

- Visitor demand: Approximately 2,000 daily (in 1993, the demand was 750,000 persons/year ~ 2055 persons/day)
- Number of cars entering the park per day in 2008: 780 veh/day. (x2.5 = 1950 persons/day)
- Contingency:
  - Chosen based upon judgment. Realistically, there will be slow days and erratic arrivals when smaller revenue will be generated:
    - Rainy day
    - Cold/winter day
    - Economic problems
    - Road closures
    - Etc.
  - Shuttle contracts will often be 3-5 years instead of as-needed.
- No allowance made for park operations outside of administrative position. For example, no lease fees were included for parking at the Princeville Center.
- No explicit knowledge of website operation/administrative costs. This is considered a "best guess."
- **Note: The estimates provided below portray minimalist costs. The Kaua'i Bus and Speedishuttle both operate with costs of approximately $20 per round trip, but might have higher contingency costs. Note also that the Kaua'i Busses operate with greater carrying capacity per bus.**

Five scenarios were considered:

<u>Scenario 1: 900-person limit with no shuttle</u> – (No shuttle).

<u>Scenario 2: 900-person limit with 50 stalls and shuttle</u> – Shuttle ridership is estimated to be 775 per day, with the other 125 arriving via vehicles using day-long parking passes; 6 vans necessary to operate continuously to meet this demand.

- Assumes that people will be beholden to the shuttle schedule, and that there will be 10 trips/day (arrivals can only occur during 9 of them).
- Carrying capacity:
  - 6 ADA Vans x 15 persons/trip x 9 trips/day = 810 persons/day>775 2persons/day requirement.
- Cost
  - 6 vans @ $920/day = $5,520
  - Administrator w/web startup @$610/day = $610
  - Total = $6,130/day
  - Per rider @775 riders = $7.91/person/day
  - With 30% contingency for low or sporadic ridership, etc. = **$10.28 /person/day**

<u>Scenario 3: 900-person limit without parking lot and with shuttle</u> – Shuttle ridership is estimated to be 900 per day; 7 vans necessary to operate continuously to meet this demand.

- Assumes that people will be beholden to the shuttle schedule, and that there will be 10 trips/day (arrivals can only occur during 9 of them).
- Carrying capacity:
  - 7 ADA Vans x 15 persons/trip x 9 trips/day = 945 persons/day>900 persons/day requirement.
- Cost
  - 7 vans @ $920/day = $6,440
  - Administrator w/web startup @$610/day = $610
  - Total = $7,050/day
  - Per rider @900 riders = $7.83/person/day
  - With 30% contingency for low or sporadic ridership, etc. = **$10.18 /person/day**

<u>Scenario 4: Unconstrained with 50 stalls and shuttle</u> – It is estimated that approximately 2,000 visitors per day visit Hāʻena State Park. During our field investigation, 775 vehicles per day were counted entering the park. Fourteen vans would be necessary to operate continuously in order to meet this demand.

- Assumes that the number of visitors remains constant at 2,000/day minus 125 persons that arrive by vehicle, but will be beholden to the bus schedule; no additional capacity allowed for peak demand. In essence, this is 1875/135 = 14 vans.
- Cost
  - 14 vans @ $920/day = $12,880
  - Administrator w/web startup @$610/day = $610
  - Total = $13,490/day
  - Per rider @1,875 riders = $7.19/person/day
  - With 50% contingency for low or sporadic ridership, etc. (higher due to increased demand volatility) = **$10.79/person/day**

<u>Scenario 5: Unconstrained without parking lot and with shuttle</u> – It is estimated that approximately 2,000 visitors per day visit Hāʻena State Park. During our field investigation, 775 vehicles per day were counted entering the park. Fifteen (15) vans would be necessary to operate continuously in order to meet this demand.

- Assumes that the number of visitors remains constant at 2,000/day and will be beholden to the bus schedule; no additional capacity allowed for peak demand. In essence, this is 2000/135 = 15 vans.

- Cost
  - 15 vans @ $920/day = $13,800
  - Administrator w/web startup @$610/day = $610
  - Total = $14,410/day
  - Per rider @2,000 riders = $7.21/person/day
  - With 50% contingency for low or sporadic ridership, etc. (higher due to increased demand volatility) = **$10.80/person/day**

Table 5 compares the estimated costs to those of other transit services.

Table 5: Comparison of Estimated Transit Costs

Name	Roundtrip Cost/Passenger	Cost/Bus/12-hour
HSP Shuttle -- Scenario 2 (900-Person Limit with 50 Stalls)	**$ 10.28**	**$ 920.00**
HSP Shuttle -- Scenario 3 (900-Person Limit without Parking Lot)	**$ 10.18**	**$ 920.00**
HSP Shuttle -- Scenario 4 (Unconstrained with 50 stalls)	**$ 10.79**	**$ 920.00**
HSP Shuttle -- Scenario 5 (Unconstrained without Parking Lot)	**$ 10.80**	**$ 920.00**
Kaua'i Bus	$ 11.41*	$ 828.00
SpeediShuttle	$ 18.00	$ 1305.99*
TheBus	$ 8.40	$ 609.46*

*Costs derived based on a ratio between Hāʻena State Park shuttle scenarios versus 12-hour cost per bus.

V. CONCLUSIONS

Traffic along Kūhiō Highway along the roads leading to Hāʻena State Park is relatively light. However, minor queuing exists at the 1-way historic bridges between Princeville and Hāʻena State Park. It is estimated that the bridges operate at approximately 39 percent of capacity.

The Hāʻena State Park Master plan seeks to:

1. Limit the number of daily visitors to 900 per day.
2. Reduce the number of on-site parking stalls to a maximum of 100.
3. Consider providing a shuttle between Hāʻena State Park and Princeville as an alternative.

<u>Traffic Analysis</u>

It is anticipated that the recommended improvements will reduce daily traffic through the 1-way historic bridges by as much as 35 percent during the critical PM peak hour of traffic, and improve operations along the 1-way historic bridges. Refer to Table 3 for a comparative analysis of the different scenarios.

<u>Shuttle</u>

Implementation of Scenarios 2-5 would require the creation of a shuttle service between Princeville and Hāʻena State Park.

The shuttle would consist of 20-passenger vans that would operate continuously between 6:00 AM and 6:00 PM, with a round-trip duration of 70 minutes. The cost of this service is estimated at between 10 and 11 dollars per round trip. This is consistent with the estimated $11.41 person/round trip cost for the Kauaʻi Bus.

It would appear that all of the bridges along the shuttle route would have adequate capacity to handle the gross vehicle weights.

The effect of the shuttle and vehicle access restrictions to the park would be a reduction in traffic along Kūhiō Highway.

VI. RECOMMENDATIONS

1. Implement scenarios 1, 2, or 3, described below. Options 4 and 5 are not recommended as they do not meet the objective of limiting the number of visitor arrivals to 900 persons/day.

   Scenario 1: 900-person limit with 100 stalls without shuttle – It is recommended that parking passes be issued and that carpooling be encouraged.

   Scenario 2: 900-person limit with 50 stalls and shuttle – Shuttle ridership is estimated to be 775 per day, with the other 125 arriving via vehicles using day-long parking passes; 6 vans necessary to operate continuously to meet this demand.

   Scenario 3: 900-person limit without parking lot and with shuttle – Shuttle ridership is estimated to be 900 per day; 7 vans necessary to operate continuously to meet this demand.

2. Seek federal funding (if available) for the capital improvement costs.

3. (Scenarios 2-3) Install signage at the Princeville Park ‘n Ride location to inform visitors that they must catch the shuttle to visit Hāʻena State Park unless they have obtained a parking pass in advance. Recommend that no entry tickets or parking passes be distributed at the park.

4. Require all persons, even those with annual passes to obtain entry ticket prior to entering Hāʻena State Park. This can be done through receipts, wristbands, or ticket stubs. This will prevent visitors from parking in surrounding communities or other nearby parking lots.

VII. REFERENCES

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3. FHWA Work Zone, Traffic Analysis Tools Volume IX: Work Zone Modeling and Simulation – A Guide for Analysis, (date unknown).
4. Hawaii Department of Transportation, Kuhio Highway (Route 560) Historic Roadway Corridor Plan, 2005.
5. The Keith Companies, Master Plan and Draft Environmental Impact Statement, 2001.
6. Transportation Research Board, HCM2010: Highway Capacity Manual, 2010.

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APPENDIX A

TRAFFIC COUNT DATA

Number	Date	Time	Wed.		Thu.		Fri. (Holiday)		Sat.		Sun.		Mon.	
			8/13/2008		8/14/2008		8/15/2008		8/16/2008		8/17/2008		8/18/2008	
			Enter (Channel 1)	Exit	Enter (Channel 1)	Exit	Enter (Channel 1)	Exit	Enter (Channel 1)	Exit	Enter (Channel 1)	Exit	Enter (Channel 1)	Exit
		12:00 AM			0	0	0	0	0	0	0	0	1	1
		12:15 AM			0	0	0	0	0	0	0	0	0	0
		12:30 AM			0	0	0	0	0	0	0	0	0	0
		12:45 AM			0	0	1	0	0	1	0	0	0	0
		01:00 AM			0	0	0	0	0	0	0	0	0	0
		01:15 AM			0	0	0	0	0	0	2	0	0	0
		01:30 AM			0	0	1	0	0	0	0	0	0	0
		01:45 AM			0	0	0	0	0	0	0	0	0	0
		02:00 AM			0	0	0	0	0	0	0	0	0	0
		02:15 AM			0	0	0	0	0	0	0	0	0	0
		02:30 AM			0	0	0	0	0	0	0	0	0	0
		02:45 AM			0	0	0	1	0	0	0	0	0	0
		03:00 AM			0	0	0	0	0	0	0	0	0	0
		03:15 AM			0	0	0	0	0	0	0	0	0	0
		03:30 AM			0	0	0	0	0	0	0	0	0	0
		03:45 AM			0	0	0	0	0	0	0	0	0	0
		04:00 AM			0	0	0	0	0	0	1	0	0	0
		04:15 AM			0	0	0	0	0	0	0	1	0	0
		04:30 AM			0	0	0	0	0	0	0	0	0	0
		04:45 AM			0	0	3	1	0	0	0	0	0	0
		05:00 AM			0	1	0	0	0	1	0	0	0	0
		05:15 AM			1	0	0	0	0	1	0	0	0	0
		05:30 AM			0	1	1	0	0	0	0	0	0	0
		05:45 AM			2	1	0	1	1	0	0	0	0	1
		06:00 AM			1	1	1	0	4	0	1	1	4	0
		06:15 AM			1	1	1	2	1	0	4	0	0	0
		06:30 AM			3	1	5	0	3	2	1	0	1	0
		06:45 AM			4	1	1	0	2	1	3	0	2	1
		07:00 AM			4	1	3	1	2	4	4	0	4	0
		07:15 AM			11	0	2	2	6	0	12	0	3	5
		07:30 AM			6	2	16	5	4	0	6	0	7	2
		07:45 AM			6	2	12	5	4	0	3	0	7	4
		08:00 AM			12	0	9	5	10	2	8	3	6	2
		08:15 AM			19	7	8	6	13	5	11	3	11	6
		08:30 AM			19	0	18	2	9	2	6	5	11	7
		08:45 AM			23	0	14	5	19	7	8	2	7	3
		09:00 AM			25	0	17	7	9	4	8	4	17	2
		09:15 AM			22	3	23	4	23	8	15	7	13	13
		09:30 AM			26	2	18	4	14	10	8	7	33	7
		09:45 AM			38	0	21	6	10	10	8	6		
		10:00 AM			38	7	22	10	30	10	10	12		
1	8/13/2008	10:15 AM	25	10	27	4	23	11	17	14	16	13		
2	8/13/2008	10:30 AM	27	11	29	13	15	7	18	10	21	10		
3	8/13/2008	10:45 AM	31	16	29	10	15	11	26	13	22	11		
4	8/13/2008	11:00 AM	31	23	28	22	18	20	22	13	16	6		
5	8/13/2008	11:15 AM	21	27	22	14	29	17	32	23	33	12		
6	8/13/2008	11:30 AM	21	24	33	20	23	16	18	18	24	22		
7	8/13/2008	11:45 AM	18	25	14	31	19	11	20	15	17	13		
8	8/13/2008	12:00 PM	20	18	22	31	23	20	26	21	27	17		
9	8/13/2008	12:15 PM	21	18	13	14	14	17	26	22	31	16		
10	8/13/2008	12:30 PM	21	20	18	21	18	21	20	28	24	26		
11	8/13/2008	12:45 PM	13	16	19	29	21	17	25	14	25	26		
12	8/13/2008	01:00 PM	26	29	18	26	12	19	24	25	25	18		
13	8/13/2008	01:15 PM	24	25	31	24	28	23	14	27	18	21		
14	8/13/2008	01:30 PM	19	15	14	32	15	15	18	17	27	21		
15	8/13/2008	01:45 PM	19	32	15	29	22	19	23	26	23	19		
16	8/13/2008	02:00 PM	21	27	15	35	23	27	27	27	27	22		
17	8/13/2008	02:15 PM	16	23	21	22	13	17	5	18	18	24		
18	8/13/2008	02:30 PM	16	23	15	23	10	22	26	20	18	18		
19	8/13/2008	02:45 PM	14	12	18	28	15	18	19	24	19	28		
20	8/13/2008	03:00 PM	18	26	11	26	15	19	19	16	29	20		
21	8/13/2008	03:15 PM	12	19	11	34	18	18	14	17	16	29		
22	8/13/2008	03:30 PM	17	30	16	36	11	26	18	24	19	25		
23	8/13/2008	03:45 PM	20	28	17	24	9	13	12	25	17	20		
24	8/13/2008	04:00 PM	12	25	4	18	12	18	18	25	6	21		
25	8/13/2008	04:15 PM	8	26	15	15	16	18	13	24	11	24		
26	8/13/2008	04:30 PM	16	26	8	19	12	11	20	30	12	15		
27	8/13/2008	04:45 PM	12	28	18	10	13	23	5	17	17	21		
28	8/13/2008	05:00 PM	10	14	9	21	13	19	8	21	14	19		
29	8/13/2008	05:15 PM	5	18	11	10	7	19	12	23	8	17		
30	8/13/2008	05:30 PM	11	12	6	15	10	16	3	16	11	21		
31	8/13/2008	05:45 PM	9	8	8	14	11	13	9	5	7	13		
32	8/13/2008	06:00 PM	14	9	4	7	5	10	7	8	12	17		
33	8/13/2008	06:15 PM	5	5	6	20	11	20	6	14	10	13		
34	8/13/2008	06:30 PM	10	1	7	8	9	16	5	5	12	10		
35	8/13/2008	06:45 PM	11	6	6	4	9	10	6	8	12	12		
36	8/13/2008	07:00 PM	12	2	5	17	4	10	6	5	7	11		
37	8/13/2008	07:15 PM	7	21	0	9	4	30	3	19	3	30		
38	8/13/2008	07:30 PM	2	22	2	7	1	11	1	9	1	17		
39	8/13/2008	07:45 PM	0	4	0	2	3	7	0	5	3	10		
40	8/13/2008	08:00 PM	0	1	3	1	0	3	2	2	0	8		
41	8/13/2008	08:15 PM	0	0	0	2	0	0	0	3	1	3		
42	8/13/2008	08:30 PM	1	1	0	2	2	0	3	1	0	3		
43	8/13/2008	08:45 PM	0	0	0	0	0	1	0	3	1	1		
44	8/13/2008	09:00 PM	0	0	1	0	0	1	0	0	0	1		
45	8/13/2008	09:15 PM	0	0	0	0	0	0	0	1	0	0		
46	8/13/2008	09:30 PM	0	0	0	0	1	1	0	0	0	0		
47	8/13/2008	09:45 PM	0	0	1	0	0	0	0	0	0	0		
48	8/13/2008	10:00 PM	0	0	0	0	1	1	1	1	1	0		
49	8/13/2008	10:15 PM	0	0	0	0	0	1	0	0	0	0		
50	8/13/2008	10:30 PM	0	0	0	1	0	2	0	0	0	1		
51	8/13/2008	10:45 PM	0	0	0	0	2	1	0	1	0	0		
52	8/13/2008	11:00 PM	0	0	0	0	0	2	0	0	0	0		
53	8/13/2008	11:15 PM	0	0	0	0	1	1	0	0	0	0		
54	8/13/2008	11:30 PM	0	0	0	0	0	0	0	2	0	0		
55	8/13/2008	11:45 PM	0	0	0	0	0	0	0	0	0	0		
	Daily Total				**831**	**781**	**753**	**736**	**761**	**773**	**780**	**776**		
					1612		1489		1534		1556			

APPENDIX B
CAPACITY ANALYSIS BASIS

WORK ZONE MOBILITY AND SAFETY PROGRAM

**Traffic Analysis Tools Volume IX: Work Zone Modeling and Simulation
A Guide for Analysts**

Wisconsin DOT Work Zone Signal Optimization

Wisconsin DOT Work Zone Signal Optimization

Work Zone Characteristics	
Transportation Analysis:	
Approach	Traffic Signal Optimization
Modeling Tools	Synchro/SimTraffic
Work Zones:	
Type	Type I and IV
Network Configuration	Isolated
Geographic Scale:	
Work Zone Size	Small
Analysis Area	Local

Use of Signal Optimization Tools in Work Zone Traffic Analysis

Signal optimization tools such as Passer, Synchro/SimTraffic, and Transyt 7F have a variety of applications for work zone analysis, especially in urban and suburban environments. Broadly speaking, these applications can be grouped in three categories:

1. Preparing timing plans for temporary signals used to manage traffic within a construction site.
2. Adjusting signal timing on corridors that are directly impacted by construction.
3. Adjusting signal timing to improve progression on corridors that serve as alternate routes or detours around a work zone.

Temporary Signals. Figure 29 shows an example of the use of Synchro/SimTraffic to optimize the timing of a temporary traffic signal. In this case, two-way one-lane operation will be in effect during a bridge construction project (in other words, eastbound and westbound traffic will be sharing a single lane). Synchro's Ring/Barrier Editor was used to create a configuration that mimics the operation of the temporary signal by alternately sending eastbound and westbound traffic along the restricted section. Synchro's signal optimization algorithm was then used to establish a timing plan that minimizes traffic delays. The analysis also provides an indication of the extent of queuing on the approaches to the one-lane segment, which is useful in determining wheth access to side roads will be blocked by queued traffic.

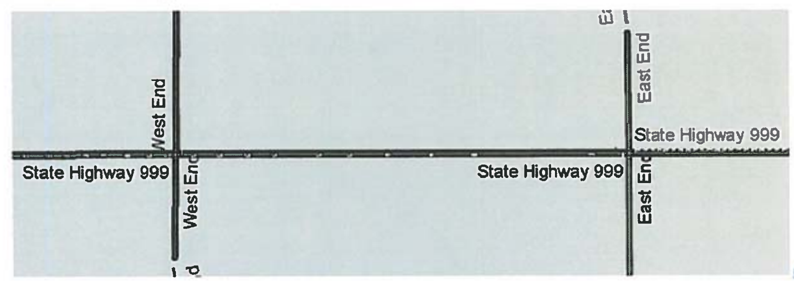

Figure 29 Synchro/SimTraffic Model of a Work Zone with Two-Way One-Lane Operation

*Note the westbound vehicles queuing while eastbound traffic is allowed to proceed.

This method can also be used to evaluate the impact of work zone length on capacity and throughput for sites with two-way one-lane operations. As shown Figure 30, the capacity of two-way one-lane sections is sensitive to the length of the restricted section. Therefore, in many cases there is a trade-off betwe what is convenient for construction operations and what is acceptable in terms of traffic impact.

Run Date: 2012/05/04

Hawaii Department of Transportation

Highways Division **Highways Planning Survey Section**

2011 Program Count - Summary

Site ID: B73056000391 **Town:** Kauai **DIR 1:** +MP **DIR 2:** -MP **Final AADT:** 0

Functional Class: RURAL:MAJOR COLLECTOR **Count Type:** CLASS **Counter Type:** Tube **Route No:** 560

Location: Kuhio Hwy b/t Waipa BR_end of stripe

TIME-AM	DIR 1	DIR 2	TOTAL	TIME-AM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL	TIME-PM	DIR 1	DIR 2	TOTAL
DATE : 07/14/2011															
12:00-12:15	4	1	5	06:00-06:15	6	4	10	12:00-12:15	57	36	93	06:00-06:15	30	39	69
12:15-12:30	3	1	4	06:15-06:30	6	4	10	12:15-12:30	52	42	94	06:15-06:30	37	34	71
12:30-12:45	1	2	3	06:30-06:45	9	13	22	12:30-12:45	45	50	95	06:30-06:45	31	32	63
12:45-01:00	1	1	2	06:45-07:00	13	15	28	12:45-01:00	47	41	88	06:45-07:00	23	27	50
01:00-01:15	2	0	2	07:00-07:15	20	12	32	01:00-01:15	62	41	103	07:00-07:15	18	23	41
01:15-01:30	1	1	2	07:15-07:30	8	18	26	01:15-01:30	53	37	90	07:15-07:30	27	21	48
01:30-01:45	0	0	0	07:30-07:45	14	22	36	01:30-01:45	57	36	93	07:30-07:45	13	18	31
01:45-02:00	0	2	2	07:45-08:00	22	29	51	01:45-02:00	47	57	104	07:45-08:00	17	26	43
02:00-02:15	1	1	2	08:00-08:15	28	19	47	02:00-02:15	43	63	106	08:00-08:15	16	21	37
02:15-02:30	3	1	4	08:15-08:30	19	15	34	02:15-02:30	53	57	110	08:15-08:30	17	17	34
02:30-02:45	1	0	1	08:30-08:45	23	27	50	02:30-02:45	58	52	110	08:30-08:45	20	8	28
02:45-03:00	1	0	1	08:45-09:00	36	27	63	02:45-03:00	50	54	104	08:45-09:00	11	8	19
03:00-03:15	0	0	0	09:00-09:15	45	29	74	03:00-03:15	46	67	113	09:00-09:15	8	12	20
03:15-03:30	0	1	1	09:15-09:30	42	20	62	03:15-03:30	44	67	111	09:15-09:30	11	10	21
03:30-03:45	1	0	1	09:30-09:45	46	23	69	03:30-03:45	55	94	149	09:30-09:45	8	1	9
03:45-04:00	0	0	0	09:45-10:00	52	37	89	03:45-04:00	40	74	114	09:45-10:00	10	6	16
04:00-04:15	1	0	1	10:00-10:15	35	34	69	04:00-04:15	34	68	102	10:00-10:15	14	5	19
04:15-04:30	0	1	1	10:15-10:30	46	21	67	04:15-04:30	32	61	93	10:15-10:30	8	5	13
04:30-04:45	0	2	2	10:30-10:45	55	26	81	04:30-04:45	51	53	104	10:30-10:45	6	3	9
04:45-05:00	0	1	1	10:45-11:00	38	36	74	04:45-05:00	26	56	82	10:45-11:00	6	3	9
05:00-05:15	2	3	5	11:00-11:15	51	46	97	05:00-05:15	28	57	85	11:00-11:15	9	1	10
05:15-05:30	1	7	8	11:15-11:30	69	39	108	05:15-05:30	40	59	99	11:15-11:30	9	0	9
05:30-05:45	2	1	3	11:30-11:45	50	39	89	05:30-05:45	41	43	84	11:30-11:45	9	1	10
05:45-06:00	3	4	7	11:45-12:00	43	38	81	05:45-06:00	37	51	88	11:45-12:00	7	4	11

	DIR 1	DIR 2			DIR 1	DIR 2	
AM COMMUTER PERIOD (05:00-09:00)	DIR 1	DIR 2		PM COMMUTER PERIOD (15:00-19:00)	DIR 1	DIR 2	
TWO DIRECTIONAL PEAK				TWO DIRECTIONAL PEAK			
AM - PEAK HR TIME	08:00 AM to 09:00 AM			PM - PEAK HR TIME	03:00 PM to 04:00 PM		
AM - PEAK HR VOLUME	106	88	194	PM - PEAK HR VOLUME	185	302	487
AM - K FACTOR (%)			4.28	PM - K FACTOR (%)			10.75
AM - D (%)	54.64	45.36	100.00	PM - D (%)	37.99	62.01	100.00
DIRECTIONAL PEAK				DIRECTIONAL PEAK			
AM - PEAK HR TIME	08:00 AM to 09:00 AM	07:45 AM to 08:45 AM		PM - PEAK HR TIME	03:00 PM to 04:00 PM	03:15 PM to 04:15 PM	
AM - PEAK HR VOLUME	106	90		PM - PEAK HR VOLUME	185	303	
AM PERIOD (00:00-12:00)				PM PERIOD (12:00-24:00)			
TWO DIRECTIONAL PEAK				TWO DIRECTIONAL PEAK			
AM - PEAK HR TIME	11:00 AM to 12:00 PM			PM - PEAK HR TIME	03:00 PM to 04:00 PM		
AM - PEAK HR VOLUME	213	162	375	PM - PEAK HR VOLUME	185	302	487
AM - K FACTOR (%)			8.28	PM - K FACTOR (%)			10.75
AM - D (%)	56.80	43.20	100.00	PM - D (%)	37.99	62.01	100.00
NON-COMMUTER PERIOD (09:00-15:00)				6-HR, 12-HR, 24-HR PERIODS	DIR 1	DIR 2	Total
TWO DIRECTIONAL PEAK				AM 6-HR PERIOD (06:00-12:00)	776	593	1,369
PEAK HR TIME	01:45 PM to 02:45 PM			AM 12-HR PERIOD (00:00-12:00)	804	623	1,427
PEAK HR VOLUME	201	229	430	PM 6-HR PERIOD (12:00-18:00)	1,098	1,316	2,414
DIRECTIONAL PEAK				PM 12-HR PERIOD (12:00-24:00)	1,463	1,641	3,104
PEAK HR TIME	01:00 PM to 02:00 PM	01:45 PM to 02:45 PM		24 HOUR PERIOD	2,267	2,264	4,531
PEAK HR VOLUME	219	229		D (%)	50.03	49.97	100.00

Peak Bi-directional Volume

CAPACITY @ Waipa BRIDGE = 1400

conclusion: → Waipa bridge op at 35% cap.

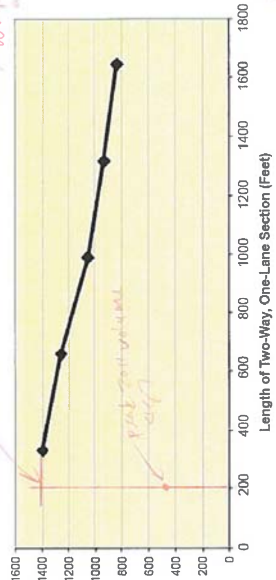

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Figure 30 Capacity vs Length for Two-Way One-Lane Flagging Operations

Adjusting Timing on Corridors Affected by Construction. Normally, signal timing plans are developed based on the assumption that all of the lanes t exist at each intersection will be available for traffic to use. This assumption may not be true during construction. For example, take an intersection where two of the three lanes have been closed to traffic. In this case, all traffic is directed to use the right lane, severely impacting the capacity of the signalized intersection.

In such situations, to avoid excessive queuing and delay it may be necessary to make fundamental changes in the signal timing at individual intersections c along an entire corridor. In the example shown in the photo, it may be desirable to increase the cycle length to compensate for the fact that left, thru, and right turning vehicles are sharing a single lane. To maintain good traffic progression along the corridor, signal offsets may need to be adjusted to account f reduced travel speeds. In addition, temporary changes in access to business properties along the corridor may affect turn patterns, requiring adjustments i signal phasing and splits. The use of a signal optimization tool allows all of these variables to be addressed comprehensively.

Adjusting Timing on Parallel Routes. The Daniel Webster Hoan Memorial Bridge carries Interstate 794 over the Milwaukee River in Milwaukee, Wiscons As shown in Figure 31, on December 13, 2000 there was a structural failure on one span of the bridge. The failure required immediate lane closures, resulting diversion of all traffic to other routes.

To accommodate increased traffic on the arterial street that runs directly parallel to I-794, the City of Milwaukee used signal optimization tools to prepare a revised traffic signal timing plan for the Kinnickinnic Avenue/First Street corridor (WIS 32). The revised signal timing plan was implemented less than 48 hours after the incident occurred (and at minimal cost). It increased the green time allocated to north-south thru traffic, and reduced the amount of time allocated to side streets. The revised signal timing is believed to have been instrumental in reducing traffic delays and minimizing the overall impacts of th bridge failure and subsequent reconstruction activities.

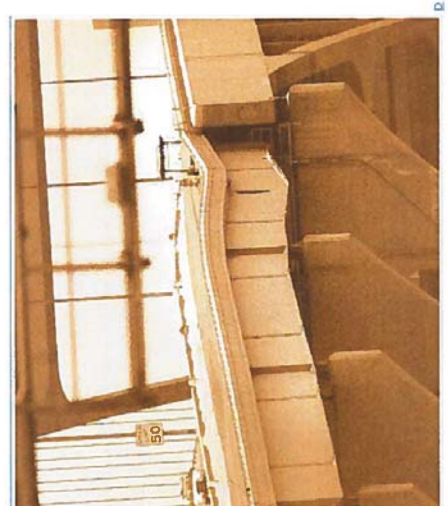

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Figure 31 Structural failure on Daniel Webster Hoan Memorial Bridge, December 13, 2000.

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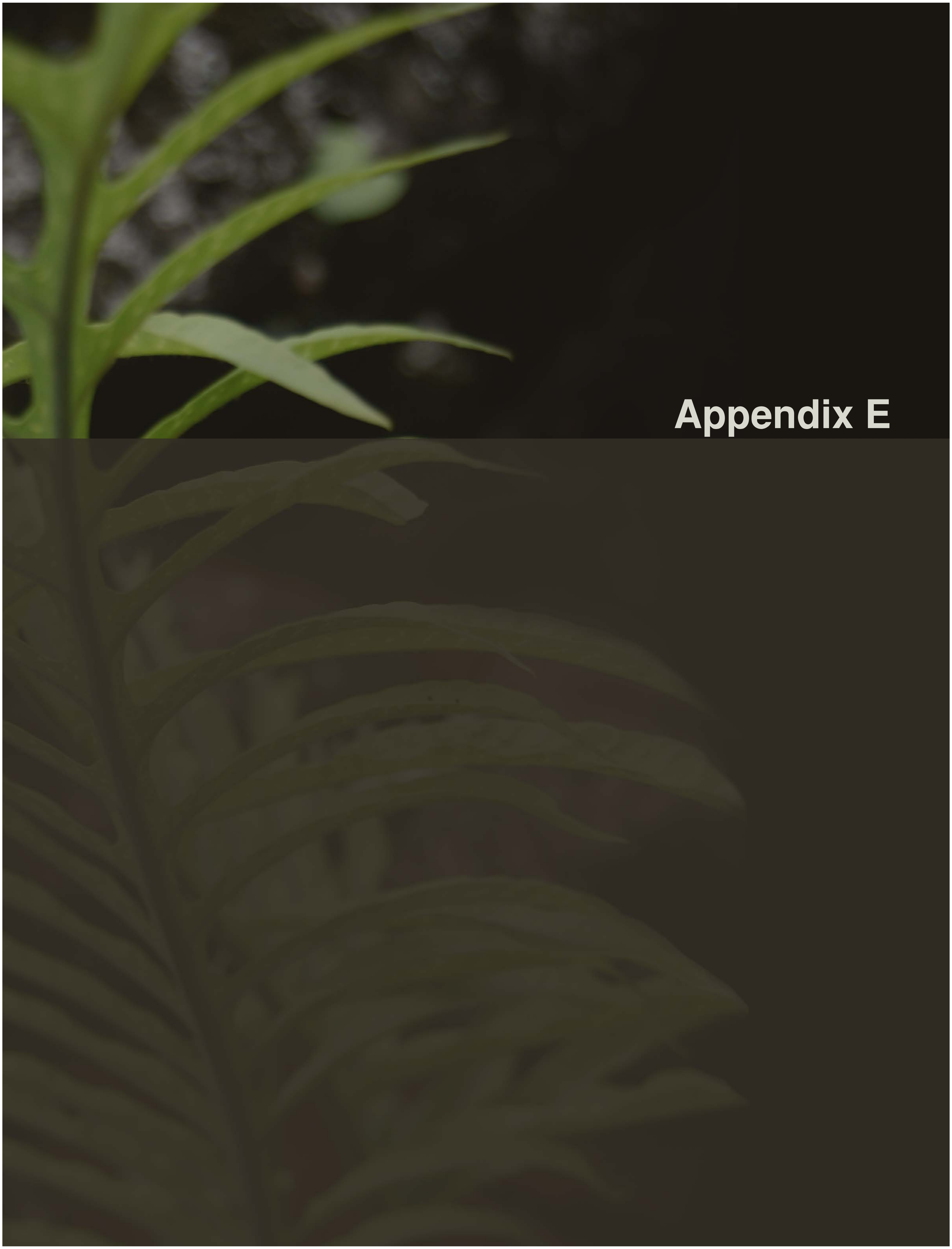
FHWA



Appendix E

Kennedy/Jenks Consultants

Hawaii Office (formerly Engineering Solutions, Inc.)
98-1266 Kaahumanu Street, Suite 204
Pearl City, Hawaii 96782
808-485-2223
FAX: 808-488-3776

Wastewater Preliminary Engineering Report

Haena State Park Master Plan

Prepared for

PBR Hawaii & Associates, Inc.
1001 Bishop Street, Suite 650
Honolulu, Hawaii 96813

November 2010

K/J Project No. 1000711.00

WASTEWATER PRELIMINARY ENGINEERING REPORT
HAENA STATE PARK MASTER PLAN

TABLE OF CONTENT

I. INTRODUCTION

A. Project Location and Description

Haena State Park is located on the north shore of Kauai, at the end of Kuhio Highway. It is bounded by the Na Pali Cliffs to the west, the base of Makana to the south, Limahuli Stream to the east and the Pacific Ocean to the north.

There are three (3) TMK parcels within the Park boundary. The parcel north of Kuhio Highway is identified by TMK 5-9-008:001 and encompasses approximately 52 acres. South of Kuhio Highway, parcels TMK 5-9-001:022 and 025, encompasses approximately 180 acres.

The parcels identified by TMK 5-9-008:001 and 5-9-001:022, are owned by the State of Hawaii. The third parcel, TMK 5-9-001:025 contains the Kauluapaoa Heiau and Keahualaka hula platform and is owned by the County of Kauai and managed by the State Historic Preservation Division (SHPD), Department of Land and Natural Resources (DLNR). Haena State Park utilizes approximately 65.7 acres of the coastal area for recreational uses.

The Park experiences heavy usage throughout the week and is considered one of the highest utilized parks in the State. It is used by the public for picnics, snorkeling, swimming and hiking. It is estimated approximately 708,400 visitors experienced the many geological and cultural features of this unique park in 2007.

II. EXISTING SITE CONDITIONS

A. Soil

Based on *Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii*, five soil classes are present at Haena State Park. Its western coastline consists of Mokuleia fine sandy loam (Mr), while its northern coast is defined as Beach (BS). Marsh (MZ), Hanalei silty clay (HnA) and Hanalei silty clay with deep water table (HrB) are present further inland.

Beach soil extends up to 150 feet inland from the northern coast. This soil consists of light-colored sands resulting from the breakdown of coral and seashells.

Mokuleia fine sandy loam extends up to 800 feet inland from the western coast. Its surface layer contains 16 inches of fine sandy loam and its subsurface contains 34 to 48 inches of single-grain and loamy sand. This soil exhibits moderately rapid permeability in its surface layer and rapid permeability in its subsurface.

Marsh soil is present approximately 800 feet inland from the western coast of Haena State park. This soil type covers small, low-elevation areas where water stands at the ground surface. Grasses, bulrushes and other herbaceous plants thrive in these areas.

Hanalei silty clay (HnA) soil is present in the western and inland portions of the Park. Its surface layer contains 13 inches of dark-gray, silty clay, of which the top 10 inches

contain brown and red mottles. Its subsoil contains 13 inches of dark-gray and dark grayish-brown silty clay loam. The water table in this soil type is typically less than 3 feet below the ground surface. This soil experiences moderate permeability and is strongly acidic in its surface layer.

Hanalei silty clay with deep water table is present in the eastern and inland portions of the Park. This soil is similar to Hanalei silty clay; however it contains fewer mottles and is located in areas where the water table is greater than 3 feet below the ground surface.

Soil test borings and percolation tests were not performed specifically for this preliminary engineering report. Instead, the previously performed percolation test results at the existing comfort station are referenced to preliminarily size the disposal fields. Percolation rates test results of 4.14 minutes/inch were obtained in December 2009 for the constructed wetland project at the existing Ke'e comfort station.

B. Topography

The Master Plan incorporates improvements and facilities north of Kuhio Highway and leaves the areas south of Kuhio Highway virtually untouched. The ground elevation in this area ranges from sea level to approximate 70.0 feet above mean sea level (MSL) at the entrance to the Park.

The ground elevation south of the Kuhio Highway rises sharply with steep slopes and form the cliffs of Napali beyond the shoulder of the roadway.

The 100-year base flood elevation ranges from sea level to elevation 24.0 feet above MSL.

C. Wastewater System

The original comfort station at Ke'e Beach was constructed in 1979 under DLNR Job No. 54-KP-11. It consisted of 3 water closets, 1 urinal and 2 lavatories. These fixtures drained into a 6.0 to 8.0 foot diameter cesspool, approved by DOH.

In 2001, the cesspool was replaced by a 2,500 gallon septic tank and approximately 2,700 square foot (sf) leach field located to the north and east of the comfort station. Record drawings for the construction of the individual wastewater system replacement were not available.

In 2008, the existing comfort station was demolished and replaced, under DLNR Project No. H10C663A. The new comfort station retains the same fixture count as its predecessor; 3 water closets, 1 urinal and 2 lavatories, which is estimated to generate 2,016 gpd.

The outdoor shower is located to the south of the comfort station. Greywater from the showers is allowed to drain and infiltrate into the surrounding soils.

In the Fall of 2010, the wastewater system for Ke'e Beach comfort station will be modified and upgraded to add a subsurface constructed wetland to further treat and improve water quality of the wastewater before discharging into the ground, at the request of the community. The system consists of 4-inch diversion valves and piping; 2-

1,500 gallon primary treatment fiberglass tanks with battery-operated alarm control and panel; 968 sf of constructed wetland and 1,358 sf of infiltration field and appurtenances. The existing septic tank and leach field will continue to serve as an emergency backup system in the event the constructed wetlands system goes down.

Electric power is currently not available anywhere within Haena State Park and has been a limiting factor in the development of other wastewater treatment options.

In addition to the existing wastewater system for the comfort station, an abandoned cesspool was found at the old house site near Limahuli Stream. The existing Allerton House and Caretaker's cottage should also have abandoned cesspool(s). If any of these facilities are renovated the wastewater systems should also be upgraded or abandoned completely.

III. DESIGN PARAMETERS

In 2001, The Keith Companies developed a Community Preferred Master Plan for Haena State Park. The Community Preferred Master Plan and all other alternatives discussed proposed two (2) restroom facilities. This included restoration and retrofit of the existing comfort station at Ke'e Beach and a new facility near the visitors center consisting of either chemical or compost toilets. In addition, the wastewater facilities for the caretaker's cottage and the DLNR Park's baseyard would have had to be considered although they were not specifically discussed in the report.

The 2010 revised version of the 2001 draft Master Plan consolidates any new facilities to a central area around the existing parking lot, thereby consolidating the wastewater treatment and disposal system. In addition, electrical power will be brought in to the existing parking lot to service the new visitors center and other facilities.

Based on the new concept and on-going community meeting discussions, the following parameters were used to evaluate wastewater alternatives and provided initial guidelines and recommendations.

A. Existing Comfort Station and other Wastewater Facilities

The existing comfort station at Ke'e Beach and its individual wastewater system consisting of primary treatment tanks, constructed wetlands and infiltration field will remain in service. Other existing wastewater system on existing facilities, specifically cesspools, will be abandoned and not utilized even if the facility it is serving is renovated. A new individual wastewater system will be required.

B. Wastewater Flow

The treatment and disposal of wastewater is regulated by the State of Hawaii Department of Health, under the Hawaii Administrative Rules (HAR) Title 11, Chapter 62. Because there is no public county sewer system in the area, the State Department of Health (DOH) regulates and oversee the wastewater system at Haena State Park.

The existing comfort station at Ke'e Beach is sized to handle 2,016 gallons per day (gpd) which currently handles the entire population of the Park. Any additional restroom facilities would help reduce and split this flow amongst the various restroom facilities.

As it is the goal of the community to limit the usage of the Park and protect its ecology, the 2,016 gpd of generated wastewater flow should be initially used as the estimated quantity for design. This equates to approximately 403 visitors per day, based on 5 gallon per person per day for picnic parks (toilet wastes only) per DOH standards.

C. Water Quality and Reuse

To use treated wastewater for any other use then disposal is regulated the "*Guidelines for the Treatment and Use of Reclaimed Water*", prepared by Hawaii State Department of Health (DOH), Wastewater Branch, May 15, 2002. In essence the DOH recognizes three (3) levels of recycled water, simply defined as follows:

> **R-1 water**, the highest level of treatment is wastewater treated by oxidation to secondary effluent (Biochemical Oxygen Demand (BOD) <30, Total Suspend Solid (TSS) <30), then filtered to 2 NTU turbidity and disinfected with fecal coliform shall not exceed 2.2 per 100 ml using 7 days of results, 23 per 100 ml in more than one sample in 30 day period and 200 per 100 ml in any sample.
>
> **R-2 water** is disinfected, secondary treated wastewater with effluent fecal coliform shall not exceed 23 per 100 ml using 7 days of results and 200 per 100 ml in more than one sample in a 30 day period.
>
> **R-3 water** is an undisinfected, oxidized, wastewater effluent.

A summary of suitable uses for the various levels of treated wastewater is provided on Table 3-1 from their Guidelines, which can be found in Appendix A.

IV. WASTEWATER TREATMENT ALTERNATIVES

The various possible wastewater treatment alternatives discussed below are summarized on fact sheets from the State of Hawaii, Department of Health, "*On-Site Wastewater Treatment Survey and Assessment Study*", January 2008. These fact sheets can be found in Appendix B.

A. Holding Tanks

Holding tanks do not provide any treatment, but also do not discharge treated wastewater effluent on-site. Holding vessels are sized to temporarily handle a few days' supply of wastewater and allow the pumper truck to periodically remove the wastewater from the Park.

Because of the remoteness of Haena State Park, narrow roadways and multiple one-lane bridges leading to the Park, this is not a very attractive option for pumper trucks and not economically viable.

B. Waterless/Low Water Systems including Compost Toilets

Composting toilets have been implemented in unsewered, rural, and suburban areas for over 30 years. These toilets do not require water and process human waste with aerobic digestion in unsaturated conditions. If used correctly, solid waste is reduced to 10 to 30% of its original volume. However, it takes a long period of time to decompose before it is suitable for soil amendment. They are not meant for high usage. In addition, the waste material may have to be removed by a septage vacuum pump truck periodically, therefore the toilets should be placed in an area accessible to a truck.

Composting toilets are environmentally friendly if used correctly. They have been installed at various places in Kauai, including trails at Hanakapi'ai, Hanakoa, and Kalalau as well as at the adjacent, Limahuli Garden.

Two main types of composting toilets are available, one with the decomposition chamber attached to the toilet and one with the chamber separated from the toilet. Aside from the two main types, there are many composting toilet modifications available to facilitate the aerobic treatment process. Oxygen is required for an aerobic treatment process and a constant supply and concentration of oxygen will accelerate the treatment process. Also, odor reductions incurred by the modifications also reduce vector (pest) attraction to fresh waste. Some of the available modifications are as follows:

a. Waste can be periodically separated into different containers based on its age, allowing older wastes to continue the process of decomposition without being contaminated by fresh waste. Urine is evaporated while aerobic digestion decomposes fecal material.

b. Electric fans can be added to facilitate the aerobic digestion process within the decomposition chamber by exchanging gaseous by-products of aerobic digestion with oxygen from outside of the chamber. The addition of a fan will require electric power to the site.

c. A mechanical device can be installed to churn decomposing material to ensure an adequate oxygen supply for aerobic bacteria. The addition of a churning device will require electric power to the site.

d. Cover materials including saw dust, peat moss, rotted leaves, straw, grass clippings and other organic materials can be used to soak up liquid and eliminate odors. This method separates the urine from the feces and allows fecal decomposition to continue without odors. Cover materials must be restocked as needed and users are given the responsibility of maintaining them.

e. Separate chambers for urine and feces will allow urine to undergo nitrification. This process turns urine into an odor free and nearly pathogen free liquid. Fecal matter will still decompose through aerobic digestion.

f. In the absence of electric service, non-electric toilets or solar power can be used. Non-electric toilets are limited to 4 persons a day for vacation use and 2 persons a day for continuous use, assuming 3 uses per person every day. A solar panel can be installed to power a ventilation fan. Solar powered toilets are limited to 6

persons a day for vacation use and 4 persons a day for continuous use, assuming 3 uses per person every day.

Composting toilets have an expected service life of over 25 years. Installation can be moderately priced, depending on the type and number of composting toilets. For electric versions, there is a small daily electric cost associated with powering the fans and churning equipment. Power consumption for the fans and churners typically range between 365 to 3000 kWh/year.

C. Septic Tanks

Septic tanks are the traditional way of disposing of on-site wastewater from remote locations. They are generally used to remove scum, grease and solids while providing some primary anaerobic treatment before discharge into the disposal system. Inert material, slow decomposing solids, grease and scum will accumulate in the septic tank and must be periodically removed. Septic tanks are sensitive to soaps, chemicals and large flows of water as the system relies on anaerobic bacteria growth to breakdown biological wastes. If the septic tank is upset due to these factors, wastewater will not receive normal treatment and effluent may shorten the lifespan of the disposal system.

There are two types of septic tanks available for commercial use, single chambered and double chambered. Both types of septic tanks rely on tank volume to provide wastewater detention times long enough to separation of solids from the wastewater flow. As wastewater influent enters the tank, its velocity is slowed to a rate where particles mixed with the water can settle out of the liquid either by sinking or floating. In a healthy septic tank, there are distinguishable sludge and scum layers on the bottom of the tank and on the water surface, respectively. A baffle on the effluent end of the septic tank allows clarified water, from between the sludge and scum layers in the tank, to drain into the disposal system.

Double chamber septic tanks are similar to single chamber tanks with the exception of a concrete separator that forces the wastewater to enter two chambers before leaving the tank. The first chamber typically utilizes the first two-thirds of the tank length and works similarly to a single chamber septic tank. Holes in the concrete separator at 40% the depth of the tank allows clarified water to enter the second chamber of the tank, while sludge and scum on the tank bottom and water surface are detained in the first chamber. The second chamber acts similarly to a single chamber septic tank, allowing some anaerobic treatment while remaining solids are allowed to separate from the wastewater. Much like the single chamber septic tank, a baffle is used on the effluent end of double chamber tanks. The result of using two chambers is a better quality effluent with less suspended solids that could "boil over" into the disposal system.

Commercial septic tanks in Hawaii are made of pre-cast concrete or fiberglass and are typically available in sizes between 750 and 5,000 gallons. Some sizes can be cast in Honolulu, but most must be shipped from the continental United States. Access to the site may be a limiting factor in the maximum size of tank provided.

Septic tanks have an expected service life of 50 years or more. The cost of installation and materials is moderate, depending on the type of tank and the site conditions present. Periodic maintenance costs include the removal of grease, scum and solids by a vacuum septic pump truck. Areas where septic tanks are installed must be accessible by these trucks. Due to the differing conditions, some tanks may accumulate solids faster than others, making it difficult to determine a "rule-of-thumb" time period for pumping. Most public facilities should be initially pumped and monitored quarterly until a required frequency pattern is established.

D. Aerobic Treatment Units

Aerobic treatment units (ATU) are typically used when wastewater effluent quality must be higher than produced by septic tanks. ATU generally uses mechanical components to oxidize organic material, decrease suspended solids and reduce pathogens.

The standard aerobic treatment process consists of the following four stages:

a. Solid Removal – A pre-loader receives wastewater from the building sewer before it reaches the aerobic treatment unit. The pre-loader works like a septic tank to remove solids from the wastewater flow.

b. Aeration – After solid removal, the wastewater flows into the aerobic tank's first compartment, where mechanical blowers introduce oxygen into the compartment to fuel the aerobic treatment of biological waste.

c. Settling – Wastewater then flows into the next compartment, where activated sludge are allowed to settle out of the wastewater.

d. Disinfection – The final stage is an optional disinfection stage. This stage can be implemented or omitted depending on the quality of effluent required or preferred before disposal. Disinfection is typically accomplished through the use of chlorine tablets. Other disinfection options include liquid chlorine or ultra-violet (UV) light. By providing disinfection, R-2 water quality is achieved.

Aerobic treatment unit efficiency is dependent on temperature, tank geometry, tank material, concentration of solids, and type of mixing/aeration device. It is also, highly sensitive to changes in wastewater composition.

Aerobic treatment unit mechanical components have a service life of 10 to 20 years. They cost significantly more than septic tanks because of the higher material costs and extra equipment that must be installed with the aerobic unit. Also, there is a small daily electric cost associated with the aeration equipment, pumps and disinfection equipment. Power consumption for an aerobic treatment unit is typically 700 to 3,600 kWh/year.

A form of an aerobic treatment unit is a sequence batch reactor (SBR), with the characterizing difference of a single chamber used for all processes including equalization, biological treatment, and secondary clarification. It is a fill-and-draw activated sludge system that requires two or more reactors in a pre-programmed sequence of operation of at least 4 steps.

The SBR produces better effluent quality than septic tanks and aerobic units, but requires sophisticated equipment and higher levels of maintenance. Electrical power is required for this alternative. According to the EPA, the SBR uses approximately 1100 to 3650 kWh/year.

E. Centralized Wastewater Treatment Systems

In a centralized treatment system, waste from each facility are collected, treated and disposed of at a central location. This alternative may require some sites to install a small pump station to lift the wastewater to the central treatment plant, if located at a lower elevation than the treatment plant and are not able to be piped by gravity.

A conventional package treatment plant, like the ATU and SBR, is able to provide reliable, high quality secondary effluent and with continuous disinfection, at least R-2 water for reuse. With additional filtration and disinfection, these systems could produce R-1 water.

They are available in concrete, fiberglass and corrosion control coated steel. Experienced labor and a certified wastewater operator are required to maintain a package treatment plant due its sophisticated control system and monitoring and recordkeeping requirements. Electrical power is required for this alternative. Mechanical components for the treatment plant and lift stations have service life of 10 to 20 years.

F. Natural Systems including Constructed Wetlands

Of the natural treatment systems, a constructed wetlands system as being installed at the existing comfort station was evaluated for its cost effectiveness treatment. There are two (2) types of constructed wetlands used in the United States as briefly described in "*Natural Systems for Wastewater Management and Treatment*", by Reed, Crites and Middlebrooks:

> "Free-water surface (FWS) wetland. In this type, the water surface is exposed to the atmosphere, the bed contains emergent aquatic vegetation, a layer of soil to serve as a root media, a liner if necessary to protect the groundwater, and appropriate inlet and outlet structures. The water depth in this type of wetland can range from a few centimeters to 0.8 meter or more, depending on the purpose of the wetland. Normal depth of 0.3 m (1 foot) is typical.
>
> Subsurface-flow (SF) wetland. In this case the excavated basin is filled with a porous media, usually gravel and the water level is maintained below the top of the gravel. The same species of vegetation are used in both types of wetlands. In the SF case the vegetation is planted in the upper part of the gravel media. A liner is also used, if necessary to protect groundwater quality. The depth of the media is typical 0.3-0.6 m (1-2 feet)."

These systems require pretreatment to remove the solids before biological treatment. Aeration is also recommended to improve water quality, if possible. These systems generally require more land area than most on-site systems, require start-up periods to establish vegetation and may require backup systems for rainfall.

Currently, there are no regulations in Hawaii governing the construction and management of these systems and require special approval on a case by case bases from DOH.

V. WASTEWATER DISPOSAL ALTERNATIVES

The various possible wastewater disposal alternatives discussed below are summarized on fact sheets from the State of Hawaii, Department of Health, "*On-Site Wastewater Treatment Survey and Assessment Study*", January 2008. These fact sheets can also be found in Appendix B.

A. Absorption Bed

An absorption bed is the typical disposal system for individual wastewater systems, unless conditions require a smaller disposal area. Synonymous to the term leach field, it consists of leaching chambers placed on a level sub-grade surface. Traditionally, perforated pipe with gravel beds had previously been used, but is no longer preferred as it tends to clog and eventually lead to failure. Perforated pipe also provides a lower available detention volume than leaching chambers. The size of the absorption bed is dependent on the amount of flow and the soil percolation rate in the installation area.

This disposal system can be used with septic tanks, aerobic units, natural systems and as redundant, backup systems for wastewater treatment with reuse. As with any constantly used systems, suspended solids in effluent and bacteria in the soil will accumulate in the absorption bed until the soil can no longer handle its hydraulic loading. This failure usually occurs 20 to 30 years after installation. However, the leaching chambers make this system easier to maintain and rehabilitate.

B. Seepage Pit

Seepage pits are not usually used unless special conditions warrant it. It is the preference of DOH to use absorption bed versus seepage pit for disposal as the absorption beds distributes the wastewater load over a larger area versus a concentrated discharge. Seepage pits are classified as underground injection wells in the State of Hawaii and may require yearly monitoring and sampling as determined by DOH.

Existing cesspools have been converted to seepage pits in cases where site area is limited and the groundwater table is not affected.

C. Water Resource Management and Reuse

The Kauai Department of Water provides potable water to the site through a 4-inch PVC water line that terminates at the entrance to the Park with a 1-inch water meter (Water Meter No. 083000140). Within Haena State Park, a 3-inch galvanized iron pipe runs along the edge of Kuhio Highway in an east-west direction until its terminus at the Ke'e beach comfort station. Recorded water usage from October 2003 to November 2006 is documented to average 2,125 gpd. It should be noted these records are before the showers were installed. The average usage matches closely to the estimated wastewater generated.

A non-potable, 6-inch HDPE pipe diverts an average of 760,000 gallons per day (gpd) of water from Limahuli Stream to irrigate the loi (taro patches) field north of Kuhio Highway

and west of the parking lot.

Besides these 2 water sources, rainwater and natural springs provide water for the abundant plant life around the Park.

Depending on the quality of the treated effluent, use of the reclaimed water for various irrigation and other non-potable uses can be identified and implemented with the Master Plan based on the DOH Recycled Water Table 3-1. Consideration should be given to the following:

1. Reusing treated wastewater for the landscaping around the new Visitors Center, Maintenance Baseyard and Caretaker's Cottage.
2. Reusing wastewater and stormwater off the existing parking lot for toilet flushing at the Visitors Center to conserve water.
3. Reducing stream diversion by collecting, storing and using rainwater.
4. Capturing and storing rainwater for non-potable uses.
5. Using non-potable water for fire protection.

VI. SUMMARY AND EVALUATION OF ALTERNATIVES

A matrix summarizing the various treatment alternatives advantage, disadvantage, impacts on the park and potential uses is provided on the following table.

Disposal options are limited and in this case dependent on the treatment option selected. In all cases where wastewater effluent disposal is on-site, an absorption bed will need to be provided.

HAENA STATE PARK MASTER PLAN
WASTEWATER TREATMENT ALTERNATIVE MATRIX

	HOLDING TANKS	COMPOSTING TOILETS	SEPTIC TANK	AEROBIC TREATMENT UNIT	CONSTRUCTED WETLANDS (Subsurface Flow)	GRAVITY SEWER AND PUMP STATIONS TO CENTRALIZED WASTEWATER PACKAGE PLANT FOR REUSE	RECIRCULATING SAND FILTER FOR REUSE (not discussed in report)
ADVANTAGES	• Electrical power not required. • Will not discharge nutrients or pathogens into the environment.	• Does not require water. • Will not discharge nutrients or pathogens into the environment • Environmentally friendly.	• Electrical power not required. • Simple operation.	• Better quality effluent provided. • Effluent is allowed to be discharged to groundwater with disinfection.	• Better quality effluent provided. • Subsurface design minimizes odors, vector attraction and potential of public contact within the wetlands. • Passive, natural treatment process.	• Recycled water is considered zero discharge. • Highest quality effluent can be provided. • Effluent is allowed to be discharged to groundwater. • Reduces potable water demand for irrigation.	• Recycled water is considered zero discharge. • High quality effluent provided. • Effluent is allowed to be discharged to groundwater. • Reduces potable water demand for irrigation.
DISADVANTAGES	• Content of tank must be pumped on a regular basis and disposed of off-site. • Must be monitored and routinely checked to assess water level. • No treatment provided. • Possible odors from wastewater going septic.	• If not properly maintained, composting toilets have a potential for odors and vector attraction. • Purchase cost for specific organic materials to properly maintain the composting system. • Without proper ventilation or maintenance, odors may be generated. Requires power. • Possible odors from wastewater going septic.	• Only primary treatment is provided. • Treatment process is easily upset with the introduction of toxic substances, like chemicals and bleach into wastewater; shortening the life of disposal systems. • DOH requires a 3 foot vertical separation between the disposal system and groundwater. • The soil absorption area in a septic system must remain unsaturated to function properly.	• Electrical power is required for continuous operation of the aerobic units. • The aerobic treatment process is sensitive to temperature, location, tank geometry, tank material, concentration of solids, and type of mixing. • Treatment process is easily upset with the introduction of toxic substances, like chemicals and bleach into wastewater; shortening the life of disposal systems. • Increased operation and maintenance with the potential of equipment malfunctions and failures.	• Large footprint required. • Phosphorus, metals and other organics removed from the wastewater are bound in wetland sediments and accumulate over time. • Requires pretreatment. • Effluent quality not totally dependable or consistent. • Requires startup times for plants to get established.	• Electrical power is required as well as a standby generator. • Increased operation and maintenance with the potential of equipment malfunctions and failures. • Requires backup disposal and/or storage in the event of a system failure, per DOH.	• Electrical power is required for recirculating pumps. • Cost of media. • Maintenance required for sand bed and pumps. • Requires pretreatment. • Requires backup disposal and/or storage in the event of a system failure, per DOH.
APPROPRIATE SIZE FOR USE	• Single family residences	• Low use application only	• Recommend flow range of 1,000 gpd to 5,000 gpd. • Existing comfort station design flow of 2,100 gpd based on fixture counts.	• Recommend flow range of 1,000 gpd to 5,000 gpd • Existing comfort station design flow of 2,100 gpd based on fixture counts.	• The larger the flow, the greater the land area required. The existing comfort station requires approximately 1,530 square feet of constructed wetlands.	• Great benefit derived from sufficient flows. No limitation	• Great benefit derived from sufficient flows.
IMPACT ON PARK FUNCTIONS AND OPERATION	None	None	None	None	Area must be fenced and will be restricted from park usage.	None	Areas where recycled water applied may be temporarily restricted from public use.
AREA OF DISTURBANCE	• Minimal	• Small	• Existing comfort station required 2,500 gallon septic tank and approximately 2,700 square feet leach field	• Same as for a septic tank and leach field	• Existing comfort station requires 2- 1500 gallon pre-treatment tanks, approximately 1,530 square feet of constructed wetlands and 1,360 square feet disposal field.	• Large	• Large
WATER QUALITY IMPACT ON ENVIRONMENT	None	None	Medium-High	Medium	Medium-High	Low	Medium
CONSTRUCTION COST IMPACTS	Low	Medium	Medium	Medium-High	Medium-High	High	Medium-High

HAENA STATE PARK MASTER PLAN
WASTEWATER TREATMENT ALTERNATIVE MATRIX (Continued)

	HOLDING TANKS	COMPOSTING TOILETS	SEPTIC TANK	AEROBIC TREATMENT UNIT	CONSTRUCTED WETLANDS (Subsurface Flow)	GRAVITY SEWER AND PUMP STATIONS TO CENTRALIZED WASTEWATER PACKAGE PLANT FOR REUSE	RECIRCULATING SAND FILTER FOR REUSE (not discussed in report_
OPERTION & MAINTENANCE COST IMPACTS	High	Medium-High	Low	Medium	Medium	High	Medium-High
SPECIAL MAINTENANCE REQUIREMENTS	None	Requires continuous ventilation	None	Requires continuous application of compressed air	Requires maintenance and upkeep of plants	Requires continuous maintenance of equipment Requires certified operator	Requires continuous energy consumption
REGULATORY IMPACTS (Monitoring, recording and special operations)	• Continuous monitoring of tank water level	• Quarterly inspection	• Annual inspections for residence • Quarterly inspections for public facilities	• Quarterly inspections	• Requires special approval from DOH. • Quarter inspections	• Monitoring and recordkeeping of the treatment and water reuse required by the DOH. • A wastewater grade operator license is required.	• Monitoring and recordkeeping required by the DOH. • A wastewater grade operator license is required.
APPLICABLE USAGE	• Maintenance Baseyard • Caretaker's Cottage	• Maintenance Baseyard • Allerton's Caretaker's Cottage at trail head	• All Facilities	• All Facilities	• Visitor Center / Comfort Station	• All Facilities	• Visitor Center / Comfort station

VII. RECOMMENDATIONS

During the community meetings, it was agreed that any wastewater system proposed treat the wastewater effluent for potential reuse, to protect the grounds and surrounding environment of the Park from any on-site disposal. It is believed by being good stewards of the Park, the environment will be preserved for future generations.

Therefore, at a minimum, aerobic treatment units with absorption beds should be consider. Beyond this, water resource management and reuse options as discussed hereinbefore should be seriously taken into consideration during design.

Also, specifically, discussed were:

1. R-2 water quality effluent be provided at the visitor's center, with additional treatment for reuse.
2. The absorption bed be placed under the parking lot to provide separation and avoid contamination of the loi patches.
3. Providing aeration to the existing constructed wetlands primary treatment tanks through the use of a photovoltaic system.
4. Compost toilets only be considered for low usage areas, if at all.

APPENDIX A

TABLE 3-1 SUMMARY OF SUITABLE USES FOR RECYCLED WATER

(*from Guidelines for the Treatment and Use of Recycled Water, May 15, 2002*)

TABLE 3-1 SUMMARY OF SUITABLE USES FOR RECYCLED WATER

SUITABLE USES OF RECYCLED WATER	R1	R2	R3
IRRIGATION: (S)pray, (D)rip & Surface, S(U)bsurface, (A)LL=S D & U, Spray with (B)uffer, (N)ot allowed, /=or			
Golf course landscapes	A	U/B	N
Freeway and cemetery landscapes	A	A	N
Food crops where recycled water contacts the edible portion of the crop, including all root crops	A*	N	N
Parks, elementary schoolyards, athletic fields and landscapes around some residential property	A	U	N
Roadside and median landscapes	A	U/B	N
Non-edible vegetation in areas with limited public exposure	A	AB	U
Sod farms	A	AB	N
Ornamental plants for commercial use	A	AB	N
Food crops above ground & not contacted by irrigation	A	U	N
Pastures for milking and other animals	A	U	N
Fodder, fiber, and seed crops not eaten by humans	A	AB	DU
Orchards and vineyards bearing food crops	A	D/U	DU
Orchards and vineyards not bearing food crops during irrigation	A	AB	DU
Timber and trees not bearing food crops	A	AB	DU
Food crops undergoing commercial pathogen destroying process before consumption	A	AB	DU
SUPPLY TO IMPOUNDMENTS: (A)llowed (N)ot allowed			
Restricted recreational impoundments	A	N	N
Basins at fish hatcheries	A	N	N
Landscape impoundments without decorative fountain	A	A	N
Landscape impoundments with decorative fountain	A	N	N
SUPPLY TO OTHER USES: (A)llowed (N)ot allowed			

TABLE 3-1 SUMMARY OF SUITABLE USES FOR RECYCLED WATER

SUITABLE USES OF RECYCLED WATER	R1	R2	R3
IRRIGATION: (S)pray, (D)rip & Surface, S(U)bsurface, (A)LL=S D & U, Spray with (B)uffer, (N)ot allowed, /=or			
Golf course landscapes	A	U/B	N
Freeway and cemetery landscapes	A	A	N
Food crops where recycled water contacts the edible portion of the crop, including all root crops	A*	N	N
Parks, elementary schoolyards, athletic fields and landscapes around some residential property	A	U	N
Roadside and median landscapes	A	U/B	N
Non-edible vegetation in areas with limited public exposure	A	AB	U
Sod farms	A	AB	N
Ornamental plants for commercial use	A	AB	N
Food crops above ground & not contacted by irrigation	A	U	N
Pastures for milking and other animals	A	U	N
Fodder, fiber, and seed crops not eaten by humans	A	AB	DU
Orchards and vineyards bearing food crops	A	D/U	DU
Orchards and vineyards not bearing food crops during irrigation	A	AB	DU
Timber and trees not bearing food crops	A	AB	DU
Food crops undergoing commercial pathogen destroying process before consumption	A	AB	DU
SUPPLY TO IMPOUNDMENTS: (A)llowed (N)ot allowed			
Restricted recreational impoundments	A	N	N
Basins at fish hatcheries	A	N	N
Landscape impoundments without decorative fountain	A	A	N
Landscape impoundments with decorative fountain	A	N	N
SUPPLY TO OTHER USES: (A)llowed (N)ot allowed			

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Guidelines for the Treatment
and Use of Recycled Water 5/15/02

Table 5-1 Summary of Typical Onsite Wastewater Treatment System Effluent Water Quality

TREATMENT SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms Per 100 mL	COMMENTS
Septic Tank	132 - 217	49 - 161	39 - 82	11 - 22	40,000 – 160 million	(USEPA, 2002 and Hallahan, 2002)
Low water/Waterless Toilets	-	-	-	-	-	No effluent. By-products require disposal/use outside scope of this handbook
Continuous Flow, Suspended Growth	10 - 50	15 - 60	30 - 40% removal	10 - 20% removal		(USEPA, 2002)
Continuous Flow w/ fixed internal packing	10	15	7 - 22			
Sequenced Batch Reactor ATU	5 - 15	10 - 30				
Single Pass Sand Filter	2 - 4	3 - 16	0.5 - 6	40% removal	60-1500	
Recirculating Sand Filter	3 - 10	3 - 9	3 - 8		10-25	
Enhanced Phosphorus Removal	-	-	-	1 - 2 mg/L	-	
Enhanced Nitrogen Removal	-	-	40 - 80% removal	-	-	
Emerging Trace Contaminant Removal	-	-	-	-	-	
Chlorine Disinfection	-	-	-	-	Reduction of 99.0-99.9%	
UV Disinfection	-	-	-	-	Reduction of 99.9%	

APPENDIX B

WASTEWATER TREATMENT AND DISPOSAL ALTERNATIVES - FACT SHEETS

(from On-Site Wastewater Treatment Survey and Assessment Study, January 2008)

Septic Tanks

Fact Sheet P-1

A septic tank is a tank that serves as both a settling and skimming tank. Grit and other solids settle to the bottom of the tank and create a layer of sludge. Oil, grease, fat, and other floatables rise to the top creating a layer of scum. Accumulated sludge and scum must be removed on a regular basis; failure to do so will lead to carryover of these materials into downstream systems leading to their failure. Where site conditions indicate higher quality effluent is required, septic tanks are used as pretreatment for other treatment systems, including biological treatment systems.

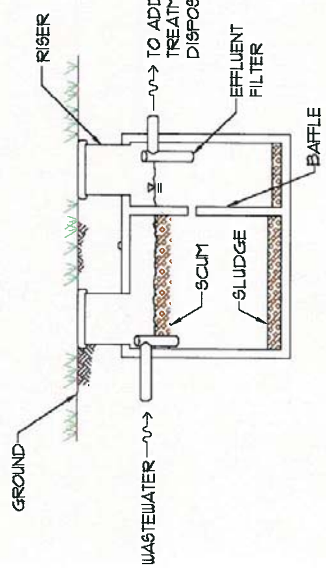


Figure 5-2 Typical Double Chambered Septic Tank

Considerations and Restrictions

A septic tank is purchased prefabricated, made of concrete or fiberglass, and it must meet the International Association of Plumbing and Mechanical Officials (IAMPO) material and property standards for prefabricated septic tanks. However, depending on site conditions, sometimes it is easier to construct a tank in-place. A constructed in-place septic tank must be designed in accordance with IAPMO specifications and stamped by a licensed structural engineer. Regardless of how a tank is constructed, it must be waterproof to prevent leakage and protected from corrosion in accordance with HAR 11-62, Subchapter 3.

The capacity of a septic tank is an important aspect in the treatment of wastewater prior to disposal. The required capacity of residential septic tanks can be referenced using HAR 11-62, Subchapter 3. The City and County of Honolulu "Design Standards of the Department of Wastewater Management" or the applicable county publication must be consulted.

A septic tank must be installed by a licensed contractor to comply with spacing and minimum distance requirements, as described in Chapter 3 of this document. Use of a septic tank requires the selection of a downstream disposal system (see Chapter 4).

Table 5-3 Summary of Advantages and Disadvantages of Typical Onsite Wastewater Treatment Systems

Treatment System	Advantages	Disadvantages or Limitations
Septic Tank	▪ No moving parts ▪ Easily maintained with periodic pumping	▪ Only primary treatment provided
Low water/Waterless Toilets	▪ Incinerators – waste is sterile and can be thrown away like household rubbish ▪ Composting toilets – offer recycling of waste ▪ Chemical – viable temporary system	▪ Incinerators – require other utilities such as electricity or natural gas ▪ Composting – long periods of treatment ▪ Chemical – usually temporary, must be pumped often
Continuous Flow, Suspended Growth ATU	▪ Habitually meets Class I effluent standards	▪ Continuous energy requirements ▪ Poor maintenance leads to degraded effluent quality ▪ Requires long startup times-not good for seasonal flows
Continuous Flow, w/ Fixed Packing	▪ Habitually meets Class I effluent standards	▪ Energy consumption ▪ Requires long startup times-not good for seasonal flows
Sequenced Batch Reactor ATU	▪ Habitually meets Class I effluent standards ▪ High Nitrification/Denitrification	▪ Energy consumption is costly ▪ Requires computer controls
Single Pass Sand Filter	▪ High TSS removal ▪ Proven technology	▪ High cost associated with media ▪ Maintenance required to prevent biomat clogging and ponding
Recirculating Sand Filter	▪ High denitrification	▪ Energy consumption with recirculating pump ▪ Cost of media ▪ Maintenance required of the bed and the pump
Enhanced Phosphorus Removal	▪ Removes phosphorus in areas that have low calcium, low iron, or low aluminum soils ▪ Helps protect surface water in soils that fail to remove phosphorus	▪ For media filters, construction costs can double due to expense associated with phosphorus attenuating media
Enhanced Nitrogen Removal	▪ Helps prevent groundwater contamination ▪ Prevents eutrophication of surface waters	▪ Requires aerobic and anoxic cycles or stages for biological removal of nitrogen ▪ Plumbing code does not regulate separate black- and graywater plumbing
Enhanced Emerging Contaminant Removal	▪ Necessary to remove medication and hormones that are not consumed by biological treatment	▪ Added expense associated with powdered activated carbon or other chemical absorbants
Chlorine Disinfection	▪ Safest and simplest with chloride tablets ▪ Cheapest means of disinfection	▪ Requires monitoring to ensure chloride tablets are always present to provide chloride ▪ Residual chlorine may harm downstream organisms
UV Disinfection	▪ No residual chemicals disposed in environment	▪ Bulbs are expensive ▪ Requires power ▪ Can be ineffective in high TSS environments

Effluent Quality
In accordance with HAR 11-62, Subchapter 33, septic tank effluent must be discharged into a soil absorption system, a sand filter, a subsurface irrigation system (with director approval), or another treatment system. Septic tanks remove approximately 30% of BOD and 30% of TSS from typical domestic wastewater resulting in effluent quality of BOD ranging between 138 mg/L and 240 mg/L, and suspended solids in the range of 49 to 155 mg/L.

The DOH requires the installation of a screen on the effluent end of the septic tank to enhance solids removal and thereby prevent clogging of disposal systems. The effluent filter can be installed on the effluent tee on the inside of the septic tank, or in a separate structure outside the tank to facilitate access for required periodic cleaning, without which backups will occur.

Typical Installed Costs (2007)
A 1,000-1,250 gallon residential septic tank costs approximately $5,000-$12,000 installed, including material, equipment, and labor. An effluent filter is about $200-$700 installed. The cost of a septic tank does not include the disposal system (see Chapter 4).

Operation and Maintenance Costs
The decomposition rate of the solids that settle to the bottom of the tank and those that accumulate in the scum layer on the surface is slow, resulting in the accumulation of solids in the septic tank. Because of the accumulation of solids and scum, periodic pumping is required (every 2-3 yrs) to keep the tank functioning as designed and prevent solids from breaking and overflowing to the soil absorption system. The estimated cost for these pumping services range between $150 and $550 per visit. Assuming that the septic tank is pumped every 2-3 years, the equivalent cost is about $50-$200 per year. Pumping costs vary due to difficulty accessing the tank, haul distances, and limited pump truck capacity. Minimal use of kitchen sink grinders will help reduce the solids load, and extend the time between pumping of the septic tank and any downstream treatment units.

The effluent filter must be cleaned on a regular basis because of the growth of bacteria that will clog the filter. Frequency of cleaning is dependent on the size of the screen, environmental conditions, and type of wastewater entering the septic systems. Some manufacturers recommend cleaning every 1-3 years depending on level of use and site conditions. Cleaning consists of hosing off the filter into the septic tank and can be done by the homeowner.

Septic Tank Summary

Meets NSF 40 Standards	No
Effluent BOD:	132-217 mg/L
Effluent TSS	49-161 mg/L
Removes 50% total influent nitrogen	No
Effluent Nitrogen:	39-82 mg/L
Effluent Phosphorus:	11 -22 mg/L
Effluent Fecal Coliform:	1,000,000 /100 mL
Maintenance Level:	2-3 yrs
Power Required:	No
Typical Installed Cost:	$5,000-$12,000 /1,000 gal

Waterless/Low Water Systems Fact Sheet P-2

Low water or waterless system is a broad, generic term given to a range of treatment systems that use little water or no water in collecting or treating human waste. It includes incinerating toilets, composting toilets, and chemical toilets.

Incinerating toilets use heat or combustion to degrade human waste into water, carbon dioxide, and ash. Incinerating toilets are one of a few treatment technologies that do not require a soil disposal system. However, the ash from the incineration must be disposed of, usually with municipal refuse in a landfill. Incinerating toilets may use natural gas, liquid propane, or electricity to incinerate the human waste, and are usually designed to handle only feces, urine, and paper. Ventilation for the toilet must be supplied.

Composting toilets receive human waste and stabilize it through natural degradation. The waste is mixed with starting mulch, and allowed to degrade and dehydrate for a period of up to 12 months, depending on usage. The composted material removed from composting toilets is suitable as a soil amendment, however, such use is restricted as described in HAR 11-62 in order to protect public health. The toilets come in automatic, semi-automatic, and manual versions. The automated models usually include heaters, ventilation fans, and a mechanical means to mix or aerate the compost.

Chemical toilets are toilets which have a chemical reservoir beneath them that catches the human waste. The chemicals in the toilet slightly disinfect the human waste and also provide a deodorant. Chemical toilets do not completely break down human waste and must be pumped frequently due to a very limited holding capacity. The contents of chemical toilets must be taken to a local wastewater treatment facility. The contents should not be poured into a home septic tank or aerobic treatment unit as the chemicals will have adverse effects on the biology of the treatment system.

Considerations and Restrictions
Incinerating toilets are acceptable, long-term treatment systems, but they are typically only found in temporary or seasonal housing. The by-products (ash) must be periodically removed, but because it is sterile after incineration and poses no nutrient threat to the environment, it can generally be disposed of as household garbage. Without proper ventilation, odors may be generated (both from the human waste and the process of combustion.) Additional utilities are required (natural gas, propane, or electricity).

Composting toilets are also acceptable long term treatment systems, but are also an item typically only found in seasonal housing, campsites or other locations not occupied fulltime. Composting requires long periods of time to stabilize the human waste and may create odor problems. Those systems that do not use electricity for evaporative fans or mixing require more attention from the operator to maintain function. The produced compost is suitable as a soil applied fertilizer, but cannot be used for crops meant for human consumption, and its use is restricted by HAR 11-62.

Chemical toilets are a temporary means of treatment. The limited capacity and frequent pumping lend the system for uses that are of short duration, such as a few days. As anyone who has been to a large public gathering knows, chemical toilets are also a good augmentation to existing restroom facilities during short events or festivities.

Suspended Growth Aerobic Treatment Systems *Fact Sheet B-1*

A suspended growth aerobic treatment system (one type of ATU) is a biological treatment system where microorganisms are kept in suspension by mixing air with wastewater influent and concentrated underflow or sludge (from a clarifier) in an aeration tank.

From the aeration tank, the mixture is passed into a settling basin (clarifier), where microorganisms settle to the bottom forming a layer of sludge. The liquid is passed to a disposal system or another process for additional treatment. Some of the sludge solids in the settling basin will undergo decomposition, while the remainder accumulates and must periodically be removed (pumped out) and properly/legally disposed of offsite.

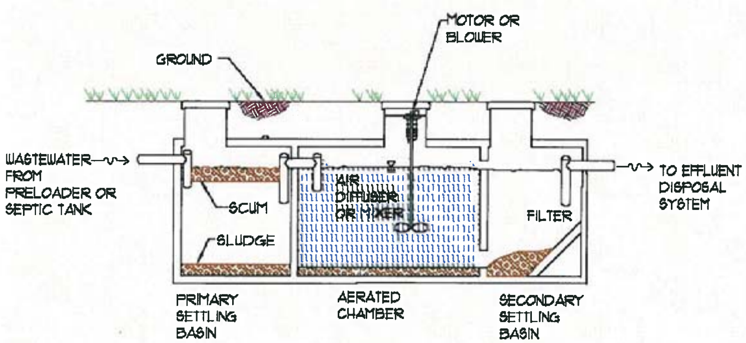


Figure 5-3 Continuous Flow, Suspended Growth Aerobic System with Settling Basins

Considerations and Restrictions

If the suspended-growth aerobic treatment system does not include an integral primary settling basin, a separate septic tank or pre-loader should be installed upstream of the aerobic treatment unit. The purpose of this additional tank is to remove readily settleable solids and floating matter that will reduce suspended solids loading and protect downstream mechanical equipment.

Consideration should be given to determine how best to use the existing grades to allow gravity flow from septic tank to aerobic treatment system to disposal system.

Power is needed to serve the blowers, pumps, controls, and monitoring and alarm systems in the ATU.

Use of a suspended-growth ATU requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Suspended-growth aerobic treatment systems can treat domestic wastewater and achieve effluent quality of BOD concentrations in the range of 5-50 mg/L and TSS concentrations of 5-60 mg/L. However, it should be noted that suspended-growth ATUs are not the most optimal to reduce nitrogen or phosphorus.

Typical Installed Costs (2007)

Complete installation including materials, equipment and labor can range between $20,000-30,000. This cost does not include the cost for a preloader/septic tank, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs

Operation and maintenance costs are dependent on labor costs and electricity but range from $400 to $600 a year. Trained professionals should manage the aerobic system which should be inspected every 3-4 months with sludge/scum pumping performed as needed.

These systems are sensitive to high and low temperatures, heavy loading of solids, toxic chemicals (including chemical cleansers and the like), power failures, and influent flow variability.

Suspended Growth Summary	
Meets NSF 40 Standards	Yes
Effluent BOD:	5-50 mg/L
Effluent TSS	5-60 mg/L
Removes 50% total influent nitrogen	No
Effluent Nitrogen:	10-60 mg/L
Effluent Phosphorus:	4-18 mg/L
Effluent Fecal Coliform:	1,000,000 /100 mL
Maintenance Level:	Quarterly
Power Required:	Yes
Typical Installed Cost:	$20,000-$30,000 /1,000 gallons

Combined Attached and Suspended Growth Aerobic Treatment Systems — *Fact Sheet B-2*

Combined attached and suspended growth systems are a type of ATU in which microorganisms form a slime layer on the surface of submerged or semi-submerged media. Treatment occurs as the wastewater passes over the microorganisms.

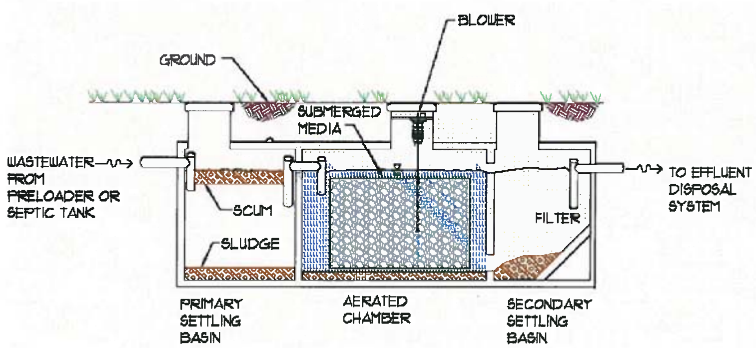


Figure 5-4 Combined Attached and Suspended Growth Reactor

Considerations and Restrictions
If the combined growth ATU does not include an integral primary settling basin, a separate septic tank or pre-loader should be installed upstream of the aerobic treatment unit. The purpose of this additional tank is to remove readily settleable solids and floating matter that will reduce suspended solids loading and protect downstream mechanical equipment.

Consideration should be given to determine how best to use the existing grades to allow gravity flow from septic tank to aerobic treatment system to disposal system. In addition, the system should be sited such that it can easily be accessed and inspected.

Use of a combined attached and suspended growth ATU system requires the selection of a disposal system (see Chapter 4).

Effluent Quality
Effluent BOD and TSS concentrations of 5-40 mg/L are expected from a combined growth system. Complete nitrification is expected (conversion of ammonia to nitrate) and phosphorus removal is expected to be between 10 and 15%.

Typical Installed Costs (2007)
Installation costs range from $20,000 to $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs
Costs to operate combined growth ATU systems range from $35-$100 per year in energy, and management (pumping, inspection, and analysis) can cost $100-$200 per year. Energy consumption is on the order of 1-8 kW-h/day. Extended power outages will result in odorous conditions. Trained professionals should manage the ATU system which should be inspected every 3-4 months with sludge/scum pumping as needed.

These systems are sensitive to high and low temperatures, heavy loading of solids, toxic chemicals (including chemical cleansers and the like), power failures, and influent flow variability.

Attached and Suspended Growth Summary	
Meets NSF 40 Standards	Yes
Effluent BOD:	10-30 mg/L
Effluent TSS	15-60 mg/L
Removes 50% total influent nitrogen	Possible
Effluent Nitrogen:	7-22 mg/L
Effluent Phosphorus:	2-10 mg/L
Effluent Fecal Coliform:	1,000,000 /100 mL
Maintenance Level:	Quarterly
Power Required:	Yes
Typical Installed Cost:	$20,000-$30,000 /1,000 gallons

Sequencing Batch Reactors (SBR) — Fact Sheet B-3

A Sequencing Batch Reactor (SBR) is a form of ATU in which all of the aerobic and clarifying processes occur within a single tank. The tank may be constructed from concrete, fiberglass, or high-density polyethylene (HDPE). A SBR is designed to operate by sequencing through at least four (4) steps as follows:

1) FILL: tank is filled with wastewater to a predetermined volume or time;
2) AERATION: aeration is started with the suspended microorganisms in the wastewater;
3) SETTLE: aeration is turned off and the microorganisms settle to the bottom of the tank; and
4) DECANT: decant the clarified portion as effluent.

After decanting, the cycle repeats with filling again. By allowing the tank water level to vary, providing influent stilling zones, and only decanting during aeration off cycles, these single-tank systems can be designed to operate continuously. Of great importance to the SBR process is the control system consisting of timers, level sensors, and microprocessors.

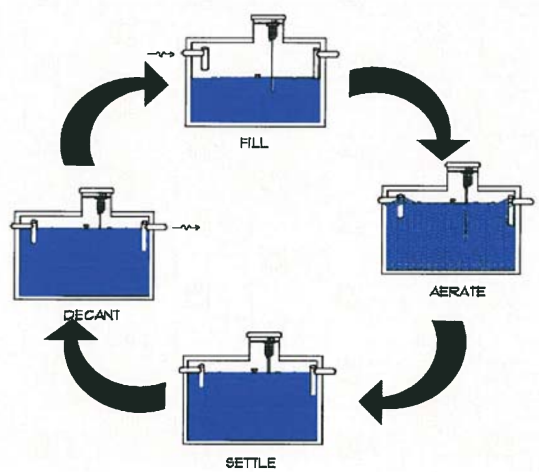


Figure 5-5 Cycles of an SBR / CBT

Considerations and Restrictions

SBRs are a type of suspended-growth ATU that can oxidize BOD and provide both nitrification and denitrification (enhanced nitrogen removal). SBRs require power, control, and monitoring and alarm systems. SBRs have mechanical equipment (pumps, blowers, decanters) which must be properly maintained to ensure optimal operation.

Use of an SBR system requires the selection of a disposal system (see Chapter 4).

Effluent Quality

Effluent from SBRs is of very good quality in terms of BOD and TSS. Typical ranges are from 5 –15 mg/L BOD and 10-30 mg/L of TSS.

SBRs will completely oxidize ammonia to nitrate via nitrification during the aeration cycle (aerobic cycle), and then facilitate nitrogen removal via denitrification during the settle and decant cycles (cycles that are anoxic). They can also provide enhanced biological phosphorus removal. The higher quality of effluent produced reduces the organic loading on the disposal system. SBRs also provide a consistent effluent, eliminating the fluctuations caused by varying influent loads.

Typical Installed Costs (2007)

Equipment costs range from $7,000-$9,000 with installation costs of $1,500-$3,000 based on Mainland costs. Current costs to install in Hawaii are in the range of $20,000 - $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks (Sheet P-1) for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operation and Maintenance Costs

Annual energy costs are less than $600 and pumping and inspection costs are greater than $100. Trained professionals should manage the SBR system, which should be inspected every 3-4 months with sludge/scum pumping as needed. Homeowner neglect and/or interference can lead to operational malfunction. Alarms to warn of system failures are critical. Energy requirements are between 3 and 10 kW-h/day.

SBR Summary

Meets NSF 40 Standards	Yes
Effluent BOD:	5-15 mg/L
Effluent TSS	10-30 mg/L
Removes 50% total influent nitrogen	Yes
Effluent Nitrogen:	7-45 mg/L
Effluent Phosphorus:	2-10 mg/L
Effluent Fecal Coliform:	1,000,000 /100 mL
Maintenance Level:	Quarterly
Power Required:	Yes
Typical Installed Cost:	$20,000-$30,000 /1,000 gallons

Packed Bed Reactors Fact Sheet B-4

A packed-bed reactor is an attached-growth biological treatment process that can be aerobic or anaerobic, upflow or downflow, continuous or intermittent dosing, single-media or multi-media and arranged in one or multiple stages. The most common prefabricated packed-bed reactor is an aerobic, down flow, continuous dosing, and continuous media type reactor. The packed-bed filter is a large excavation lined with an impermeable material that is filled with sand or other media placed over an underdrain. Wastewater is dosed at the top of the media bed, and allowed to percolate through the media (filter) to an underdrain. The aerobic biological treatment usually occurs in the first six inches of the filter surface, and chemical treatment, in the form of adsorption, occurs throughout the filter.

Packed bed reactors can be single pass (intermittent sand filters) or they can recirculate the effluent to treat the wastewater multiple times (recirculating sand filters or RSF). Ultimately, the effluent is discharged to a disposal system, similar to those discussed in Chapter 4.

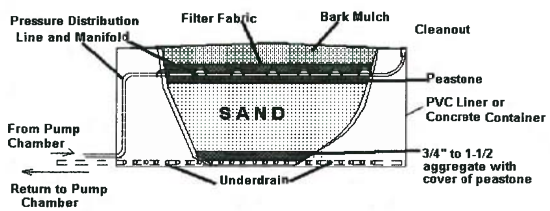


Figure 5-6 Packed Bed Filter (Adapted from USEPA)

Considerations and Restrictions
Sand filters are usually sized using hydraulic data, but consideration must also be given to the organic loading since it acts as a biofilm reactor. This type of system requires significant land area. Based on a typical application rate of 1-2 gallons per day per square foot (gpd/ft^2), it will require 500-1,000 square feet for the treatment of 1,000 gpd.

Filters may need to be covered to ensure protection against accumulation of debris from the surrounding environment, algae fouling, and an increased hydraulic load from precipitation. Coverings may be as simple as a tarp canopy, which allows ample ventilation of the bed. Otherwise, the filter may be buried in the ground to provide protection and aesthetic concealment. Extra care must be given to filters buried in the ground to ensure ventilation of the bed. Mechanical aeration (blowers) may be required.

A pump station or recycle tank is required prior to the packed-bed filters to assist with equal distribution in the dosing pipelines across the media bed area.

Use of a packed bed system requires the selection of a disposal system (see Chapter 4).

Effluent Quality
Effluent BOD is typically 5 mg/L and TSS is typically about 10 mg/L. Biological nitrogen removal is approximately 18-33%. Fecal coliforms are reduced by 99 to 99.99%.

Typical Installed Costs (2007)
This cost includes the excavation, the media, the underdrain, and the dosing pump. The price range for media is $10-$15 per square foot of bed area. For a 250-1,000 square foot media filter, costs should range between $15,000 and $30,000. This cost does not include the cost for a preloader, if required, or the cost for a disposal system. See Septic Tanks for a cost range for preloaders. See Chapter 4 for the costs of disposal systems.

Operational and Maintenance Costs
Operational costs include electricity for pumping and semi-skilled labor. Electrical costs can be estimated at $20-30 a year at 0.3-0.4 kW-h/day, and management costs at $150-200 per year. Every 3-4 months the filter should be inspected, and the top layer (1 inch) of media should be scraped off periodically (3 months-1 year) and properly disposed. Power outages affect the performance of sand filters, and extended outages may result in odors.

Packed-bed Reactor Summary

Meets NSF 40 Standards	Yes
Effluent BOD:	2-10 mg/L
Effluent TSS	3-16 mg/L
Removes 50% total influent nitrogen	Possible
Effluent Nitrogen:	0.5-8 mg/L
Effluent Phosphorus:	3-12 mg/L
Effluent Fecal Coliform:	1,000 /100 mL
Maintenance Level:	Quarterly
Power Required:	No
Typical Installed Cost:	$15,000-30,000 /1,000 gallons

Chlorination — Fact Sheet C-1

Chlorine is the most commonly used chemical and/or method for disinfection of water and wastewater, and has a long history of use in the US. Chlorine is effective against a wide range of pathogenic organisms. Common forms of chlorine include chlorine gas, solid or liquid chlorine (calcium hypochlorite and sodium hypochlorite), and chlorine dioxide.

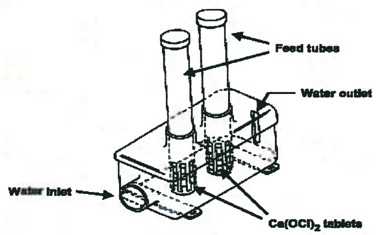


Figure 5-8 Tablet Chlorination Chamber (Adapted from USEPA)

Considerations and Restrictions

Gaseous chlorine is the most commonly used form; however, due to its highly corrosive nature and significant safety concerns, it is generally not recommended for onsite applications. Liquid hypochlorite solutions are commonly used at small treatment plants, where safety and simplicity are top priorities. Solid hypochlorite (powder or tablets) is common for onsite treatment systems (the same materials used for swimming pools and hot-tubs). All forms of chlorine are generally toxic and corrosive. They require careful handling and storage. The residual chlorine is effective as a disinfectant after the initial treatment. However, even at low concentrations, it can be toxic to aquatic life, and de-chlorination is necessary for discharges to (or impacting) surface waters.

Effluent Quality

One advantage of using chlorine as a disinfectant is its ability to exist as a residual in wastewater effluent even after initial treatment. Chlorine has been shown to reduce fecal coliforms by 99-99.99%.

Typical Installed Costs (2007)

A hypochlorite tablet feed system could cost $800-$1,000 for 1,000 gallons per day for the system itself. Labor and material costs vary depending on whether the tablet feeder is part of a pre-packaged system or added to an existing system. A gas chlorine system may cost $75,000 to treat 100,000 gallons per day.

Operation and Maintenance Costs

Operational costs for a tablet system are approximately $30-$50 per year for tablets, $75-$100 per year in labor, and $15-$25 per year in repairs and replacements.

Estimated cost for a gaseous chlorine system is approximately $4,500 for chemicals, $4000 for labor, $4,000 for power, and $6,000 for materials.

Operating and maintenance cost and tasks include power consumption, cleaning, chemicals and supplies, repairs, and labor.

Chlorination Summary

Meets NSF 40 Standards	NA
Effluent BOD:	- mg/L
Effluent TSS	- mg/L
Removes 50% total influent nitrogen	NA
Effluent Nitrogen:	- mg/L
Effluent Phosphorus:	- mg/L
Effluent Fecal Coliform:	1000-10000 /100 mL
Maintenance Level:	Quarterly
Power Required:	No
Typical Installed Cost:	$800-$1,000 /1,000 gallons

UV Disinfection — Fact Sheet C-2

Ultraviolet (UV) light is a physical disinfection agent that takes advantage of the germicidal properties of UV in the range of 240-270 nm. This radiation penetrates the cell wall of organisms, preventing reproduction. The effectiveness of UV disinfection depends on the characteristics of wastewater (particularly clarity as measured by turbidity), UV intensity, time of exposure, and reactor configuration.

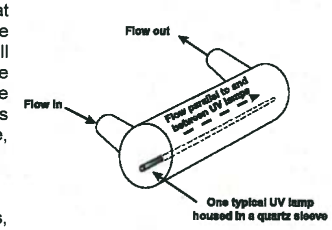


Figure 5-9 Ultraviolet Radiation Chamber (Adapted from USEPA)

Considerations and Restrictions

UV is effective in the inactivation of most viruses, spores, and cysts. UV eliminates the handling and storage of hazardous or toxic chlorine chemicals. However, UV performance is highly dependent on the quality of the wastewater it is disinfecting. High turbidity and total suspended solids will shield bacteria, making UV treatment ineffective.

Effluent Quality

UV disinfection is lacking in field studies, but typical units treating sand filter effluents can reduce fecal coliforms by 99.9%.

Typical Installed Costs (2007)

The component cost for a UV system is between $1,000-$2,000 per 1,000 gpd. Labor and material costs vary depending on whether the system is a built-in component of a packaged treatment system or added as an off-the-shelf component to enhance an existing system.

Operation and Maintenance Costs

Annual power costs are $35-$45, labor $50-$100, and lamp replacement $70-$80 per year. Power consumption is about 35 W or 307 kW-h/y.

UV Disinfection Summary

Meets NSF 40 Standards	NA
Effluent BOD:	- mg/L
Effluent TSS	- mg/L
Removes 50% total influent nitrogen	NA
Effluent Nitrogen:	- mg/L
Effluent Phosphorus:	- mg/L
Effluent Fecal Coliform:	~1,000 /100 mL
Maintenance Level:	Quarterly
Power Required:	Yes
Typical Installed Cost:	$1,000-$2,000 /1,000 gallons

Table 6-1 Typical Small Flows Wastewater Treatment System Effluent Water Quality

SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms per 100 mL	COMMENTS
Cluster systems	132-217	49-161	39-82	11-22	1 – 100 million	Assuming STEP system
Lagoons	60-140	Variable	Up to 60% removal	Minimal Removal	Variable	
Oxidation Ditches	<10	<10 if settling tank is used	Total removal with designed anoxic zone	Minimal Removal	Variable	
Attached Growth Aerobic reactors	<30	<30	<30	~10	>2000	California Water Boards
Constructed Wetlands	2-7	<20	<30	Minimal removal	90-99% removal w/HRT of 3-7 days	
Membrane Bioreactors	<5	<2	3	0.5	<200	Data from manufacturers' websites

Table 6-2 Advantages and Disadvantages of Small Flows Wastewater Treatment and Disposal Systems

System	Advantages	Disadvantages or Limitations
Cluster systems	▪ May be economical for small communities without sewers ▪ Transfers non-point discharges to a point discharge that may be more easily monitored and managed ▪ Requires less space than reliance on IWS	▪ Concentrates pollutants in one location for disposal ▪ Requires very structured and delineated management system to assign responsibility to designated parties
Lagoons	▪ Passive system with little or no energy requirements ▪ Large volume able to buffer shock loads	▪ Vector control (mosquitoes) must be managed ▪ Nuisance odors may be caused by anaerobic conditions
Oxidation Ditches	▪ High BOD removal ▪ Can be engineered to remove almost all nitrogen	▪ Aeration or mixing require power consumption
Attached Growth Aerobic Reactors	▪ Can reduce energy costs per unit of organic removal	▪ Odors and poor effluent quality may result from poor design.
Constructed Wetlands	▪ Natural process ▪ Good process to treat wastewater prior to discharge to surface water ▪ Nitrification and denitrification occur	▪ Demands large land area ▪ If free surface wetlands are constructed, there is a threat of mosquitoes or other insect vectors.
Membrane Bioreactors	▪ Extremely high quality effluent in small space	▪ Costly to build ▪ Operating conditions may cause fouling which leads to more frequent and costly cleaning

Table 4-1 Summary of Typical Disposal System Effluent Water Quality

DISPOSAL SYSTEM	BOD mg/L	TSS mg/L	Total Nitrogen mg/L	Total Phosphorus mg/L	Fecal Coliforms Per 100 mL	COMMENTS
Holding Tank (Septic Tank effluent in parathesis)	100-400 (132-217)	100-400 (49-161)	14-40 (39-82)	5-20 (11-22)	1 – 100 million	
Cesspool	100-400	100-400	15-90	5-20	1-100 million	
Seepage Pit			78 mg/kg soil		~10,000	Reported by Field et al at 3 m below pit and 30 cm from edge
Absorption Trenches	<30	4	1	<2	13	
Absorption Beds	<30	4	1	<2	13	
Elevated Mounds	<30	<20	<15	<2	13	
Evapotranspiration	Varies	Varies	Varies	Varies	Varies	
Water Reuse	< 30 mg/L	< 30 mg/L	No specs.	No specs	< 23	Requirements for R-2 water

Constructed Wetlands Fact Sheet SF-5

A constructed wetland (CW) is a man-made, marsh-like area that is designed and built to provide wastewater treatment. A lined bed of washed gravel is planted with hydroponic species whose roots absorb nutrients and create areas for aerobic treatment to take place. CWs can be designed for discharge to SWIS and will require disinfection for reuse or discharge to surface or groundwater. CWs can be generally categorized into two categories: subsurface and free flowing or surface constructed wetlands. Subsurface wetlands are designed for fluid flow that is below ground level, whereas free flow wetlands allow for wastewater to approach the surface.

Considerations and Restrictions

Wastewater pretreatment is required prior to the use of CWs. These operations include settling with a septic tank and/or screening mechanisms. CWs generally require more land space than other treatment methods, require a start-up period to establish the vegetation, must be designed such that rainfall runoff will not collect in the bed, and be designed to receive ample sunlight. Currently, there are no regulations in HAR 11-62 governing CWs, so the use of such systems requires approval. Safety issues and public access should be considered when designing and constructing CWs. Vector problems, such as mosquitoes, must be considered.

Effluent Quality

The expected BOD and TSS removal can be 60-80% for BOD and 50-90% for TSS, but depends on the nature and characteristics of the influent. Removal of nitrogen can be effective. For the typical constructed wetland located at the Riveredge Nature Center, effluent quality for a system receiving 2,000-9,300 gpd of wastewater is about 3.7 mg/L of BOD, 17.2 mg/L of TSS, and fecal coliforms of 54 per 100 mL.

Typical Installed Costs (2007)

According to the USEPA, a free flow, surface wetland should cost about $2,000-$4,000 per 1,000 gpd treated. However, for large disposal flows, the costs could approach $15,000 per 1,000 gpd treated.

Operation and Maintenance Costs

Operation and maintenance required for a CW is minimal and may include mosquito control. Occasional maintenance of the vegetation to promote growth of desired vegetation and maintaining hydraulic capacity is required. Proper maintenance of upstream processes is necessary to prevent clogging of the gravel bed.

Constructed Wetlands Summary

Meets NSF 40 Standards	No
Effluent BOD	<10 mg/L
Effluent TSS	<20 mg/L
Removes 50% total influent nitrogen	Possibly
Effluent Nitrogen	<20 mg/L
Effluent Phosphorus	- mg/L
Effluent Fecal Coliform	<100 /100 mL
Maintenance Level:	Medium
Power Required:	No
Typical Installed Cost:	$2,000-$15,000 /1,000 gallons

Holding Tanks

Fact Sheet D-1

A holding tank is a watertight concrete or plastic tank that receives either raw or treated wastewater and stores it until a pumping contractor can haul the wastewater away. Typically, holding tanks are used only as a temporary disposal system until a connection to a public system is established or an existing disposal system can be repaired or upgraded. The tank should be able to hold 2-3 days worth of storage, requiring a hauler to remove wastewater every other day before it becomes septic or overflows. Holding tanks are only allowed in public facilities.

Considerations and Restrictions
Holding tanks must be structurally sound and must remain watertight. Holding tanks are considered a temporary system until a better system can be installed. Consideration should be given to providing venting for odor control and sizing of the tank to account for any gases that may be produced due to anaerobic reactions occurring in the tank. Alarms for overflow or strict monitoring of the holding tanks is necessary to prevent overflowing wastewater.

Effluent Quality
If any treatment occurs, it is anaerobic in nature, producing odorous gases. No treatment can be assumed.

Typical Installed Costs (2007)
Assuming the excavation and cost of the tank itself are the slightly higher than septic tanks, the cost of installing a complete holding tank is $10,000-$25,000.

Operation and Maintenance Costs
Periodic pumping is required in order to prevent backups into the plumbing leading to the holding tank. For pumping up to 2 to 3 times per week, the cost would be $1,600 -$2,400 per month or $19,200 to $28,800 per year.

Holding Tanks Summary

Use in Steep Terrain	Any terrain
Use in High Ground Water Areas	Yes
Percolation Rate	N/A
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	High
Power Required:	No
Typical Installed Cost:	$10,000 -$25,000 /1,000 gallons

Table 4-3 Advantages and Disadvantages of Typical Disposal Systems

Disposal System	Advantages	Disadvantages or Limitations
Holding Tank	▪ Zero discharge to surrounding area	▪ Generally a temporary solution to a problem ▪ Must be pumped on regular basis ▪ Possible odors
Cesspool	▪ May already exist ▪ No power consumption	▪ Minimal treatment of sewage
Seepage Pit	▪ Can be easily installed where a cesspool once existed ▪ Can be used in very steep terrain locations	▪ Surface area needed for percolation may make pit so deep it discharges to groundwater ▪ Large percolation area may require multiple pits, increasing price drastically
Absorption Trenches	▪ Most common means of disposal ▪ Excavation does not disturb soil properties	▪ Limited by steep terrain and land area ▪ Sides of the trenches are not credited to percolation area
Absorption Beds	▪ Area of the entire bed bottom is credited to percolation area	▪ Extremely limited by steep terrain
Elevated Mounds	▪ A soil absorption system to overcome limitations regarding poor soil or proximity to groundwater	▪ Increased cost due to additional backfill requirements. ▪ Requires energy consumption due to pumping wastewater to above ground dispersion system
Evapotranspiration	▪ Non-leaching system ▪ Can be used above UIC line with approval	▪ Works well in arid areas where the rate of evaporation is greater than the rate of precipitation ▪ Requires energy ▪ Requires additional storage capacity ▪ Requires lysimeter monitoring
Water Reuse	▪ Reduces water demand for potable water for irrigation ▪ Considered zero discharge	▪ May be best suited to daily flow rates larger than the scope of this study ▪ Requires backup disposal or storage

Cesspools — Fact Sheet D-2

Cesspools are generally large, cylindrical, lined excavations used to receive untreated wastewater. Solids are retained and the liquid percolates into the surrounding soil. A cesspool is either lined with rock, or constructed with mortar-less brick or perforated concrete rings. Cesspools are not considered a treatment system because virtually no treatment occurs that would protect the surrounding environment. Therefore, cesspools are considered to be only a disposal device.

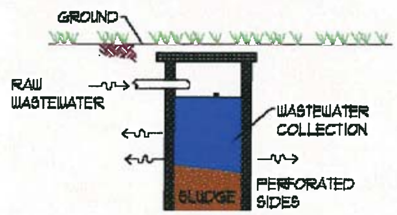


Figure 4-1 Cesspool

Considerations and Restrictions

New cesspools are severely restricted and prohibited in designated critical wastewater disposal area on all islands as defined in the HAR 11-62. New cesspools are currently still legal in specific areas of Hawaii County. Refer to the CWDA maps in Appendix C. Because of the slow decomposition rate, the solids in the wastewater will eventually clog the cesspool. The pores of the lining can be re-opened using caustic soda or a very strong acid. However, even these solvents will eventually fail to open the pores, and the cesspool will have to be closed and replaced.

Effluent Quality

Effluent quality is only slightly better than the quality of raw wastewater as only large solids are removed from the wastewater. When used following a treatment system, no treatment is assumed and the cesspool functions as a seepage pit (see D-3).

Typical Installed Costs (2007)

$15,000 for excavation, lining and backfill.

Operation and Maintenance Costs

The organic solids that settle to the bottom of the cesspool decompose at a very slow rate, resulting in accumulation of solids. Because of this accumulation, periodic pumping is required, ranging from $150 to $550 per visit, depending on site conditions and volume pumped.

Cesspools Summary	
Use in Steep Terrain	Yes
Use in High Ground Water Areas	No
Percolation Rate	Designated by DOH
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost:	up to $15,000 /1,000 gallons

Seepage Pits — Fact Sheet D-3

The construction of a seepage pit is similar to that of a cesspool. The difference between the two is that the seepage pit receives treated wastewater, whereas a cesspool receives untreated wastewater. The effective absorption area of a seepage pit is measured along the sidewalls of the pit. No allowance is made for the bottom of the pit according to HAR 11-62.

Considerations and Restrictions

Seepage pits should be considered when the land area available to dispose of effluent is insufficient for absorption beds/trenches, when the terrain is too steep for other disposal systems or when an impermeable layer overlies more suitable soil. Design criteria should be referenced in HAR 11-62.

Seepage pits are often found where cesspools once existed. The addition of a septic tank or other treatment system upstream from the cesspools enables the owner to consider converting the cesspool into a seepage pit, if the cesspool does not have any problems like spills or overflows. However, in cases where a new seepage pit is to be installed, it may be more expensive than other systems due to the greater depth of excavation. Seepage pits may also be sited such that they are below the aerobic zone in soil, resulting in little or no oxidation of organic compounds as compared to shallower systems such as absorption systems.

Effluent Quality

There have been few studies that have investigated the effluent characteristics of seepage pits. It is commonly believed that seepage pits do not provide the same level of treatment as other disposal systems. However, in a 2007 study, it was shown that seepage pits in loamy soil eliminated E. Coli, a fecal coliform, from wastewater as well as absorption trenches did. Organic loads adjacent to the absorption trenches were actually higher than they were for the seepage pits. Effluent from seepage pits was also lacking in ammonia nitrogen, indicating effective nitrification. Total nitrogen was similar to background levels within six feet of the bottom of the seepage pits.

Typical Installed Costs (2007)

Conversion of a cesspool into a seepage pit will cost approximately $5,000. Installing a new seepage pit is much more expensive, depending on the soil conditions, but will generally cost approximately $10,000 each. Multiple seepage pits may be required, depending upon site-specific percolation rates.

Operation and Maintenance Costs

The overwhelming issue for seepage pits is not the maintenance of the pits themselves, but the maintenance of the treatment systems preceding the pits. Proper operation and maintenance of the septic tank(s) or ATU(s), extends the life of the seepage pit and decreases the likelihood of solids clogging in the seepage pit. If upstream processes allow passage of solids to the seepage pit, periodic sludge pumping will be required.

Seepage Pits Summary	
Use in Steep Terrain	Yes
Use in High Ground Water Areas	Usually no
Percolation Rate	Faster than 60 min/in
Relative Footprint When Compared To Conventional Drainfield	Small
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost:	$10,000 /1,000 gallons

Absorption Beds — Fact Sheet D-5

Absorption beds are subsurface wastewater infiltration systems (SWIS) that have beds at least three feet wide. Absorption beds are similar to absorption trenches. For an absorption trench system, there is a distinct section of undisturbed soil between the absorption trenches. With an absorption bed, the area designated for disposal is excavated, and a layer of gravel is installed with the distribution pipe laid atop. In the case of gravelless systems, the plastic chambers are laid on the exposed soil. In essence, the wastewater will be spread over the entire area, instead of restricted to beneath the distribution pipe.

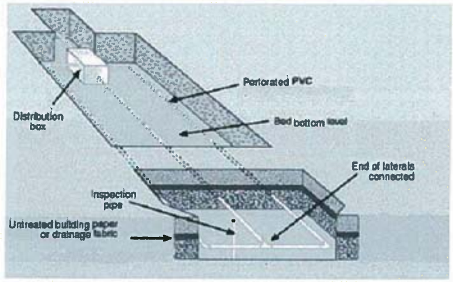


Figure 4-3 Bed disposal system (Adapted from Kent County, DE DPW)

<u>**Considerations and Restrictions**</u>
Beds are not allowed in terrain with slopes exceeding 8%. Since the entire area of the bed is considered as absorption area the total amount of land required is smaller compared to an absorption trench system. Roots from bushes and trees will damage the performance of the absorption system, therefore, root barriers should be utilized.

<u>**Effluent Quality**</u>
Effluent quality from an absorption bed will be similar to that of absorption trenches (see D-4).

<u>**Typical Installed Costs (2007)**</u>
These costs include excavation, gravel, piping, and/or plastic chambers/storage panels. Typical costs are about $7,000-$18,000 per 1,000 gpd of treated wastewater.

<u>**Operation and Maintenance Costs**</u>
Operational and maintenance issues are the same as for trenches. See Appendix A for tips extending the functional life of SWIS.

<u>**Absorption Beds Summary**</u>	
Use in Steep Terrain	<8% slope
Use in High Ground Water Areas	No
Percolation Rate	Faster than 60 min/in
Relative Footprint When Compared To Conventional Drainfield	Medium
Maintenance Level:	Low
Power Required:	No
Typical Installed Cost:	$7,000-$18,000 /1,000 gallons

Elevated Mounds — Fact Sheet D-6

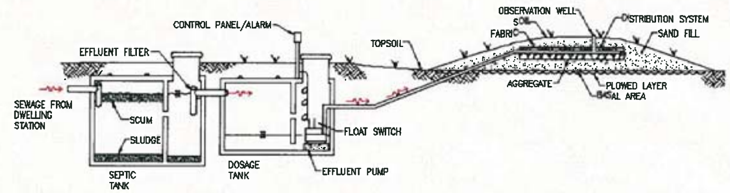


Figure 4-4 Elevated Mound System

Elevated mound systems are engineered mounds of sand/soil used to create acceptable soil conditions for effluent disposal and/or to create vertical separation from groundwater. The land on which the mound will be placed is first tilled, and a layer of sand and distribution system is placed over the tilled surface. The top of the mound is covered with surrounding soil and aesthetically landscaped.

<u>**Considerations and Restrictions**</u>
Mounds are commonly used in areas where absorption trenches and beds cannot be used, such as when the terrain is excessively steep, when there is a high groundwater table, or when the soil percolation rate is not conducive for a SWIS. Landscaping is required as the mounds could reach a height of three feet. As shown in the figure above, the disposal point is higher than the treatment system, therefore a pump system will be required.

<u>**Effluent Quality**</u>
Effluent quality for an elevated mound system is similar to that of an absorption trench or bed (see D-4).

<u>**Typical Installed Costs (2007)**</u>
Construction costs range from $10,000 to $15,000, but can go as high as $25,000 per 1,000 gpd of treated wastewater in Hawaii.

<u>**Operation and Maintenance Costs**</u>
Since the elevated mound system requires a pump to lift the effluent to the specific elevation, the pump's power costs need to be budgeted. The estimated power consumption is approximately 100 – 300 kW-h per year. The same care must be provided to the mound as would be provided to trenches or beds. See Appendix A for tips on maintenance.

<u>**Elevated Mounds Summary**</u>	
Use in Steep Terrain	Yes
Use in High Ground Water Areas	Yes
Percolation Rate	All
Relative Footprint When Compared To Conventional Drainfield	Large
Maintenance Level:	Medium
Power Required:	Yes
Typical Installed Cost:	up to $25,000 /1,000 gallons

Evapotranspiration — Fact Sheet D-7

Evapotranspiration (ET) is the combined effect of wastewater disposal by direct evaporation and by plant transpiration. ET is the discharge of pretreated effluent to a porous bed containing water-tolerant plants. Wastewater effluent is discharged into the bed, and wicking or capillary action draws the water to the surface where it is either taken up by the plants and transpired or evaporated from the surface of the bed. These systems may or may not be designed with an impermeable liner. If the system is designed with a liner, the system is considered "zero-discharge", and disposal is strictly dependent on transpiration through the plants and evaporation. However, if the liner is not used, the disposal system sizing criteria can also account for absorption via the soil. This type of system is known as evapotranspiration-infiltration (ETI). ET and ETI require large surface areas for year round disposal and are most suited for very arid climates where evaporation rates are much higher than precipitation rates.

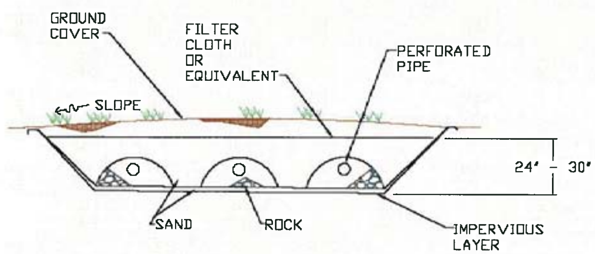


Figure 4-5 Cross Section of an ET Bed

Typical components of an ET system may include drip or distribution lines, a flushing and filtering mechanism, a controller to automate the dosing cycles, a distribution pump, and several alternating drainfields. DOH approves these systems on a case-by-case basis, and systems exist in the State of Hawaii. Record keeping of lysimeter (soil pore water sampler) data is required to ensure that this alternative system is operating effectively.

Considerations and restrictions

These systems are considered non-standard/alternative systems by DOH. Evapotranspiration is best suited for environments where the rate of evaporation significantly exceeds the rate of precipitation. Zero discharge systems, like evapotranspiration, that prevent wastewater from leaving the site (and/or reaching groundwater) can be used above the UIC line, pending approval from DOH on a case-by-case basis. Other considerations include:

- Stormwater runoff should drain away from the system. Gutters and drainpipes shall be directed away from the system.
- Use high transpiration plants suitable for the wetness at ground level.
- Consider additional ET/ETI beds as required to enable owner to deal with operating difficulties or system failures and alternate loads.

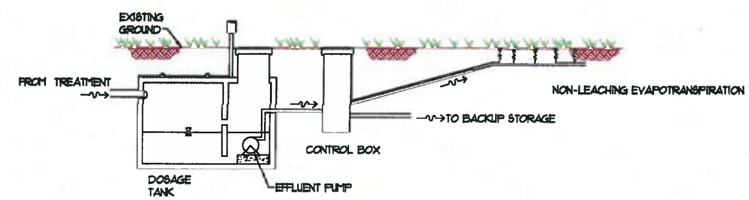


Figure 4-6 Subsurface Evapotranspiration Profile of Typical ET System

Effluent Quality

Few studies have adequately quantified the quality of the effluent from this disposal system. Trial and error has been the norm for these types of systems, so success rates are very hard to determine, as well as quality of effluent.

Typical Installed Costs (2007)

Because of the large surface area used, ET/ETI systems can be expensive. Values can range between $15,000 and $25,000 per 1,000 gpd of treated wastewater.

Operation and Maintenance Costs

Operational costs are on the order of $20 a year for simple inspection of observation wells, plus electrical costs for pumping when needed. Other maintenance requirements include minor landscape work, such as trimming the vegetation. Upstream treatment operations and processes should be properly maintained and pumped as needed to avoid overflow of solids into the ET bed.

Evapotranspiration Summary	
Use in Steep Terrain	No
Use in High Ground Water Areas	Yes
Percolation Rate	
Relative Footprint When Compared To Conventional Drainfield	Large
Maintenance Level:	High
Power Required:	Yes
Typical Installed Cost:	up to $25,000 /1,000 gallons

Wastewater Reuse — Fact Sheet D-8

The reuse of wastewater for non-potable needs can offset potable water use thereby reducing overall demand on the potable water supply. Therefore, water reuse or reclamation has become increasingly popular. If an effluent meets certain Department of Health water quality requirements, then the recycled water can be utilized in landscaping, agricultural irrigation, and even toilet flushing.

The highest level quality of recycled water defined by DOH is R-1, and is the only level of recycled water that may be used above the UIC line, on a case-by-case basis. The requirements for R-1 recycled water are quite strict and fairly expensive to achieve with a small flow onsite treatment system. However, the requirements for R-2 and R-3 water are less stringent making recycling of effluent less difficult.

Considerations and Restrictions

Care should be taken to ensure that there is no crossing of recycled water lines and potable water lines. Distinguishing markings (standard purple pipe) should be used to identify recycled water lines. Strict monitoring and record keeping are required. The frequencies and types of parameters to be monitored are determined by the level of effluent quality and the method of application of the recycled water. Daily, weekly, and annual records of the treatment and water reuse project may be required. The State of Hawaii Department of Health has published *Guidelines for the Treatment and Reuse of Recycled Water*, available at the DOH website http://www.hawaii.gov/health/environmental/water/wastewater/forms.html. These guidelines will help in the planning and design of any wastewater recycling system. The frequency of monitoring and reporting may be reduced for on-site systems by DOH on a case-by-case basis.

Effluent Quality

Recycling of water does not improve the quality of the effluent, but it does have minimum standards that must be met to be safe for human health and the environment.

Typical Installed Costs (2007)

The costs associated with the specific concept of recycling water are too specific to give a general price range

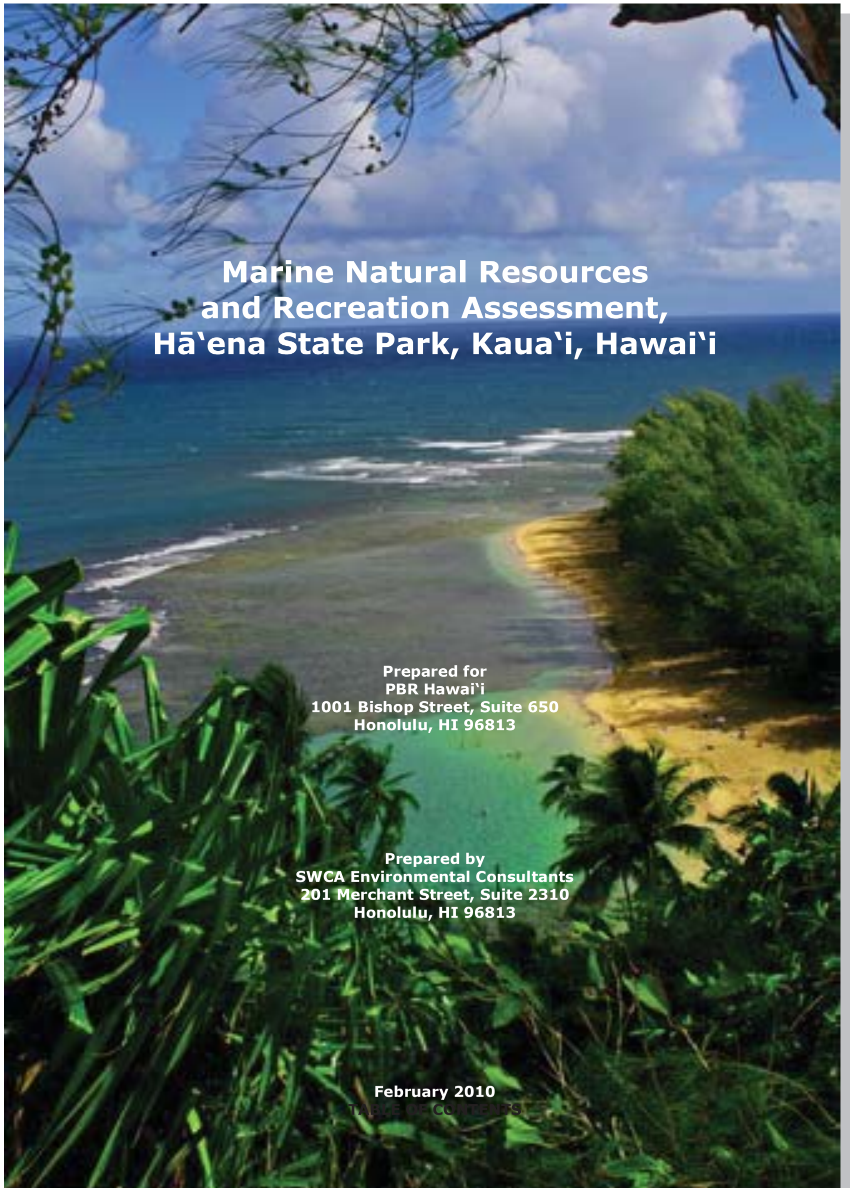
Operation and Maintenance Costs

Without a definitive concept of a proposed system, operation and maintenance costs cannot be generalized.

Wastewater Reuse Summary

Use in Steep Terrain	Approval needed
Use in High Ground Water Areas	Possible
Percolation Rate	All
Relative Footprint When Compared To Conventional Drainfield	Unknown
Maintenance Level:	Unknown
Power Required:	Unknown
Typical Installed Cost:	Unknown

Appendix F



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1.0 Background

In March 2008, PBR Hawai'i tasked SWCA Environmental Consultants with the description of the marine resources of the Hā'ena State Park. The project encompasses 64 acres within the park boundaries and the adjacent nearshore waters and Kē'ē Beach. Information to be provided includes a description of the physical characteristics including shoreline erosion; inventory of biological resources, and an assessment of recreational resources and current visitor impacts. Included in these tasks is a discussion of special design considerations, resource management concepts, and interpretive concepts for marine recreation use.

The overall goal of the project is to plan for a public park that accommodates recreational opportunities, preserves the significant natural, cultural, and scenic resources, and enhances the natural park setting. The objectives of this project include refinement of the draft Community Preferred Master Plan prepared in 1999 by The Keith Companies, Inc., and providing information to support preparation of an EIS for the future development of Hā'ena State Park. The intent is to balance public usage of the park's recreational resources with the protection and preservation of the natural and scenic features and significant cultural resources within, and associated with, the park area.

SWCA conducted extensive literature reviews, and performed brief reconnaissance surveys of marine resources at the park, and compiled geospatial data to prepare resource maps. The report was prepared by Tiffany Thair, B.A., John Ford, M.S., Robert A. Kinzie III, Ph.D., and Ryan Taira, B.A.

2.0 Introduction and Setting of the Coastal Environmental at Hā'ena State Park

Hā'ena State Park is located within Ka'īlio Shore sub-area of Hā'ena (Clark 1992). Four coastal sub-areas are recognized between Kē'ē and Hā'ena Point (Figure 1). The beaches of these areas are fringed with scattered beachrock slabs along the water line. The mouth of Limahuli Stream, a small intermittent stream, and freshwater seeps bisect the beach within the Park boundaries. The backbeach area consists of low sand dunes roughly 4 to 8 ft high that are overgrown with ironwood and false kamani trees. The roots of ironwood in many areas are exposed due to erosion by the action of storm waves. Immediately seaward of Kē'ē Beach, located within the Ka'īlio Shore, is a shallow lagoon that provides one of the most popular swimming areas in Hawai'i (Clark 1999). The lagoon is formed by a shallow fringing reef platform that joins the shore roughly 200 feet to the east of highway's end at Kē'ē Beach.

Clark (1992) provided a comprehensive description of the reef structure within the Park boundaries which remains accurate today. In 2003 and 2007, the Center for Coastal Monitoring and Assessment (CCMA), National Ocean Service, Biogeography Branch, in cooperation with Analytical Laboratories of Hawai'i, published detailed maps of the reef and benthic marine habitat at Hā'ena State Park (Figures 2-4). Sand and reef pavement comprise the dominant marine geomorphologic structures between Kē'ē Beach and Maniniholo Bay to the east. From Maniniholo Beach west to Hā'ena Point the reef consists of aggregate reef, scattered coral and rock, and rubble with small patches of reef pavement. The reef pavement is covered with macro-algae, coralline algae, and corals; however, the sandy lagoon floors and channels are uncolonized.

Ocean conditions at the Park are typical of exposed northern coasts in Hawai'i. Between October and May, North Pacific storm swells bring dangerously high surf in excess of 10 feet to the area (Clark 1992). When trade wind swells are prevalent between June and September, surf heights and swells at Hā'ena generally reduced (Clark 1992). North east trade winds are present between 90-95 percent of the year and almost always generate some surf activity on the outer reef margins. Predominant long shore currents run east to west outside the reef. Dangerous rip currents are created in reef channels by storm waves and tidal conditions. Haraguchi (1979) suggested tidal currents ranging from 0.1 to 1.0 knots, and Clark (1992) suggested that such current velocities were not usually a concern for nearshore ocean recreation

activities. Nevertheless, life guards at Kē'ē Beach strongly objected to SWCA biologists' plan to conduct snorkel surveys of the outer reef during a day with unusually calm conditions in November 2008.

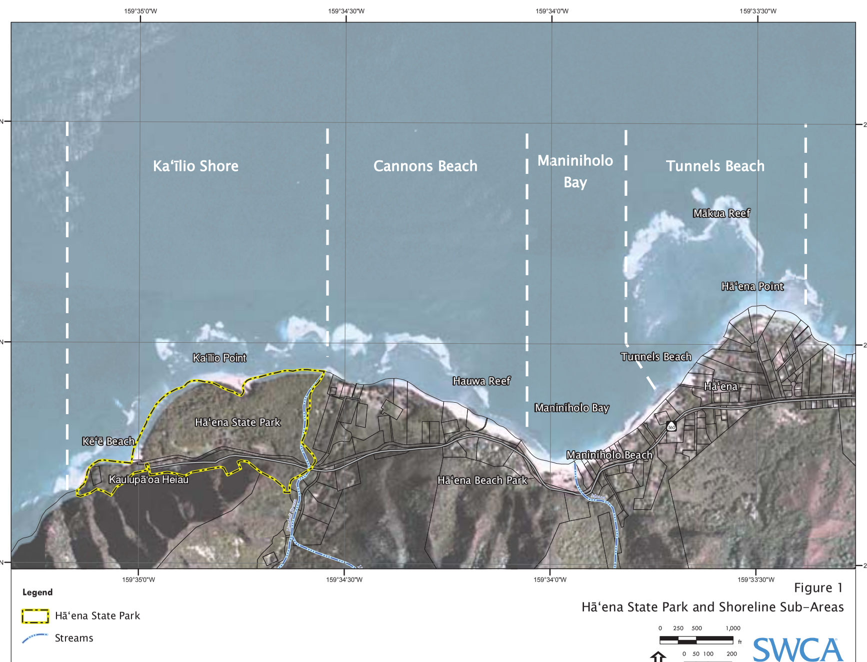

Figure 1
Hā'ena State Park and Shoreline Sub-Areas

Source: State of Hawaii GIS; NOAA; PDC;
Clark, J. 1992. Beach and ocean recreation study, Ha'ena, Kaua'i. Contract report prepared for Division of State Parks, Department of Land and Natural Resources, State of Hawaii, Honolulu. 49pp

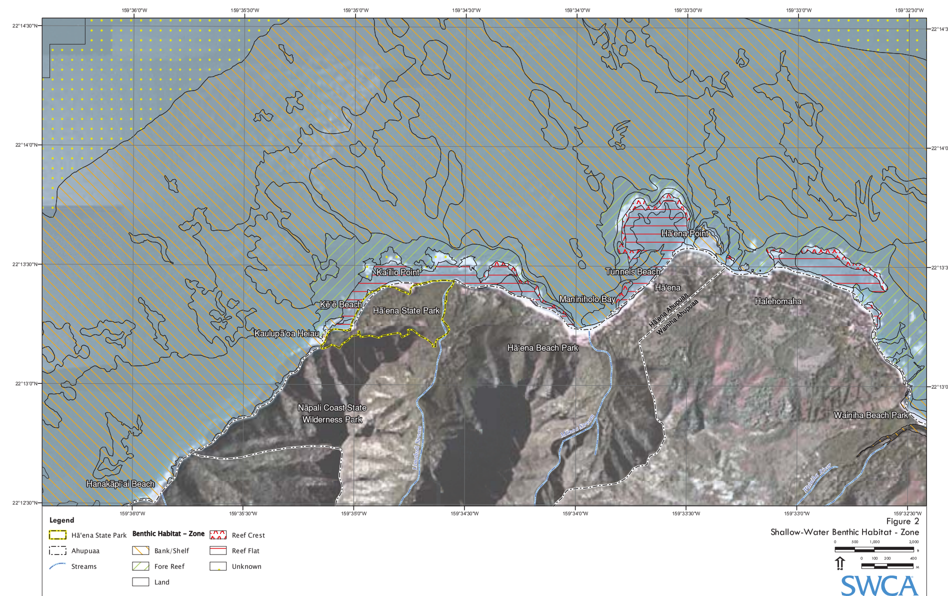

Figure 2
Shallow-Water Benthic Habitat - Zone

Source: State of Hawaii GIS; NOAA; PDC

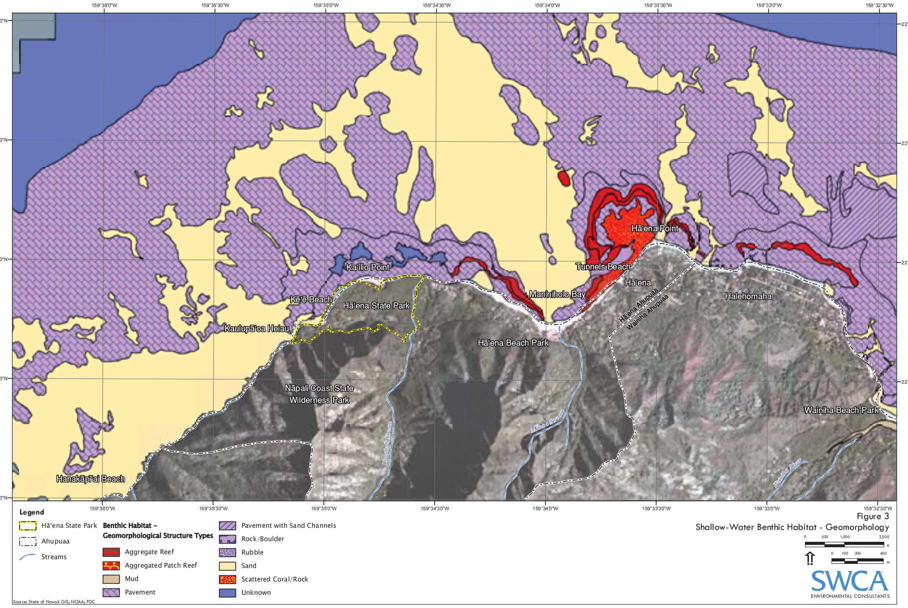

Figure 3
Shallow-Water Benthic Habitat - Geomorphology

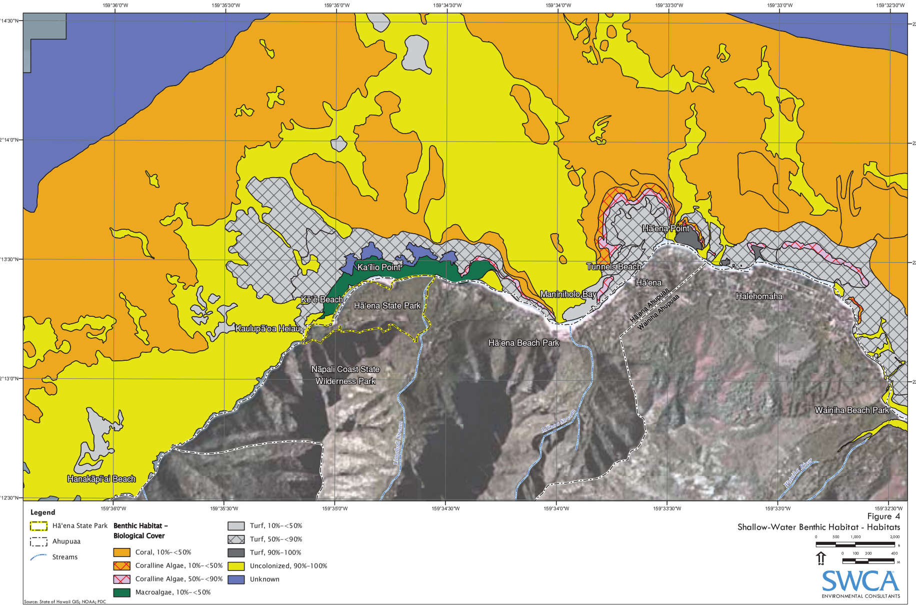

Figure 4
Shallow-Water Benthic Habitat - Habitats

3.0 Beach Erosion

Kēʻē Beach and shoreline of Hāʻena State Park are exposed to high surf during the winter months and occasionally during the summer months. Storm waves are responsible for erosion of sand dunes behind the beach. Waves sweeping across the beach undermine ironwood trees, exposing their roots and occasionally toppling them onto the beach. High surf also generates a powerful rip current that runs out the narrow channel at the west end of the lagoon to the open ocean creating a hazard for swimmers and divers.

To determine the extent of erosion and beach loss, the Hawaiʻi Shoreline Study, an initiative of the University of Hawaiʻi (UH) Coastal Geology Group (http://www.soest.hawaii.edu/coasts/), provides information on shoreline change data to assist in decision-making for actions affecting the coastal zone. The Surfrider Foundation maintains valuable links to beach erosion resources on its website (http://www.surfrider.org/).

The shoreline at Hāʻena State Park is subject to a number of natural hazards including tsunami, storm surge, high winds, coastal erosion, sea-level rise, and high waves. Evaluating changes to the configuration of shorelines helps define zones of avoidance for conservation of sensitive areas, and identify appropriate means to mitigation and control beach loss.

The UH erosion study area, bounded by Nāpali coast on the west and Hāʻena Point on the east, encompasses a total of 166 transects. Here the shoreline consists of carbonate sand, exposed beach rock, and basalt boulders deposited by stream discharge. The fringing reefs at Kēʻē, Limahuli, and Hāʻena cause waves to break in various directions along the shore. Figure 5 illustrates the draft results of beach loss studies conducted by the UH Coastal Geology Group in the vicinity of Kēʻē Beach and Hāʻena State Park. The UH Coastal Geology Group estimated that the overall rate of beach erosion between Kēʻē Beach and Hāʻena State Park is -0.9 ft/yr. Along the eastern-most portion of Hāʻena State Park sand is eroding at an average rate of -1.2 ft/yr, while the central area around Limahuli Stream mouth is eroding at an average rate of -1.0 ft/yr.

The western-most area by Kēʻē Beach is eroding at an average rate of -0.6 ft/yr. Figure 5 also illustrates the location of historic beach configurations mapped from previous aerial imagery and registered to a common coordinate system through the use of geographic information systems (GIS) technology.

4.0 Water Quality

The marine waters of the Hāʻena State Park are considered Class AA coastal waters by the State Department of Health (DOH) (HAR 11-54). Class AA waters possess high ecological and recreational value. It is the objective of Class AA waters that these remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent possible, the wilderness character of these areas is to be protected.

Within the defined reef at Hāʻena, Class AA waters are bounded by areas less than 18 meters (60 feet) in depth. Uses to be protected in the class of waters include oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment. Until recently, the coastal waters of Hāʻena State Park were not actively monitored by DOH. However, in late 2005, the DOH Clean Water Branch (CWB) and the Hanalei Watershed Hui (HWH) joined in the protection of Kauaʻi beaches through a partnership between DOH and the community based organization. Hanalei Watershed Hui's involvement allowed DOH to increase the number of beaches that it monitors on Kauaʻi, and the frequency at which they are sampled. Hāʻena Beach Park is one of the beaches covered under this agreement.

Table 1 illustrates the results of initial water quality sampling at Hāʻena State Park. DOH (2008) noted that state standards for enterococci were attained at Hāʻena. The reported parameters for temperature, salinity, dissolved oxygen, pH, and turbidity reflect clean coastal waters within Hawaiʻi DOH water quality

standards for Class AA waters. Coliform and enterococci levels are not reported here, but were found to be within state standards for Class AA waters.

Table 1. State of Hawaiʻi Department of Health water quality monitoring data collected at Kēʻē Lagoon within Hāʻena State Park.

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/l)	DO (%)	pH	Turbidity (NTU)
1/18/2005	8:29:00 AM	24.09	34.52	6.13	93.2	8.17	5.47
8/4/2005	8:41:00 AM	24.84	34.41	5.06	78	7.92	0.7
8/10/2005	8:46:00 AM	26.16	34.4	5.38	85.1	7.97	0.84
8/17/2005	8:50:00 AM	25.73	34.53	4.58	71.9	7.95	0.69
8/31/2005	8:59:00 AM	26.82	34.44	5.26	83.9	8	0.79
9/8/2005	8:53:00 AM	25.95	34.39	5.8	91.1	8.12	1.61
9/14/2005	8:52:00 AM	26.02	34.17	5.99	94	8.12	3.27
9/21/2005	8:52:00 AM	26.13	33.66	5.59	87.9	8.07	2.47
9/28/2005	8:34:00 AM	25.61	33.78	5.74	89.3	8.16	1.08
12/12/2006	8:03:00 AM	24.78	35	6.12	91.2	8.03	2.37

5.0 Marine Biological Resources

Clark (1992) presented a general description of marine resources within the Park boundaries. The results of five previous marine studies of Kēʻē Beach and reef (The Keith Companies 2001; Stepath 1999); Limahuli Beach and reef (Jokiel and Brown 2000); and nearby Hanalei Bay (Friedlander and Parrish 1998) were cited to prepare a description of the nearshore marine environment. These studies were supplemented with a brief snorkel reconnaissance of the Kēʻē Lagoon and inner reef flat conducted on November 3, 2008 by SWCA biologists Dr. Robert Kinzie and John Ford. Additional anecdotal information on species observed by others was obtained from oral histories recorded by Maly and Maly (2003), and related records of interviews with area residents and fishermen (PBR database).

Eighty (80) fish species representing 26 families have were reported from nearshore waters along the north shore of Kauaʻi by the four previous surveys referenced above (Table 2). Species abundance and diversity within the Kēʻē Lagoon and reef flat is lower than that found at the outer reef/offshore sites (Jokiel and Brown 2000, Stepath 1999, this study), with only 46 species of fishes occurring here. Kēʻē Lagoon and reef flat provide an excellent habitat for juvenile reef fishes. Fish assemblages in the Limahuli offshore study site had the greatest number of individuals and highest biomass observed on fish transects around Kauaʻi in 1999 (Friedlander 2000). Wrasses, surgeonfishes, and damselfishes comprised the majority of the species observed in the lagoon and along the reef flat at Kēʻē. Small schools of wekeʻula (*Mulloidichthys vanicolensis*), hinalea lau-wili (*Thalassoma duperrey*), maʻiʻiʻi (*Acanthurus nigrofuscus*), omaka (*Stethojulis balteata*), and manini (*Acanthurus triostegus sandvicensis*) were commonly observed within the lagoon and reef flat. For many species, juveniles appeared to be very common along the reef flat.

Fish diversity is much greater on the seaward side of the reef crest and studies conducted nearby, off Limahuli Stream and in Hanalei Bay, recorded over 160 species of fishes in these areas (Jokiel and Brown 2000, Friedlander and Parrish 1998). Friedlander (2000) found that fish biomass at the Limahuli offshore site to be more than twice that observed at the site with the second largest biomass (Hoʻai Bay near Poʻipu offshore) and an order of magnitude greater than the inshore habitat at Limahuli. Among 60 reefs monitored by the Hawai'i Coral Reef Assessment & Monitoring Program (CRAMP), the shallow reef station (1m) at Limahuli ranked 58 in species richness, 51 in density, 57 in biomass, and 57 in diversity. Limahuli 10m ranked 5 in species richness, 24 in density, 8 in biomass, and 21 in diversity. The most abundant species were the hinalea lauwili (*Thalassoma duperrey*) and the kole (*Ctenochaetus strigosus*) at the 3m and 10m reefs respectively. The species with the highest biomass were the manini (*Acanthurus triostegus*) and the māikoiko (*Acanthurus leucopareius*) at the 3m and 10m reefs respectively (Jokiel and Brown 2000).

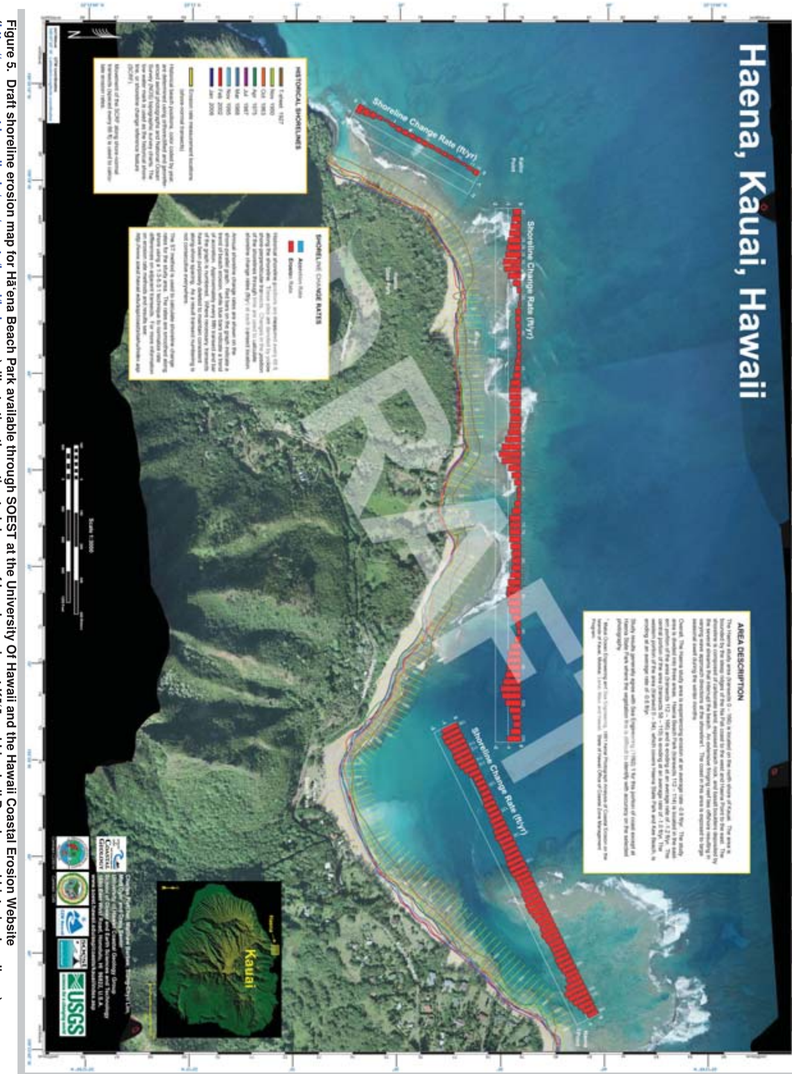

Figure 5. Draft shoreline erosion map for Hā'ena Beach Park available through SOEST at the University Of Hawaii and the Hawaii Coastal Erosion Website (http://www.soest.hawaii.edu/asp/coasts/kauai/index.asp), illustrating the estimated degree of beach erosion at Kē'ē and Limahuli Beaches and historic shorelines.)

TABLE 2. List of marine shore fishes observed within and adjacent to Kēʻē Lagoon and Reef Flat, Hā`ena State Park

Fish Species	Hawaiian or Common Name	SWCA	Stepath (1999)	The Keith Companies (2001)		CRAMP Data (1998-2004)		Friedlander et al 2003
		Present/Absent A=adult/J=juvenile	Index of Relative Dominance (IRD)	Present/Absent Shallow Inshore	Present/Absent Seaward Slope	#/125 sq m 1m depth	#/125 sq m 10 m depth	Top 20 Fish IRD (Rank)
Abudefduf abdominalis	mamo	A	2					60.13 (14)
Abudefduf sordidus	kupipi	A	2	✔				
Acanthurus achilles	paku'iku'i		2					
Acanathurus blochii	pualu	A					1.5	
Acanthurus dussumieri	palani			✔			1.0	
Acanthurus leucopareus	maikoiko	A	5		✔		34.5	147.27 (7)
Acanthurus nigrofuscus	ma'i'i'i		168	✔		2.0	11.5	512.07 (1)
Acanturus nirgrorus	maiko			✔	✔			
Acanthurus olivaceous	n'ena'e					0.5	10.0	85.23 (11)
Acanthurus triostegus	manini	A	757	✔	✔	18.5	2.5	88.87 (10)
Anampses cuvier	opule			✔			1.5	
Aulostomus chinensis	nunu			✔			0.5	
Bodianus bilunulatus	a'awa					0.5	1.0	
Calotomus carolineus	ponuhunuhu	A,J					0.5	
Catherhines dumerilii	o'ili						1.0	
Canthigaster amboinensis	Ambon toby						2.5	
Canthigaster jactator	Hawaiian whitespotted toby	A				1.0	6.0	
Centropyge potteri	Potter's angelfish						1.5	
Cephalpholis argus	roi						1.0	40.99 (17)
Caranx melampygus	omilu	J		✔	✔			
Chaetodon auriga	kikakapu						1.0	
Chaetodon fremblii	kikakapu	A					0.5	
Chaetodon miliaris	lauwiliwili			✔				
Chaetodon multicinctus	kikakapu						3.0	
Chaetodon quadrimaculatus	lauhau	A				0.5		
Chaetodon unimaculatus	lauhau						1.0	
Chlorurus perspeculatus	uhu uliuli	A,J		✔	✔			66.40 (13)
Chlorurus sordidus	uhu	A,J						155.29 (6)
Chromis hanui	chocolate-dipped chromis						0.5	
Chromis ovalis	oval chromis			✔			8.0	
Chromis vanderbilti	blackfin chromis			✔				28.29 (20)
Cirrhitops fasciatus	piliko'a		2	✔				
Cirrhitus pinnulatus	po'poa'a			✔			0.5	
Conger cinereus	puhi uha	Dead on beach						
Coris flavovittata	hilu		2					
Coris venusta	hinalea		28	✔		4.0		
Ctenochaetus strigosus	kole			✔	✔		46.5	408.95 (3)
Entomacrodus marmoratus	pao'o	A						
Fistularia commersonii	nunu peke	J	35					
Gomphosus varius	hinalea i'iwi	J	9					
Halichoeres ornatissimus	ohua	A				0.5	3.0	
Kuhlia xenura	aholehole				✔			
Kyphosus sp	nenue	A	2	✔	✔		26.0	
Labroides phthirophagus	Hawaiian cleaner wrasse	A					4.5	
Lutjanus kasmira	ta'ape						1.0	
Melichthys niger	humuhumu 'ele 'ele						10.5	487.72 (2)
Monotaxis grandoculis	mu				✔		0.5	
Mulloidychthys vanicolensis	weke 'ula		5	✔	✔		5.0	
Mulloidychthys flavolineatus	weke'a'a	A, J		✔	✔			
Myripristis sp.	mempachi				✔			
Naso literatus	umaumalei	A						216.65 (5)
Naso unicornis	kala	A		✔	✔		1.5	34.42 (18)
Paracirrhites arcatus	piliko'a			✔			3.0	
Paracirrhites forsteri	hilu piliko'a			✔			1.0	
Parupeneus bifasciatus	munu						0.5	
Parupeneus cyclostomus	moano kea						2.0	
Parupeneus multifasciatus	moano	A		✔		0.5	11.5	42.38 (16)
Paurpeneus pleurostigma	malu						1.0	
Parupeneus porphyreus	kumu	A	2	✔	✔			
Pervagor spilosoma	o'ili 'uwi'uwi			✔				
Plageotremus goslinei	Gosline's fangblenny	A	2				1.0	
Platybelone argalus	aha	A		✔				
Plectroglyphydodon imparipennis	bright-eyed damselfish	A	354			1.5		
Plectroglyphydodon johnstonianus	blue-eyed damselfish			✔			0.5	
Priacanthus meeki	aweoweo				✔			
Pseudocheilinus octotaenia	eightstripe wrasse						1.0	
Rhinecanthus rectangulus	humuhumu nukunuku a pua'a	A	21	✔		3.0		33.28 (19)
Scarus psittacus	uhu							67.86 (12)
Scarus rubroviolaceus	palukaluka	A,J					0.5	101.68 (8)
Scorpaenopsis sp.	scorpionfish				✔			
Spratelloides delicatulus	piha	A		✔				
Stegastes fasciolatus	Pacific Gregory		209	✔	✔		9.0	52.83 (15)
Stethojulis balteata	omaka	A	168	✔		28.0	1.5	
Sufflamen bursa	humuhumu lei						3.5	
Thalassoma ballieui	hinalea luahine						2.5	
Thalassoma duperrey	hinalea lauwili	A,J	412	✔	✔	46.0	21.5	338.27 (4)
Thalassoma purpureum	hou		2	✔	✔			
Thalassoma trilobatum	awela	A,J	442			1.0		
Zanclus cornutus	kihikihi	A			✔		1.0	
Zebrasoma flavescens	lau'ipala							92.10 (9)

Fish biomass at the Limahuli offshore site was dominated by large mobile herbivores, mainly surgeonfishes, triggerfishes, and parrotfishes. On the shallow Limahuli reef flat, small wrasses and surgeonfishes made up most of the fish biomass. Friedlander (2000) attributed the high standing stock of fishes observed at this site to the high spatial complexity of the habitat and the relatively light fishing pressure. During winter when high waves pound the exposed north shore of Kauaʻi, fishing pressure is further reduced. This situation creates a de facto marine preserve along the north shore for nearly six months each year by excluding fishers from access to nearshore waters within the Park. Little comparable information on the marine invertebrates of Kēʻē Lagoon and reef is available from previous studies; however, the CRAMP studies have monitored benthic invertebrates at Limahuli (Jokiel and Brown 2000) (Table 3). Coral cover rank is 36 among 60 reefs studied statewide. Coral cover was found to be very similar between the 2 sampling periods. Coverage by macro-algae was found to be relatively low; however, there was a high percentage of crustose coralline algae and turf algae present. Despite the proximity to the mouth of Limahuli Stream, a low percentage of fine sediments with low content of terrigenous material was found in this high wave energy environment. No rare or unusual species were observed.

The CRAMP coral cover rank for mid-water (10m or 33 ft) habitat at Limahuli is 31 among the 60 reefs studied statewide (Table 4). As with the shallow station, coral cover was very similar between the 2 sampling periods, and macro-algae coverage was found to be relatively low. As with the shallow reef station, there was a high percentage of crustose coralline algae and turf algae.

Table 3. CRAMP shallow water (1m) video-transect data of coral cover for Limahuli Reef of percent cover over between 1999 and 2004. Source: Paul Jokiel, HIMB.

Video Transect data (1m): % Cover:	6/7/1999		7/15/2000		6/3/2002		9/7/2004	
Coral Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cyphastrea ocellina	0	0	0	0	0	0	0	0
Fungia scutaria	0	0	0	0	0	0	0	0
Leptastrea purpurea	0	0	0	0	0	0	0	0
Montipora flabellata	2.2	1.5	2.0	1.4	3.2	1.8	1.9	1.4
Montipora patula	0.8	0.8	0.9	1.1	0.1	0.2	0.3	0.7
Montipora studeri	0	0	0	0	0	0	0	0
Montipora capitata	0.0	0.1	0	0	0.1	0.3	0.0	0.1
Pavona duerdeni	0	0	0	0	0	0	0.0	0.1
Pavona maldivensis	0	0	0	0	0	0	0	0
Pavona varians	0	0	0	0	0	0	0	0
Pocillopora damicornis	0	0	0	0	0	0	0	0
Pocillopora eydouxi	0	0	0	0	0	0	0	0
Pocillopora ligulata	0	0	0	0	0	0	0	0
Pocillopora meandrina	0.1	0.2	0.5	0.6	0.9	1.6	0.1	0.1
Porites brighami	0.7	1.0	1.1	0.6	1.4	1.5	0.1	0.1
Porites compressa	0	0	0.3	1.1	0.2	0.6	0	0
Porites evermanni	0	0	0	0	0	0	0	0
Porites lichen	0	0	0	0	0	0	0	0
Porites lobata	11.1	7.2	9.7	3.7	16.8	10.6	14.8	8.1
Porites rus	0	0	0	0	0	0	0	0
Psammocora nierstraszi	0	0	0	0	0	0	0	0
Total Coral	**14.9**	7.5	**14.5**	5.1	**22.8**	11.4	**17.2**	8.5
Species Richness	**7**		**6**		**8**		**9**	
Macro-algae	1.0	1.3	0.3	0.5	0.4	0.5	0.2	0.1

Abbott and Hunter (2000) conducted a statewide study to document the location, abundance, and distribution of alien and invasive algae species. A primary objective of their research was to map the distribution of the most prominent alien and invasive species of algae in the state to enable managers to track rates of expansion and invasion of new sites in the future. One of their field research sites included Kaʻilio Point at Hāʻena. No invasive species of marine algae were found on the reef during their studies.

A complete list of algae observed by Abbott and Hunter (2000) within 0 – 5 m (0 – 16 ft) depth in 2000 and 2002 surveys appears in Table 5.

Table 4. CRAMP mid-water (10m) video-transect data of coral cover for Limahuli Reef of percent cover over between 1999 and 2004. Source: Paul Jokiel, HIMB.

Video Transect data (10 m): % Cover:	8/4/1999		7/11/2000		6/3/2002		9/7/2004	
Coral Species	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Cyphastrea ocellina	0	0	0	0	0	0	0	0
Fungia scutaria	0	0	0	0	0	0	0	0
Leptastrea purpurea	0	0	0	0	0.20	0.63	0	0
Montipora flabellata	1.8	2.4	1.1	1.2	0.7	1.3	0.4	0.6
Montipora patula	14.5	7.4	17.5	8.8	22.2	8.4	20.6	9.1
Montipora studeri	0	0	0	0	0.2	0.7	0	0
Montipora capitata	0.1	0.1	0.5	0.8	0.1	0.1	0.2	0.2
Pavona duerdeni	0	0	0.0	0.1	0.1	0.1	0.0	0.1
Pavona maldivensis	0	0	0	0	0	0	0	0
Pavona varians	0.0	0.1	0.2	0.3	0.0	0.1	0.3	0.5
Pocillopora damicornis	0	0	0	0	0	0	0	0
Pocillopora eydouxi	0	0	0.2	0.7	0.6	1.9	0	0
Pocillopora ligulata	0	0	0	0	0	0	0	0
Pocillopora meandrina	0.6	0.7	0.6	0.8	0.6	0.9	0.9	0.9
Porites brighami	0.0	0.1	0.0	0.0	0	0	0	0
Porites compressa	0.1	0.3	0.0	0.1	0	0	0	0
Porites evermanni	0	0	0	0	0	0	0	0
Porites lichen	0	0	0	0	0	0	0.1	0.1
Porites lobata	2.4	6.3	0.1	0.3	0.3	0.6	0.3	0.5
Porites rus	0	0	0	0	0	0	0	0
Psammocora nierstraszi	0	0	0	0	0	0	0	0
Total Coral	**19.5**	6.7	**20.4**	8.9	**25.1**	8.2	**22.7**	8.7
Species Richness:	**8**		**9**		**10**		**9**	
Macro-algae	0.3	0.8	0.2	0.3	0	0	0.1	0.1

6.0 Endangered Marine Species and Habitats

Endangered humpback whales (*Megaptera novaeangliae*) are found seasonally in the offshore waters of Kaua'i's north shore. The marine waters at Hā'ena State Park lie within the Hawaiian Humpback Whale National Marine Sanctuary established under Subtitle C of Public Law 102-587, as amended by Pub. L. 104-283. The sanctuary boundaries of the Kaua'i unit consist of the submerged lands and waters seaward from the shoreline, cutting across the mouths of rivers and streams to the 100-fathom (183 meter) isobath from Ka'īlio Point eastward to Mōkōlea Point (Figure 6).

Among the goals and objectives of the National Marine Sanctuaries Program are to support and coordinate long-term scientific research on the resources on these marine areas; to enhance public awareness and wise use of the areas; and to give particular attention to the protection of the area's natural resource and ecosystem values.

The Hawaiian monk seal (*Monachus schauinslandi*), was listed as an endangered species pursuant to the Endangered Species Act (ESA) on November 23, 1976 (41 FR 51612) and remains listed as endangered. Hawaiian monk seals, regular residents of the Northwest Hawaiian Islands, began appearing more frequently on Kaua'i and Ni'ihau beaches in the 1960's. The National Marine Fisheries Service (NMFS) believes that the total Hawaiian monk seal population is at its lowest level in recorded history and it is estimated that about 1,200 individuals are alive today. They are distributed predominantly in six Northwestern Hawaiian Islands (NWHI), with subpopulations at French Frigate Shoals, Laysan and Lisianski Islands, Pearl and Hermes Reef, and Midway and Kure Atoll. Small numbers also occur at Necker, Nihoa, and in the Main Hawaiian Islands (MHI). In 2005, the total number of individual monk seals in the MHI was estimated to be 77.

The number of monk seals born in the MHI has increased since the mid-1990 (http://www.fpir.noaa.gov/). In 2006 and 2007 there were 12 and 13 pups born, respectively, within the MHI. Scientists believe that Hawaiian monk seals are beginning to repopulate the MHI. Only a few females are actually known to have given birth on popular public beaches.

Table 5. Macroalgae observed at Ka‘īlio Point, Hā’ena (Abbott and Hunter 2000).

REEF FLAT		0 – 5 m (0 –16 ft) DEPTH	
GREEN ALGAE	*Bornetella sphaerica*	GREEN ALGAE	*Boodlea composita*
	Bryopsis pennata		*Caulerpa racemosa*
	Caulerpa taxifolia		*Caulerpa taxifolia*
	Cladophoropsis herpestica		*Chaetomorpha antennia*
	Codium arabicum		*Codium edule*
	Dictyosphaeria cavernosa		*Dictyosphaeria cavernosa*
	Dictyosphaeria versluysii		*Dictyosphaeria versluysii*
	Enteromorpha sp.		*Enteromorpha flexuosa*
	Halimeda discoidea		*Halimeda discoidea*
	Microdictyon setchellianum		*Neomeris annulata*
	Neomeris vanbosseae		*Ulva fasciata*
	Siphonocladus tropicus		*Valonia aggagrophila*
BROWN ALGAE	*Dictyota acutiloba*	BROWN ALGAE	*Colpomenia sinuosa*
	Dictyota ceylanica		*Dictyota friabilis*
	Dictyota friabilis		*Lobophora variegata*
	Padina sp.		*Padina japonica*
	Turbinaria ornata		*Rosenvingea intricata*
	Vaughaniella stage		*Sargassum echinocarpum*
RED ALGAE	*Dictyota acutiloba*		*Sargassum polyphyllum*
	Dictyota ceylanica		*Stypopodium hawaiiensis*
	Dictyota friabilis		*Turbinaria ornata*
	Padina sp.	RED ALGAE	*Asparagopsis taxiformis*
	Turbinaria ornata		*Botryocladia skottsbergii*
	Vaughaniella stage		*Dasya irridescens*
	Acanthophora spicifera		*Falkenbergia*
	Actinotrichia fragilis		*Galaxaura marginata*
	Amansia glomerata		*Galaxaura rugosa*
	Amphiroa valonioides		*Gracilaria sp.*
	Centroceras clavulatum		*Gracilaria sp.*
	Ceramium flaccidum		*Haliptilon subulatum*
	Galaxaura marginata		*Laurencia mcdermidae*
	Gelidiella acerosa		*Martensia fragilis*
	Griffithsia heteromorpha		*Melanamansia glomerata*
	Herposiphonia crassa		*Polysiphonia sp.*
	Herposiphonia delicatula		*Potrieria hornemanii*
	Herposiphonia nuda		*Pterocladiella capilacea*
	Hypnea spinella		*Rhodymenia leptophylla*
	Jania adhaerens		*Spyridia filamentosa*
	Jania pumila		
	Laurencia crustiformans		
	Laurencia sp.		
	Pterocladiella capillacea		
	Stenopeltis setchelliae		
	Tolypiocladia glomerulata		
	Womersleyella pacifica		

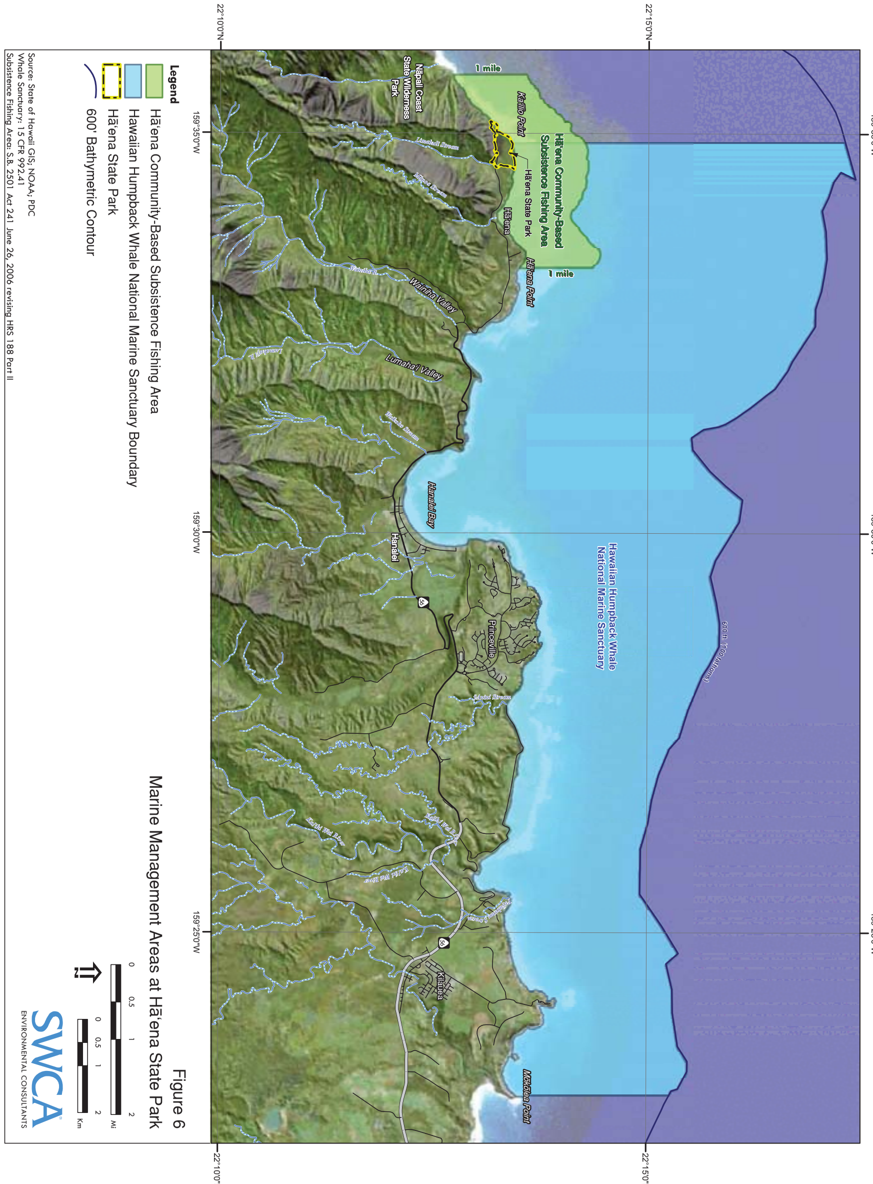

Figure 6
Marine Management Areas at Hā‘ena State Park

In 1995, 21 male monk seals, and no females, were relocated from the NWHI and released off of the Big Island of Hawai'i. Since their release, only six of these seals have been recently observed and reported. Research has also shown that the monk seals rarely migrate from the NWHI to the MHI. NMFS estimates that there are 31-40 monk seals on Kaua'i today. It is not unusual to find a monk seal resting on any north shore Kaua'i beach. Signs are posted along the beaches at various locations on the shore at Hā'ena State Park warning visitors not to harass resting seals.

The nearshore marine waters and beaches of Hā'ena State Park are not designated as critical habitat for any marine species. However, in July of 2008, the National Marine Fisheries Service (NMFS) received a petition from conservation groups to review and establish revised "critical habitat" for the monk seal.

The Endangered Species Act (ESA) in turn prohibits any changes or "destruction or adverse modification" by Federal activities (those that are federally funded or permitted) to these areas that will diminish its value as important habitat for the survival and recovery of the species. It is important to note that critical habitat designation does not turn an area into a reserve, refuge, Marine Protected Area (MPA) or a park. Public access and usage in areas that are designated as critical habitat are not affected. NMFS is currently reviewing and evaluating the recommendations contained in the petition.

Although threatened Green sea turtle (*Chelonia mydas*) nesting in the Hawaiian Archipelago is mostly limited to French Frigate Shoals (FFS) in the NWHI, they are common around all eight of the main Hawaiian Islands (MHI) (NMFS & USFWS 2007). Green sea turtles are frequently seen grazing upon algae in shallow nearshore reef waters around the north shore of Kaua'i, including the waters of Hā'ena State Park. Although there have been no recent reports of sea turtles nesting on the beach at Hā'ena, there have been 17 reported sea turtle nests on Kaua'i in the past year alone (Heacock, pers. comm.). The sandy beaches within the Hā'ena State Park are suitable for sea turtle nesting, and the possibility of a future turtle nesting there cannot be dismissed.

7.0 Recreational Resources and Assessment

7.1 Principal Existing Recreational Uses

The beautiful beaches, reef formations, cultural features, and verdant landscape of Kaua'i offer various recreation activities to locals and visitors on the island. The Hā'ena State Park, from Kē'ē Beach to the mouth of Limahuli Stream attracts a large number of visitors each year. The area is a popular spot for scenic shoreline sightseeing and ocean-related recreation. Selected recreation sites and reefs within the Hā'ena State Park boundaries are depicted in Figure 7.

The popularity of this region for recreation has increased dramatically over the past several decades. It has been estimated that Hā'ena State Park receives roughly 1,500 visitors during low periods (February) and approximately 10,600 visitors during high peak periods (August) (TKC and Earthplan 2001). Stepath (1999) counted approximately 1,250 people visiting the Kē'ē area for recreation daily during his study in June and July 1999. He found that people use the lagoon and reef flat area is highest between 10 a.m. and 6 p.m. with a peak usage at 4 p.m.

Other popular recreation areas adjacent to Hā'ena State Park include Cannons Beach, Maniniholo Beach, and Tunnels Beach. Use of the beach and nearshore waters at Hā'ena State Park are regulated by the Hawai'i Administrative Rules (HAR) for Shore Waters and Shores, Chapter 2: North Shore Kaua'i Ocean Recreation Management Area.

7.1.1 Shoreline Sightseeing

The scenic shoreline resources at Hā'ena State Park make the area an important sightseeing spot for visitors to the island. The shoreline offers views of tropical vegetation, steep mountains, sandy beaches,

ocean waters, colorful sunsets, and the Nāpali coastline. These features make it a destination point for many tourists (TKC and Earthplan 2001, Sprout and Sprout 2004, Klein 2007).

7.1.2 Beachcombing

Due to the frequency and severity of heavy surf on the northern portion of Kaua'i, shells and other marine debris are often dislodged from the reefs and carried to shore. As a result, many of the beaches in the area are popular beachcombing spots for collecting driftwood, beach glass, micro-mollusks, cats' eyes, and puka shells. Ka'īlio Shore at the east end of the beach adjacent to Limahuli Stream is one of the best shell collecting sites (Clark 1992).

7.1.3 Sunbathing

Sunbathing is a popular activity throughout the Hawaiian Islands. Sunbathing occurs at many beaches along Hā'ena State Park. The most level and widest beach section within the park is at Ka'īlio Point near Limahuli Stream. From this point, the beach narrows and becomes steeper before widening again at the lagoon. Kē'ē Beach is popular with tourists for sunbathing. Stepath (1999) found that sunbathing was the most common activity at Kē'ē Beach in June and July of 1999. Sunbathing is difficult at some areas on this part of the island during periods of heavy trade winds (Clark 1992). Clark (1992, 1999) found that visitors preferred Kē'ē Beach over Ka'īlio Point due to the convenience of showers, restrooms, and paved parking.

7.1.4 Hiking

Although there are no maintained hiking trails within the Hā'ena State Park, the trailhead to the famous 11-mile Kalalau Trail is located in the project area at the end of Kūhiō Highway. This trail provides access to the Nāpali Coast State Wilderness Park, which had 423,100 recreation visits in 2007 (DBEDT 2008). Kalalau Trail traverses five steep valleys before terminating at Kalalau Beach. The first two miles of the trail, from Hā'ena State Park to Hanakāpī'ai Beach is a popular day hike for visitors. Day-use hiking permits are required for users hiking beyond Hanakāpī'ai valley and camping permits are required for overnight hikers (Division of State Parks 2008).

7.1.5 Swimming

There are two ocean swimming areas in the vicinity of the project area located at Poholokeiki and Kē'ē Beach. Poholokeiki Channel is located where Limahuli Stream meets the shoreline. It was formed by the freshwater discharge of Limahuli Stream, which created a narrow waterway through the reef offshore. The channel offers a protected swimming area under calm ocean conditions. The water is slightly colder and less saline in the channel due to the freshwater discharge from Limahuli Stream. The suggested swimmer level for this site is "intermediate and advanced swimmers eight year of age and older" (Clark 1992). Some visitors or residents occasionally use the lower reaches of Limahuli Stream as a freshwater dipping and wading area. The level of use of Limahuli Stream for this activity is not known (TKC and Earthplan 2001).

Kē'ē Lagoon is located at the west end of Kē'ē Beach and is considered to be of statewide importance for recreational swimming. The lagoon's sandy bottom slopes gradually toward the sea to a depth of roughly 10 ft. It is connected to the open ocean by a deep, narrow channel through the reef (referred to as Puka Ulua). This swimming area is protected by the west end of Ka'īlio Reef making it suitable for all ages and swimming levels. Because of the calm, protected conditions, it is very popular with tourists and families with children. However, during periods of high surf, there is a powerful rip current that runs out the narrow channel (Clark 1999). As of 2008, there are at least two lifeguards on duty at this beach from 9A.M. to 5P.M. everyday of the year, including holidays (Yuen, PBR, pers. comm.)

7.1.6 Picnicking

Visitors and local residents use the beach at Hāʻena State Park for picnicking. Currently, there are no tables or barbecue areas;

7.1.7 Shorefishing

Although no statistics on shorefishing could be found for the Park, Hamnett et al (2004) noted that approximately 109,055 households in the state, or 31 percent of all households, enjoyed recreational fishing in 2004. Twenty-six percent of this total used pole and line fishing. The shoreline along Hāʻena State Park is an important recreational fishing area. Pole fishing is popular off the point at Kēʻē. At low tide, pole fishing also occurs off the west end of Kēʻē Lagoon. Throw-net fishing is conducted on the reef margins of the lagoon. Free dive spear fishing (without the use of SCUBA) is also popular in the area. The frequency of shoreline fishing activity increases during spring and summer when the ocean is calm more often. Fishers typically arrive at the Hāʻena State Park very early in the morning or after dark (Clark 1992).

The most valuable information on traditional fishing in the vicinity of the comes from the personal interviews of local fishermen and kupuna (Maly and Maly 2003). Several prominent local fishers from Hāʻena related stories to Maly and Maly (2003) of their fishing experience in the nearshore waters for honu (sea turtle), akule (bigeye scad), moi (Pacific threadfin), ʻama ʻama (mullet), ʻōio (bonefish), nenue (rudderfish), aholehole (flagtail), ʻāweoweo (Hawaiian bigeye), manini (convict tang), kala (bluespine unicornfish), ʻoama (juvenile goatfish), kumu (whitesaddle goatfish), pāpio and ulua (various species of jacks), heʻe (octopus), ula (lobsters), ʻaʻama (crab), and several kinds of limu (seaweed). Kahala (amberjack) and ʻōpelu (mackerel scad), ʻAhi (yellowfin tuna), ono (wahoo), aku (skipjack tuna), mahi-mahi (Dorado) were commonly caught offshore from Hāʻena.

A simple Google query of "fishing" + "Hāʻena" returns 52 pages of travel guides, vacation rentals, and real estate advertisements that entice visitors to the north shore of the Garden Isle, but with little substantive information about fishing and fisheries of the North Shore. Concern about the impact of visitors on reef resources of Hāʻena led to the enactment of a new law creating a community-based subsistence fishery area. On June 26, 2006, Hawaiʻi Governor Linda Lingle signed into law Act 241 to help protect the fish stocks and coral reef habitats within the ahupuaʻa of Hāʻena. The Act took effect on June 30, 2007. The act states that the waters of Hāʻena have been an important subsistence fishery resource for native Hawaiians and local families of the ahupuaʻa, and that the area's natural beauty attracts thousands of visitors each year to the 'end of the road' at Hāʻena State Park. It is believed that the influx of visitors has resulted in adverse impacts to fish stocks and the integrity of the coral reef habitats in the area. The purpose of the Act is to allow inhabitants of the ahupuaʻa to develop and enforce traditional regulations for the maintenance of the fishery within the Hāʻena ahupuaʻa. The approximate boundaries of the new subsistence fishing area are shown in Figure 6. Commercial activities, issuance of a commercial marine license, aquarium fishing permits, gill net fishing, spear fishing with SCUBA, must still be considered for approval by DLNR in consultation with the inhabitants of the ahupuaʻa.

In 2002, DOH statistics reported a single case of ciguatera poisoning from consumption of a knifejaw (*Oplegnathus* sp.) caught at Hāʻena.

7.1.8 Snorkeling and SCUBA Diving

Kēʻē Beach is a primary snorkeling and diving area for Kauaʻi. Snorkeling and diving occur in the protected Kēʻē Lagoon and back reef, and less often outside the reef. This activity includes organized groups of divers from clubs and classes as well as individual divers. The overhangs, tunnels, and unique reef features attract many divers. These features, in combination with excellent water visibility and protection from heavy surf, make the lagoon a popular snorkeling and diving spot (Clark 1992). Outside

of the reef, intermediate and advanced snorkeling and diving also occur during calm conditions. Reef features in this area are similar to those in the lagoon, but fish diversity and abundance is higher (Clark 1992). The quality of diving decreases in the winter due to high surf and turbidity (Nielsen 2005).

Cannon's Reef is a popular shore diving site just east of Hāʻena State Park. Water depths at this site range from 5 to 70 ft (1.5-21 m). This diving spot is suitable for beginner to intermediate divers and is considered a good snorkeling location (Nielsen 2005).

7.1.9 Surfing, Bodysurfing, and Body Boarding

Hā'ena State Park shoreline is also a popular site for surfing, bodysurfing, and body boarding, surfing being the most popular of the three (TKC and Earthplan 2001). DBEDT (2008) has defined a surfing site as "a specific wave-breaking zone caused by a shoal and having sufficient consistency to be identified as a surfable riding area, either seasonally or in a combination of seasons."

Surfing breaks located in the area are described in detail in the *Beach and Ocean Recreation Study* conducted by Clark (1992). Several surfing breaks occur offshore of the park (Figure 7). Three surfing sites break off Ka'īlioiki Reef: "Insanities", "Mad Dogs", and "Reefers". Another less popular surfing spot, "Blue Hole", is located off Ka'īlionui Reef.

These sites are infrequently surfed because the waves break very close to the reef margin and can be dangerous. The level of surfing at these sites ranges from intermediate, when waves are 2 to 5 ft (0.6 to 1.5 m) high, to advanced and expert when waves are 6 ft (1.8 m) and higher (Clark 1992).

Two other surfing breaks are located just east of Limahuli Stream, but are accessible from the Hā'ena State Park shoreline. "Winchell's" is located off Pu'u Kahuaiki Reef to the east of Pu'u Kahuanui Reef. "Bobo's" is a surfing break that forms on the forereef slope fronting Pu'u Kahuanui Reef. These breaks are suitable for intermediate to advanced and expert surfers, depending on wave height (Clark 1992).

7.1.10 Windsurfing

Statewide, "Reefers" is an important sailboarding and wave-jumping spot for windsurfers, and is considered one of the best wave-jumping sites on the north shore. During periods of moderate surf (2 to 5 ft) this spot is appropriate for intermediate windsurfers, while conditions are suitable for advanced and expert windsurfers during higher surf (6 ft and higher). "Reefers" attracts between 30 and 40 windsurfers during good conditions and is exclusively used during high tide. Windsurfing activity generally increases during high northeast trade winds (Clark 1992).

7.1.11 Boating and Kayaking

Kē'ē Lagoon is the primary take off and landing point for sea kayakers touring the Nāpali shoreline. The activity includes both individual kayakers and groups of kayakers. The lagoon offers a sand-bottom, wave protected location at the shoreline to easily enter and exit the ocean through the "Puka Ulua" channel. Poholokeiki Channel is also used as a take off and landing site by kayakers during calm seas (Clark 1992). Commercial boating is seasonal along the north shore of Kaua'i due to wave impacts and surf events, mostly occurring in summer. The closest boat launch ramp is the Hanalei Bay Offshore Mooring Area and Pier adjacent to the town of Hanalei in the northeast corner of Hanalei Bay (DBOR 2008).

7.1.12 Biking

Biking is becoming a more popular activity throughout the state and also serves as a means of transportation for some visitors (TKC and Earthplan 2001). Forest reserve roads, resort bike paths, and old agricultural roads are often used as bike trails on Kaua'i (Sprout and Sprout 2004). *Bike Plan Hawai'i* (1994), a State master plan for bikeways, is proposing a bike route that extends form the west side of Kaua'i to the north shore. Due to the narrow roads in this area, bicycle access and safety will require special consideration (County of Kaua'i Planning Department 2000).

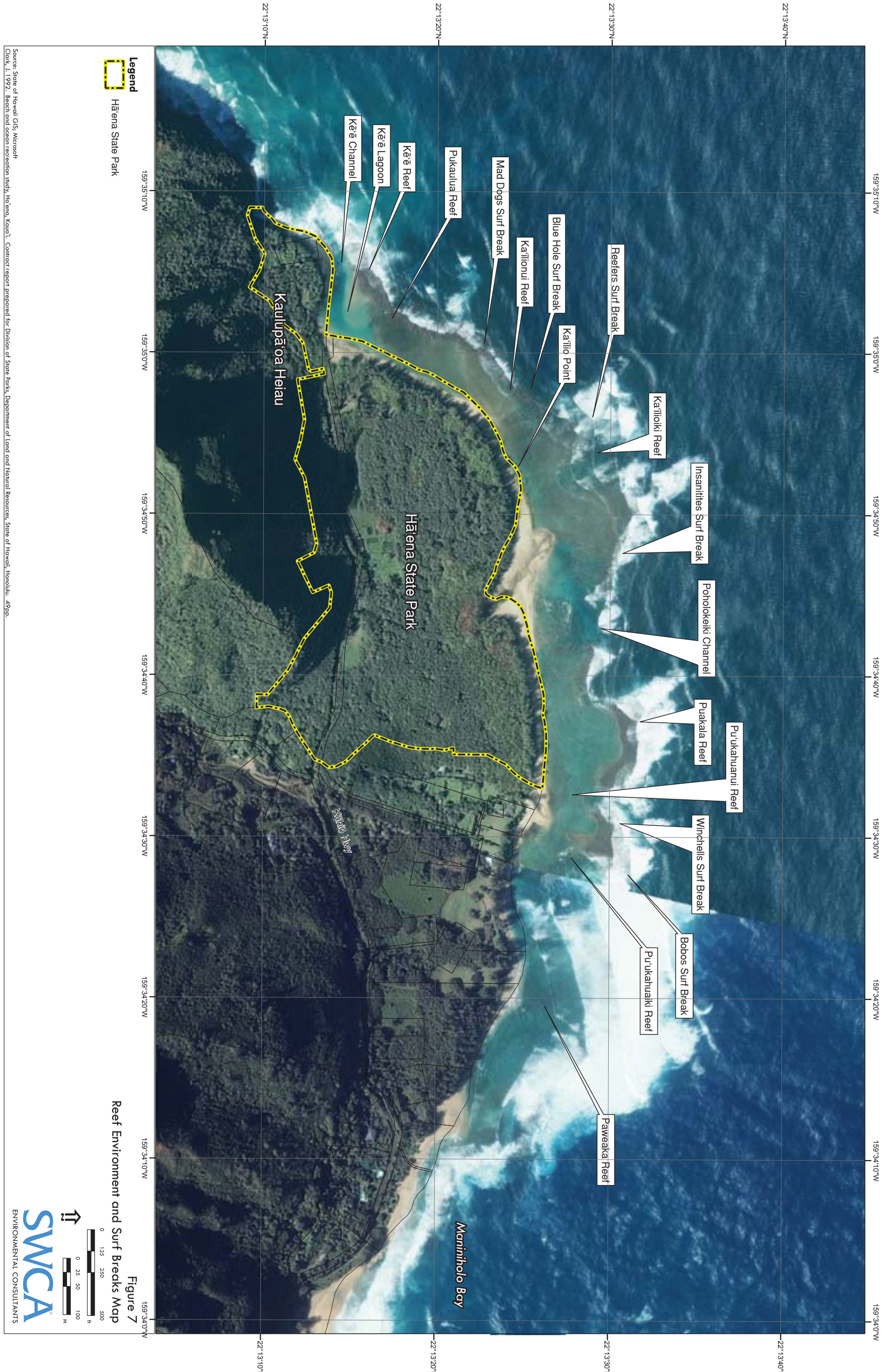

Figure 7
Reef Environment and Surf Breaks Map

Source: State of Hawaii GIS; Microsoft
Clark, J. 1992. Beach and ocean recreation study, Ha'ena, Kaua'i. Contract report prepared for Division of State Parks, Department of Land and Natural Resources, State of Hawaii, Honolulu. 49pp.

7.1.13 Off the Road Vehicle (ORV) Use

The 2001 draft park plan noted that ORVs were known to drive through the sand dunes and across the sandy beaches at Ka'īlio Point flattening dunes and impacting strand species (Clark 1992, DLNR 1999). However, this activity has essentially ceased since 2007 when a gate blocking vehicular access to the dunes was installed. Four-wheel ATVs are also used by lifeguards and can be driven along the sandy beaches as necessary in the pursuit of their duties.

7.1.14 Visiting Historical/Cultural Sites

Historical and cultural sites have the potential to be recreational and educational areas for both local residents and tourists. The cultural resources at the Hā'ena State Park are considered to be some of the most complete and well preserved features throughout the Hawaiian Islands. The Hā'ena Archaeological Complex is listed on the State and National Registers of Historic Sites. The Complex is bounded by the Pacific Ocean on the north and west, Limahuli Stream on the east, and the pali (cliff) base on the south. Feature types found within the Hā'ena Archaeological Complex include heiau, house platforms, rock shelters, agricultural complexes, enclosures, subsurface cultural deposits, cemeteries, wet caves, and source areas for volcanic glass (TKC and Earthplan 2001).

Tourists and residents can visit Keahualaka, a flat hula platform, and Kauluapā'oa Heiau, a temple dedicated to Laka, the goddess of the hula. These cultural sites are located southwest of Kē'ē Beach and are managed by the State Historic Preservation Division (SHPD) on land owned by the County. Both sites are presently used by hula halau from across the state for various ceremonies (Clark 1999).

Two wet caves situated in the Hā'ena State Park are also premier designations for visitors and residents. These ancient sea caves were formed during a higher stand of sea. Waiakanaloa Wet Cave is located mauka of Kuhio Highway in the face of the pali and Waikapala'e Wet Cave is located slightly to the east within the pali face. These deep, dark caves contain pools of cold water (Yamamoto 2006). "Spiritual" cave visits, using incense and other paraphernalia, are popular visitor activities within the caves (TKC and Earthplan 2001).

7.1.15 Wildlife Observation

Whale watching and bird watching also takes place occasionally within the park boundaries. The peak time to see endangered North Pacific Humpback whales in Hawaiian waters is late November through early May (Yamamoto 2007). Several tour operators offer whale watching tours within the boundaries of the Hawaiian Humpback Whale National Marine Sanctuary (Figure 6).

7.2 Visitor Impacts

7.2.1 Traffic Congestion and Parking Issues

Two of the most popular visitor destination areas on Kaua'i are located within the boundaries of Hā'ena State Park. Both the Kalalau Trail head and Kē'ē Beach are located at the end of the highway. The end of the highway serves as a turnaround point for all vehicles reaching this point. There are only three parking areas within the Park, one is located adjacent to the sea caves at Hā'ena Point, another was recently created near the taro ponds west of the sea caves, and the third is located at the end of the highway at Kē'ē Beach. On the lot at the end of the highway is paved. As these fill, many visitors parallel park along the seaward side of the highway margin. A high density of visitors to the area decreases the amount of available parking for local residents, and reduces the quality of user experiences (Needham et al. 2008).

7.2.2 Non-point and Point-Source Pollution

Point-source pollution is pollution from any confined or discrete conveyance such as pipes, ditches, channels, wells, or vessels. This type of pollution is also referred to as "end-of-pipe discharge" because it is often discharged from sewage treatment plants and factories close to nearshore waters (DBEDT and DOH 2000). At the Hā'ena State Park, recreational and commercial boats can create point source pollution in the offshore waters. The amount of point source pollution from these sources is unknown and likely varies during the year depending on the number of boats.

Hawai'i's Implementation Plan for Polluted Runoff Control (2001) defines non-point source pollution as "water pollution that comes from many diffuse sources rather than from a specific point, such as an outfall pipe, and is often the result of human activities." Pollutants are carried by rainwater on the surface or through the ground to the stream and oceans. These pollutants can include fertilizers, herbicides, insecticides, oil, grease, sediment, and pathogens (DBEDT and DOH 2000). Non-point source pollution is related to the amount of impervious surfaces in an area. Impervious surfaces (including roads, parking lots, sidewalks, and roofs) prevent water and pollutants from passing through the ground and percolating into the soil, expressing them into nearby aquatic environments (Schueler 1994).

At the Hā'ena State Park, pollutants from motor vehicles, trash, and other debris not properly disposed of can be carried to nearshore and freshwater areas in storm, flood, or wash water across impervious surfaces. Sewage seepage from the restroom facilities could also enter theses aquatic environments (Stepath 1999). Dipping or wading in the Limahuli Stream may contribute to soil erosion, sedimentation, and temporary impacts to water quality (TKC and Earthplan 2001).

According to the *Hawai'i Coastal Nonpoint Pollution Control Management Plan* (1996), non-point source pollution has a greater impact on nearshore waters than point-source pollution. Non-point source pollution can result in increased turbidity, sediment accumulation on coral reefs, fish kills, and destruction of aquatic habitats. Excess nutrients can also lead to eutrophication or algae blooms in coastal waters (DBEDT and DOH 2000). Toxic chemicals and pollutants can pose a risk to marine plants and animals (County of Kaua'i Planning Department 2000) and increase the risk of human diseases during aquatic recreation (DBEDT and DOH 2000).

Clean coastal water is an important component of the tourism industry in Hawai'i. More than 80% of visitors to the Islands engage in recreation activities in coastal and marine areas (Needham et al. 2008). Coastal leisure and recreation activities (swimming, diving, surfing, etc) are also vital to native Hawaiian cultural practices and local resident recreation (DBEDT and DOH 2000). Most local residents engage in ocean recreation on a regular basis (Friedlander et al. 2008). One intent of Class AA marine water quality designation at Hā'ena State Park is to protect the area in as pristine condition as possible to help insure the protection of the coral reef ecosystem offshore as well as the visitor experience to the Park.

7.2.3 Sunscreen

Some chemicals contained in commercial sunscreens can adversely impact coral reefs by promoting viral infections of endosymbiotic zooxanthellae, which are essential for the survival of coral species. The chemical compounds in sunscreen can cause dormant viruses present in zooxanthellae to continually replicate until the zooxanthellae are expelled and the coral is bleached (Buddemeier et al. 2004, Danovaro et al. 2008, and Than 2008). Sunscreens may also decrease the penetration of UV radiation, impacting marine organisms that depend on light for various functions (Eichenseher 2006, Blitz and Norton 2008). Furthermore, sunscreen agents have been shown to bioconcentrate in freshwater or brackish aquatic species (Daughton and Ternes 1999). The impact of sunscreen on the coral reef environment at the Hā'ena State Park is not known; however, according to scientific interviews by Juran (2007), the impact of sunscreen at the park is believed to be minimal compared to other sites around the state.

7.2.4 Fishing

The impact of recreational and subsistence fishing in Hawai'i has been difficult to quantify because neither recreational and subsistence fishers are required to have licenses or report their catch to the Hawai'i Division of Aquatic Resources (Friedlander et al. 2008, Zeller et al. 2008). Recently, however, there is a growing body of scientific evidence to suggest that fishing may have the greatest overall effect on the diversity and abundance of nearshore fishes on coral reefs in Hawai'i and the Pacific (Grigg 1994, Stepath 1999, Birkeland and Friedlander 2001, Williams et al 2008, Singh et al 2008).

Fishers of all kinds tend to target specific species, many of which are top carnivores. Today, these resources are scarce. In studies of shore fish populations throughout the main Hawaiian Islands, Friedlander et al (2003) found that fish standing stock and diversity were higher in areas protected from fishing pressure and in areas of greater substrate complexity. In a similar island-wide study of 89 coral reef survey sites, Williams et al (2008) found 'clear and consistent negative associations between human population density and biomass of fishes in a range of functional and taxonomic groupings'.

Declines were evident among fishes targeted by fishers, but not among non-target groups of fishes in hard bottom and mid-depth habitats. Standing stock of highly desired target species (e.g. surgeonfishes, wrasses, parrotfishes, snappers, goatfishes, big-eyes, jacks, squirrelfishes, barracuda, moi, milkfish, and hawkfish) in accessible and populous locations were significantly lower than in areas where public access was prevented and also in lightly populated or remote areas. Williams et al (2008) concluded that a number of lines of evidence point to fishing pressure as the prime driver for these negative trends.

Indiscriminant use and discard of inexpensive monofilament gillnets has had a major effect on reef fish throughout the state of Hawai'i (Endreson et al, undated). Lay gillnets take unwanted as well as target species and can lead to habitat destruction and fatal entanglement of endangered species. Objections to this controversial method of fishing have raised an emotional debate in Hawai'i (e.g. http://www.ulua-ishing.com/forum; http://gillnetskill.blogspot.com/). A general consensus to outlaw the indiscriminate use of lay gillnets (Fair Catch 2006) resulted in the enactment of new DLNR Administration Rules signed by Governor Linda Lingle in March 2007 which severely restrict the use of lay gillnets in Hawai'i.

Night spear fishing, particularly with SCUBA, has also been implicated as being detrimental to fish populations (e.g. Stepath 1999). No studies could be found that quantify the catch by free dive and SCUBA spearfishers at Hā'ena State Park or elsewhere in the state. In May 1981, a visitor disappeared while spearfishing with SCUBA at the Park, presumably the victim of shark attack.

Fishing can also adversely affect endangered marine species. During the period 1982-2007, there have been 49 documented cases of interactions between fishers and monk seals in the Main Hawaiian Islands (MHI) (Katekaru 2008). Twenty-seven of these cases were reported from Kaua'i, two of which were from Hā'ena State Park. These cases usually involved the accidental hooking by ulua fishers using slide-bait tackle.

Chaloupka et al (2008) investigated cause-specific temporal and spatial trends in sea turtle strandings in the Hawaiian Archipelago. The most common known cause of the green turtle strandings was tumor-forming disease (28%) followed by hook-and-line fishing gear-induced trauma (7%), gillnet fishing gear-induced trauma (5%), boat strike (2.5%), and shark attack (2.7%). Miscellaneous causes comprised 5.4 percent of strandings whereas 49 percent of green turtle strandings could not be attributed to any known cause (Chaloupka et al 2008). They concluded that the Hawaiian green turtle stock continues to recover following protection since the late 1970s despite exposure to disease, nets, and hook-and-line fishing gear.

7.2.5 Diving

Damage to coral reef as a result of diving has been documented worldwide (Rouphael and Inglis 1995, Tratalos and Austin 2001, and Tabata 1992). Divers and snorkelers can physically damage reef corals, invertebrates, and algae by standing on the reef, accidentally kicking coral with their fins, or stirring up silt that suffocates coral. Contact with corals can facilitate disease transmission. Physical damage to coral species can be long lasting since due to generally slow tissue regeneration (Davenport and Davenport 2006).

7.2.6 Fish Feeding

Some divers and snorkelers feed fish at Kē'ē Lagoon in order to attract large schools of fish. Feeding fish can disrupt normal distribution and abundance patterns (DLNR 1999, SPC Fisheries 2004) and alter normal reproductive output of marine species (Sweatman 1996). Fish feeding may modify natural feeding cycles of fish (Roberts 2006), and have negative effects on prey populations by minimizing feeding on algae (Milazzo et al. 2005, Hollier 2009).

Feeding large fish can attract predators that scare off smaller fish, thereby reducing local biodiversity (Davenport and Davenport 2006). This activity has been shown to interfere with natural instincts and behaviors essential for fish survival (Roberts 2006). Studies conclude that feeding fish alters fish behavior towards humans; fish become conditioned to associate humans with food, often causing fish to become aggressive to humans and inducing attacks (DLNR 1999, SPC Fisheries 2004, Roberts 2006, Hollier 2009).

7.2.7 Reef Walking

During periods of low tide and calm waters, it is possible to walk on the exposed and shallow reef flats at the Hā'ena State Park. Visitors walk on the reef to view tide pools (Yamamoto 2006) and some divers transverse the coral reef to dive off the outer portion of the reef at Kē'ē Beach (Stepath 1999), resulting in the same impacts discussed in Section 7.2.5 above. Walking on the reef has the potential to degrade areas of the reef flat by trampling corals. This can result in morality and an overall reduction in coral cover (Woodland and Hooper 1977, Stepath 1999, Juran 2007, Rodgers and Jokiel 2007). Trampling can directly or indirectly affect coral tissue, growth rates, reproductive success, and community structure (Liddle and Kay 1987, Rodgers and Jokiel 2007).

A decrease in coral cover can also impact fish populations, which are dependent on coral for shelter (Rodgers and Cox 2003), as well as algal populations (Davenport and Davenport 2006). Impacts to coral reefs can be severe, even with relatively low levels of trampling (Brown and Taylor 1999, Rodgers and Jokiel 2007). The ability of corals to withstand trampling depends on coral morphology, branch geometry, and mechanical properties (Rodgers and Jokiel 2007).

In Hawai'i, studies have found a clear pattern of decreasing coral cover with increased visitor use (Rodgers 2001, Rodgers and Cox 2003, Rodgers et al. 2003). Stepath (1999) conducted a study at Hā'ena State Park which studied the impact of humans walking on the reef flat. The peak time of reef walking was at 1:30PM. Stepath (1999) concluded that trampling may be decreasing coral cover in the nearshore waters of the Park.

7.2.8 Sand Dunes

Within the vicinity of Hā'ena State Park, the shoreline is backed by low coastal sand dunes. These ridges or mounds of sand are formed by an accumulation of wind blown sand that is trapped by strand plants at the Park. Sand dunes are dynamic features that erode during periods of high waves (usually October to May) and accrete when heavy wave action subsides (usually May to October). Sand dunes function as natural, elevated buffers that protect marine shorelines against erosion, flooding, high waves, storms, tsunamis, and other coastal hazards (Clark 1992, University of Hawaiʻi Sea Grant Extension Service and County of Maui Planning Department 1997, University of Hawaiʻi 2006).

Some recreational activities are known to affect coastal dunes in Hawaiʻi. The continuous trampling by vehicles and pedestrians on the dunes causes erosion and sand movement. Vogt (1979) found that fewer than 10,000 pedestrians walking over sand dunes during a single season can eliminate dune vegetation and result in erosion (Tabata 1980). Dune vegetation has little resistance to trampling due to the extremely low soil penetration and is slow to recover (Davenport and Davenport 2006).

ORVs also flatten dunes and impact strand species (DLNR 1999). ORVs drive through the sand dunes and across the sandy beaches at Kaʻīlio Point (Clark 1992). Both motor vehicles and pedestrian traffic can lead to sediment disruption and erosion. ORVs destroy sand coastal vegetation that helps to stabilize the dunes. ORVs can also disturb sand dune and shore ecosystems for use by wildlife including birds, turtles, worms, and crustaceans (Schlacher et al. 2008).

7.2.9 Invasive Species

An invasive species is defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Executive Order 13112). Isolated island ecosystems, such as Hawaiʻi, are vulnerable to the establishment of alien or non-native species due to a variety of factors. Islands typically have high habitat diversity, favorable climate, high resource availability, low biotic resistance, small populations, and limited social capital (Denslow et al. 2008). It is estimated that over 5,000 alien species have established in the Hawaiian Islands. Of this total, roughly 343 are marine species (Belt Collins Hawaiʻi LTD 2008).

Invasive species affect island ecosystems in a variety of ways. They compete with native flora and fauna, carry diseases, affect trophic structure, change fire regimes, alter nutrient cycling patterns, modify surface runoff of water, and alter biodiversity (Vitousek 1990, D'Antonio and Vitousek 1992, Vitousek 1992, and Belt Collins Hawaiʻi LTD 2008). The ability of invasive species to reach new areas is influenced by the number of individuals involved in a release event and the number of release events, also referred to as *propagule pressure* (Lockwood et al 2005). Propagule pressure increases in areas with high visitation (Leung and Mandrak 2007), such as recreational parks. In particular, recreational boating, diving, snorkeling, and fishing increases the risk of introducing non-native species through hulls, wetsuits, bait, or other equipment (Meliane and Hewitt 2005). Recreational hiking can also introduce invasive species, especially plants, by passive dispersal on hiker's shoes and clothing. Ironwood (*Casuarina equisetifolia*), false kamani (*Terminalia catappa*) are invasive terrestrial plant species found within the park boundaries that compete with native vegetation.

Two non-native reef fish species introduced by the Hawaiʻi Department of Land and Natural Resources Division of Aquatic Resources to supplement coastal sport fisheries are present in the nearshore waters of the Park. Although the predatory grouper roi (*Cephalopholis argus*) and the blue line snapper taʻape (*Lutjanus kasmira*) successfully established large populations throughout the main Hawaiian Islands, their impact upon preferred local species has not been well-understood and is the subject of controversy. Roi feed on small fishes over shallow reefs, while taʻape feeds over sand flats during the night (Dierking 2007, Birkeland and Dierking 2007).

Invasions by non-native limu (seaweed) in some areas of Hawaiʻi have been shown to blanket coral reefs, kill coral, and reduce water exchange within the reef (Hadfield and Koehl 2007). However, none of the four noxious invasive algae species known from Hawaiʻi were found at Hāʻena during surveys conducted there a decade ago by University of Hawaiʻi investigators Isabella Abbott and Cynthia Hunter (www.hawaii.edu/ssri/hcri/text/research/results/kauai/haena.html). Some native algae species have the potential to become invasive, or to dominate the marine substrata to the exclusion of other species, in

areas that receive excessive nutrient input or have been altered in some other way in which to foster the growth of a single species of algae. There is no evidence that this has become a problem at Hāʻena.

7.3 Park Management Requirements

The natural beauty and cultural features at the Hāʻena State Park depend on the proper management and use of the park. Management policies derived from the *Hāʻena State Park Master Plan and Draft Environmental Impact Statement* (2001) include the following:

- Prevent and rectify existing anthropogenic erosion;
- Upgrade wastewater facilities;
- Eliminate or control exotic plant species;
- Utilize non-chemical plant management techniques when feasible; and
- Identify and protect fragile habitats;

Kauaʻi's Economic Development Plan 2005-2015 (2004) states that the island's parks require "improvements and better maintenance" in order to met recreational demands. In particular, roads are inadequate for residents and visitors. The plan suggests dedicated user fees be initiated at all state parks to support maintenance and improvement costs.

DLNR, DAR, and Hawaiʻi Ecotourism Association (2005) suggest that coastal and marine recreation areas can be managed by reducing human uses or reducing the impact of human use. The strategy specifically identifies the following management techniques for coastal and marine recreation areas:
- Restrict access: reduce the level of use by determining a site's carrying capacity and setting limits on number of users or banning certain types of activities or behaviors;
- Relocate use: create artificial reefs for recreation users (in suitable areas);
- Education: modify human behavior through signage, brochures, videos, tours, etc.; and
- Mechanisms for compliance: design physical infrastructure to encourage certain limits or behaviors or institute legal or voluntary compliances with tangible consequences.

7.4 Sustainability of Recreational Uses

With proper management, most of the recreational uses currently occurring at the Hāʻena State Park can be sustainable. The sustainability of a recreational use depends on the carrying capacity of the recreational area. Within a recreational context, carrying capacity can be defined as "the amount of visitor use that can be appropriately accommodated within a park or outdoor recreation area" while providing "sustained quality recreational experiences" (Lankford et al. 2005). The carrying capacity of a recreational use is determined by evaluating the following issues:

- Physical capacity: the amount of space available for the recreational use;
- Ecological or biological capacity: the ability of natural resources to withstand the recreational use;
- Facility capacity: the degree that the recreational area is able to support visitor needs during the recreational use; and
- Social capacity: the ability of the recreational use to provide an acceptable recreation experience (Lankford et al 2005).

DLNR, DAR, and Hawaiʻi Ecotourism Association (2005) recommended development of a carrying capacity tool to help determine optimal levels of activity for the various users at various sites. Management actions stemming from such a study might include limits on commercial operating permits and regulated visitor and vehicle entry. The report also advances the concept of establishing an ecological carrying capacity to take into account the various recreational activities and the unique physical conditions at a particular reef site; to provide a sound scientific basis for proactive management;

and to allow managers to identify optimal levels of use and set limits of use and set limits for various sites before projected increases in use occur. Additional recreational impacts to reefs and local action strategies (RIS-LAS) of pertinent to Hāʻena State Park can be found in DLNR, DAR, and Hawaiʻi Ecotourism Association (2005).

A study of this kind may be beneficial to identify the sustainability of existing recreational uses within the Park boundaries. To be successful, a carrying capacity study should be adequately funded and should be conducted with the collaboration of stakeholder groups in particularly controversial projects (NOAA 2007).

7.5 Complementary and Conflicting Use Issues

There is a growing number of eco-tourists and adventure-tourists who seek remote locations in Hawaiʻi, such as Hāʻena and Nāpali, for recreation and adventure. Many Hawaiʻi residents also visit these remote areas in search of greater resources, such as free diving spearfishers, who travel throughout the state to find populations of their preferred game fishes. These remote areas traditionally had small populations of local residents, many of whom rely upon the environment for sustenance (Friedlander et al. 2008). As visitor and resident populations on the north shore of Kauaʻi, conflicts among and between recreational users are likely to increase.

7.5.1 Ahupuaʻa ʻOhana vs. Visitor and Other Residents

Ahupuaʻa ʻohana (family) are former Hāʻena residents and their descendents who have ancestors from the ahupuaʻa of Hāʻena and therefore have close ties to the land. Some private land was condemned from the ahupuaʻa ʻohana for the park establishment. Many members of the Hāʻena ʻohana are upset about the existing conditions of the park. Their specific complaints include rubbish on the beaches and trails, spiritual rituals conducted by visitors, souvenir vending, disturbing fishermen, harassing marine life, inappropriate public activities, commercial activities, and failure to heed traditional community protocols. Many believe these activities degrade the natural resources and cultural significance of the area (TKC and Earthplan 2001).

Some ahupuaʻa ʻohana members also feel that walking on the reef and using suntan oil in the area have a negative impact on the marine species, specifically limu (algae) that they collect for food. Because of the density of visitors to the park, the local ʻohana claim that can not practice cultural activities or enjoy the environment as they did in the past (Stepath 1999, TKC and Earthplan 2001). In turn, the ahupuaʻa ʻohana believe that denying them access affects their physical, mental, and spiritual health (Juran 2007).

7.5.2 Residents vs. Visitors

Residents in the Hāʻena area use Hāʻena State Park for various recreational activities, such as picnicking, camping, fishing, and windsurfing. Though residents consider the park, and especially Kēʻē Beach, to be their personal recreation area (TKC and Earthplan 2001), some will not go to the area because of the large number of tourists. Other property owners have denied public access to the beach (Juran 2007). According to a 2002 tourism study (Kauaʻi Economic Development Board 2004), Kauaʻi residents are more strongly opposed to increased tourism activity than the residents of any other island in the state.

Traffic congestion and parking are major user conflicts between residents and visitors. This congestion is the result of the popularity of Kēʻē Beach and the location of the entry point to the Kalalau trail head at the end of the highway (TKC and Earthplan 2001). A State Park Visitors Survey conducted in 2006, found between as many as 451 cars parked at the Hāʻena State Park per day. Of this total, only 13 percent were thought to be locally owned (Hāʻena State Park Visitors Survey 2006).

Residents tend to prefer Kēʻē Beach area to other sub-areas of the Park (Figure 1), and enjoy the lax enforcement and rules, vehicle access, and convenient location. Residents have requested better comfort stations and other amenities at the park. Visitors have requested improvements for security and safety, as well as upgrading existing comfort stations (TKC and Earthplan 2001).

Some residents believe that visitors should be paying fees to offset impacts to the Hāʻena State Park. All State Parks receive money through the State Parks Special Fund which is generated through camping fees, cabin rentals, concessions leases, and recreational leases (DLNR 2003). Funding may be allocated from the Hawaiʻi Tourism Authority's Transient Accommodations Tax (TAT) Trust Fund depending on the amount of money in the fund (DLNR 2003). Therefore, if visitors to the Hāʻena State Park are not staying at nearby hotels, residents argue that they are not paying for enjoyment of the area.

7.5.3 Recreation vs. Conservation

Resource conservation is outlined as an important issue in the State Comprehensive Outdoor Recreation Plan (2003). The unique natural environment of Hawaiʻi is one of the main attractions for tourists. Preserving nearshore ecosystems in Hawaiʻi is critical to the tourism industry (Rodgers and Jokiel 2007). However, the need to conserve can constrain public access if the activity has the potential to endanger resources.

Solving this conflict requires a balance between allowing public access for recreation and restricting some public use to protect resources (DLNR 2003). As at other coastal recreation areas in the state, there is a need to measure and monitor recreation carrying capacity and to establish indicators to ensure that coastal resources (as well as user experiences) do not deteriorate (Needham et al. 2008).

7.5.4 Commercial Use vs. Private Use

Hāʻena State Park is widely promoted in visitor's guides, adventure travel books, equipment rental facilities, hotels, and tour companies (TKC and Earthplan 2001). Commercial activities occurring in the park boundaries include weddings on Kēʻē Beach, kayak tours of Nāpali Coast, spiritual enlightenment tour groups, SCUBA diving instruction, and other commercial operators. Residents and native Hawaiians generally do not support having commercial activities at the Hāʻena State Park arguing that they degrade and exploit resources (TKC and Earthplan 2001). Furthermore, many residents or visitors would prefer to enjoy park without commercial operators, while others require a vendor to provide them with the necessary equipment (TKC and Earthplan 2001).

All private enterprises are required to have a state issued Special Use Permit from the Division of State Parks to conduct these activities on State owned lands. Commercial permits can provide a way to ensure compliance with legal requirements (DLNR, DAR, Hawaiʻi Ecotourism Association 2005); however, most commercial businesses which occur at Hāʻena State Park are not sanctioned by the State (TKC and Earthplan 2001).

7.5.5 Ecotourism vs. Development

Ecotourism is one of the fastest growing sectors of the tourism industry. According to the International Ecotourism Society, ecotourism is "responsible travel to natural areas that conserves the environment and improves the well-being of local people" (Blangy and Mehta 2006). Ecotourism in Hawaiʻi can be nature or culture based (http://www.hawaiiecotourism.org/Default.aspx?pageId=117830). This type of tourism is designed to prevent negative social and environmental impacts that can be associated with tourism (DLNR 2003). Development has the potential to adversely impact natural and cultural resources on which the ecotourism industry relies on.

"Hard-core" eco-tourists typically seek isolated destinations with minimal development. Thus, development has the potential to compromise the ecotourism experience of these individuals (TKC and Earthplan 2001). However, more developed facilities still have the potential to attract some eco-tourists seeking nature and culture-based activities (DLNR 2003). In addition, there are increasing concerns about sustainability and carrying capacities of ecotourism (Rodgers and Jokiel 2007). Because of their interest in remote areas, eco-tourists are also a means of passive dispersal by non-native invasive species.

7.5.6 Homeless/Squatters vs. Park Visitors

Homelessness remains an issue throughout the state as a result of nation-wide economic problems, mental illnesses, and cuts in state social programs (DLNR 2003). Squatters and homeless were evicted from the Hā'ena State Park during the Taylor's Camp era in the 1970s. However, squatters still reside in various locations throughout the isolated valleys of the adjacent Nāpali Coast and can be frequently seen at the Hā'ena State Park. Beach encampments can impact the visual image of the island, restrict users' access to facilities, create sanitation problems, and contribute to park maintenance needs (DLNR 2003, Gererna-Morales 2007). The presence of these individuals can ultimately impact the tourism industry; the Hawai'i Tourism Authority has stated that tourists have commented that seeing homeless people in parks or at the beaches makes them felt uncomfortable (Gererna-Morales 2007).

7.5.7 Windsurfers vs. Other Recreational Pursuits

Windsurfing has been shown to disrupt other recreational users at parks throughout the state (CSV Consultants 2007). Windsurfers often come close to others at high speeds. Beginning windsurfers often find control of their boards difficult and represent a greater risk to others in the water than expert windsurfers. In turn, park users, such as swimmers, sunbathers, snorkelers, and divers, can obstruct windsurfing zones and launching areas (CSV Consultants 2007).

At the Hā'ena State Park, Clark (1992) identifies only a "minor conflict" between windsurfers and fishermen. Throw-net fishing primarily occurs during low tides when the reefs are more exposed. Low tides often coincide with strong, consistent trade winds, which are ideal conditions for windsurfing. When these activities happen together, windsurfers can scare away schools of fish for throw net and pole fishermen (TKC and Earthplan 2001).

7.5.8 ORVs vs. Beach Users

ORVS can degrade the visual appearance of the beach by damaging vegetation and sand dunes. In addition, the noise and safety hazards associated with vehicle use on the beach conflict with other beach users and can detract from visitor experiences at the park (TKC and Earthplan 2001).

7.5.9 Traditional Fishing vs. Recreational Fishing

In 2006, HRS 18-22.6 designated a community based subsistence fishing area at the shoreline of the Hā'ena district "for the purpose of reaffirming and protecting fishing practices customarily and traditionally exercised for purposes of native Hawaiian subsistence, culture, and religion (SB2501). Enacted in 2007, the subsistence fishing area law was modeled after other community-based subsistence areas elsewhere in the state (e.g. Mo'omomi, Moloka'i). Because the Hā'ena area is relatively new, specific management protocols are still being discussed amongst community members (Heacock, DAR, pers. comm.). It is anticipated that the self-policing of the area as called for by the act will include protocols for recreational fishers and visitors to seek permission to fish within the area from local stewards of the resource, seasonal and take limits, limits on gear, and so forth.

The only area on the north shore of Kaua'i where nearshore marine life is protected from fishing pressure is the Kīlauea Point National Wildlife Refuge managed by the U.S. Fish and Wildlife Service. This area,

along with the more remote portions of the Nāpali Coast, may serve as defacto marine preserves because of their inaccessibility.

Reef waters of Hā'ena State Park also serve as a defacto preserve during winter months when high waves and strong currents limit fishing opportunities. Preserves provide safe havens for fish development and sources of stock enhancement following periods of increased fishing pressure on adjacent areas.

7.6 Impacts of Increased Recreational Uses

An increase in recreational uses at the Hā'ena State Park would place greater demands on existing facilities infrastructure, and on the physical, ecological, and societal capacity of the area (See Section 7.4). Attracting more recreational users would further increase current traffic congestion and parking issues for both visitors and residents. More users would also have the potential to impact stream and nearshore water quality by increasing the amount of non-point and point-source pollution in the area. The reef ecosystem would be significantly impacted by an increase in unregulated recreational activity at the Park. Potential impacts to the coral reef ecosystem as a result of increased recreation in the nearshore area include: decreased coral coverage, altered coral growth, decreased fish populations, reduced local biodiversity and increased propagule pressure of invasive species. Without an enforceable Park management plan, an uncontrolled increase in current recreational activities at the Hā'ena State Park would lead to further dune erosion and the removal of dune vegetation; create untenable traffic congestion and conflicts; increase the level of pollutants in non-point source stormwater runoff; conflicts between recreational and subsistence fishers, and between other and various users of the Park's marine waters; loss of the unique socio-cultural character of the Park are surrounding neighborhood; reduced level of enjoyment by visitors and residents alike; and ultimately as a 'worst case', the potential economic collapse of the area as a visitor destination.

8.0 Design Considerations and Resource Management Concepts

8.1 Water Quality Issues

Several design considerations can be assessed to help maintain Class AA coastal water quality standards at Hā'ena State Park as visitations increase. These include following actions:

- Conduct a high-resolution assessment of Park topography and evaluate alternate storm drainage features to minimize or slow runoff into the ocean
- Upgrade sanitation facilities and conduct regular inspection and maintenance of sanitation systems at the public restrooms to prevent sewage seepage or spillage into the ocean or groundwater
- Create parking areas remote from the Park and allow only pedestrian or shuttle bus access
- Carefully design parking areas and apply best management practices to prevent the runoff of contaminants to streams and coastal waters
- Conduct regular maintenance of, and apply best management practices to, the Kalalau Trail to prevent unnecessary soil erosion, siltation, high turbidity, and possible coral mortality within the Kē'ē Lagoon and reef
- Provide and regularly maintain an appropriate number of trash and recycling receptacles to reduce the amount of plastic and other solid waste that blows or gets washed into the ocean in storm runoff.

8.2 Shoreline Erosion

Sandy beaches are at the heart of the multi-billion dollar visitor economy in Hawai'i that provides the greatest share of the state's jobs and income. When erosion threatens the built environment a common reaction is to armor the shoreline with a seawall or revetment. Armoring may impound sand thereby impacting the sediment budget of a beach and exacerbating the erosion. Shoreline armoring also increases wave turbulence and reflection. It is common to find that the construction of one seawall on a beach leads to proliferation of additional seawalls. Armoring a chronically eroding coast leads to beach loss (Fletcher, et al. 1997). Beach loss because of seawall construction on eroding shorelines has been estimated to be 25% on Oʻahu and 20% on Maui (http://www.surfrider.org/). In an era of accelerating sea-level rise (Church and White 2006) the threat of chronic erosion and beach loss is growing and the use of shoreline data becomes a potentially significant coastal management tool in the effort to conserve beaches for future generations.

The Kauaʻi Shoreline Erosion Management Study (DHM et al 1999) developed management recommendations and plans for selected Kauaʻi shoreline areas including the area between Hāʻena and Wainiha. The recommendations developed from this and related studies for preservation and restoration of sandy beaches and setbacks to compensate for coastal erosion at the Hāʻena State Park are consistent with the policies and guidelines of HRS 205A Hawaiʻi Coastal Zone Management, Hawaiʻi Coastal Erosion Management Plan (DLNR 1997), DLNR Office of Conservation and Coastal Plans and the County of Kauaʻi General Plan (2000), and Kauaʻi County Council Ordinance 863: Shoreline Setback and Coastal Protection Ordinance. Erosion prevention and control actions specifically relevant to the Park include:

- Delineate and manage specific erosion prone areas by ʻlittoral cellsʼ. Littoral cells are self-contained beach compartments that are geographically bounded by specific physical features (e.g. groins, piers, points of land) that either provide or remove sand from the cell.
- Establish shoreline setbacks of no less than 60 feet for Hāʻena
- Prohibit shore protection structures
- Remove unpermitted shoreline structures
- Preservation of public shorelines in natural state
- Give non-structural remedies (e.g. beach nourishment) preference over structural work
- Develop and update a shoreline structure inventory

Design of future Hāʻena State Park facilities should employ the recent data and maps developed by the University of Hawaiʻi (UH) Coastal Geology Group (http://www.soest.hawaii.edu/coasts/) to calculate appropriate setbacks.

8.3 Marine Resource Issues and Conservation

Coral reef ecosystems have high gross primary productivity, yet the net productivity and potential fisheries yields on coral reefs are relatively low (Birkeland 2001). Populations of fishes and invertebrates on coral reefs can be fished out quickly and if severely depleted, may not return. Coral reef species are particularly vulnerable to overfishing partly because of their life-history adaptations. Because of the life-history traits of the targeted species and because of the nature of the ecosystem processes, we must be careful about expecting too much from coral reefs. The fisheries yield of coral reefs should not be expected to keep pace with the growing human population and its demand for protein (Birkeland 2001). Overfishing also can have a deleterious impact upon ecosystem function and marine community structure. While pelagic fisheries might be managed on a species-by-species basis, coral-reef fisheries must be managed on an ecosystem basis.

Four years of CRAMP monitoring data and several independent studies of the reefs within the Park suggest the nearshore waters of Hāʻena State Park from Kēʻē Beach to Hāʻena Point contain largely undisturbed coral reef resources that provide habitat for healthy populations of fishes and invertebrates of subsistence and recreational value. These populations can be sustained provided that they are actively managed through carefully organized stewardship programs. Excessive fishing pressure, particularly upon a limited number of target species, can lead to dramatic adverse changes in community structure. Serious reduction or collapse of fish resources at Hāʻena and/or significant damage to the reef habitat would reduce its overall importance as a visitor destination area and would deprive the local community

of a valuable subsistence resource (Birkeland 2001). Stepath (1999) has highlighted the potential problems associated with excessive and inappropriate uses of the Park waters.

Improvements to the Park facilities through the master planning process may consider the following measures to help protect and sustain the long-term viability of the marine environment. These considerations are adapted in part from the Coral Reef Ecosystem Fishery Management Plan (CREFMP) for the western Pacific which is the first ecosystem-based fishery management plan for U.S. waters:

- Encourage the development of management guidelines and protocols for the Community-Based Subsistence Fishery Area established for Hāʻena by Hawaiʻi state law within a structured administrative framework;
- Establish a permit system as part of this program that requires catch reporting to allow the evaluation of changes over time in catch per unit effort and size distribution of the resource allows management to improve (Birkeland 2001);
- Establish a program of long-term scientific monitoring of fish and invertebrate populations trends within Park marine waters;
- Allow sufficient flexibility and insure long-term monitoring to employ the principal of adaptive management and allow changes to be made to permitting processes and management actions, as deemed appropriate based upon the results of long-term monitoring and catch statistics;
- Establish a means of enforcing the permitting system for recreational fishing within the Park waters.

Consideration might also be given to the establishment of a marine protected area (MPA) adjacent to or within a portion of the Park to serve as a fishery stock replacement area.

8.4 Mitigation of Conflicting Uses

Community consensus is the best mechanism to achieve a lasting solution of recreational user conflicts. Establishment of a Park users-group consisting of stakeholders, local residents, and government agencies should meet to discuss ways in which the conflicting uses discussed in the previous sections can be mitigated. User group meetings can be led by an independent moderator or by an agency or non-profit group. Segregation of conflicting uses might be considered on a rotating user basis by day and/or month, or weather and sea-condition basis, permit, or other system.

8.5 Shoreline Access

HRS 115-4 and 115-5 provide that the public has a right of access all State beaches and shorelines situated below the "upper reaches of the wash of the waves." In general, counties have the primary authority and duty to develop and maintain public shoreline access. The State's primary role in the shoreline area is to preserve and protect coastal resources within the conservation district and support public access along and below the shoreline (HRS Chapter 205A). Because of the steep shoreline along the Nāpali Coast west of the Park, the portion of the shoreline where pedestrian access becomes feasible begins at Kēʻē Beach and extends eastward along the shore to Hāʻena Point.

- Shoreline access points can be placed to control access for specific recreational and subsistence uses, and should be limited to pedestrian access.
- No public vehicular traffic should be allowed on the beach within the Park.

9.0 Interpretive Concepts for Marine Recreational Use

A number of community-based and non-governmental (NGO) organizations, as well as government-private and NGO partnerships support periodic monitoring and educational studies of the lagoon and reef at Hāʻena State Park. These include Windward Community College (CRAMP), Makai Watch, Save our Seas, Reef Check, The Nature Conservancy, Mālāma Hawaiʻi, Community Conservation Network, Hawaiʻi Wildlife Fund, Sea Grant Program, Hawaiʻi Department of Land and Natural Resources Division of Aquatic Resources. Many of these activities are in turn supported by grants from government agencies and the private sector including those from Tesoro, Harold K.L. Castle Foundation, National Fish and Wildlife Foundation, NOAA, Hawaiʻi Tourism Authority, and others.

The State of Hawaiʻi Coastal Zone Management Program (CZMP) has prepared an Ocean Resources Management Plan (ORMP), as required by Chapter 205A of Hawaiʻi Revised Statues (HRS), through collaboration with government agencies and stakeholders. The ORMP draws on traditional Hawaiian ecosystem management principles, relies on community and private sector involvement, promotes an adaptive learning approach, identifies responsibilities and a schedule for implementation, and emphasizes interagency collaboration and public-private partnerships. Hāʻena is one of several ORMP stewardship sites being studied over the next five years.

Each of these organizations can be considered a stakeholder in the development of interpretive, education, and management programs for Hāʻena State Park. Following the successful model of Hanauma Bay on Oʻahu, consideration should be given to the establishment of a "Friends of Hāʻena State Park" organization. Such a non-profit organization can help develop and sustain a visitor education program, coordinate park cleanups by volunteer service groups, coordinate use of the park by different marine recreation groups (e.g. dive clubs, surfing contests, kayaking, etc.), provide formal and informal docent services, assist the Hawaiʻi Division of State Parks with management, and help alleviate user conflicts. A service group such as this might also serve as the point-of-contact for the community-based subsistence fishing area for those wishing to shorefish or spearfish within the Park.

Educational signage, a docent program, lectures, films, and interactive kiosks are all valuable approaches to consider for enhancement of visitor and resident enjoyment of Hāʻena State Park. More information on the Hanauma Bay carrying capacity study can be found in Lankford et al (2005). Friends of Hanauma Bay website is: http://www.friendsofhanaumabay.org/history.html).

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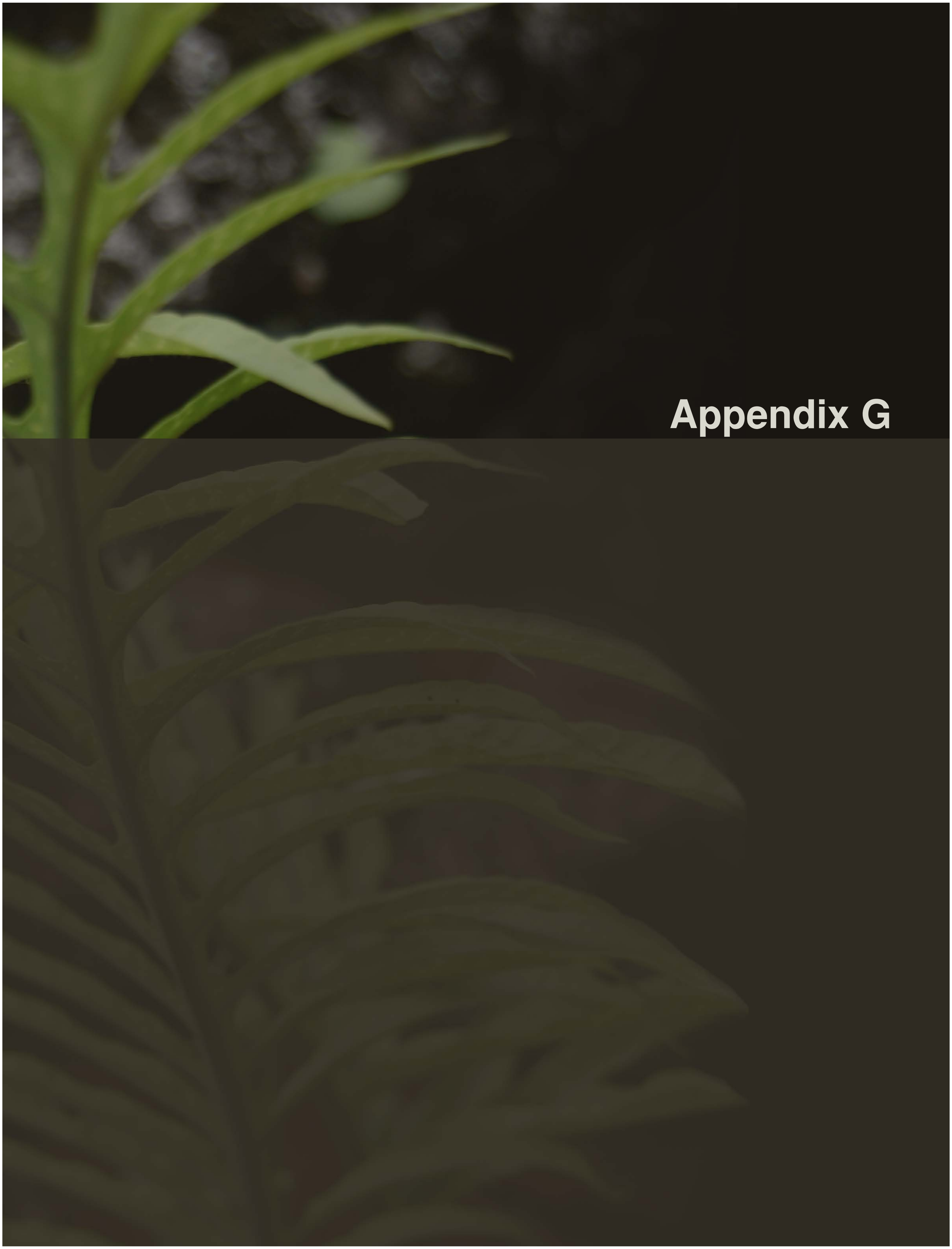

Appendix G

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, HONOLULU DISTRICT
FORT SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF:

June 15, 2009

Regulatory Branch

File Number POH-2009-00067

Eric Guinther, President
AECOS, Inc.
45-939 Kamehameha Hwy., Suite 104
Kaneohe, Hawai'i 96744

Dear Mr. Guinther:

This is in response to your October 31, 2008 letter requesting verification of a completed wetland delineation located in TMK 459008001. The wetland delineation was submitted in advance of an application for a Department of the Army (DA) permit to construct a comfort station and leach field at Ha'ena State Park located at the end of State Route 56 (Kuhio Highway), Ha'ena, Kauai, Hawaii.

From the information furnished in the report "A wetland delineation for a comfort station individual wastewater treatment system modification at Ha'ena State Park, Kaua'i" prepared by AECOS, Inc and dated October 30, 2008 and an on-site field inspection conducted on May 29, 2009 by Ms. Meris Banitilan-Smith of my staff, we have determined the following:

The delineated western area (AECOS SP-1 and SP-3) is not a wetland, as defined by the Corps wetlands definition. During the field inspection, areas sampled within the delineated area were found absent of one requisite wetland parameter, vegetation. The western border of the sampled area was dominated by *Terminalia catappa* (false kamani), which is not listed in "National List of Plant Species that Occur in Wetlands: Hawaii (Region H)" (Porter B. Reed Jr., 1988). Accordingly, this area is considered "uplands" and therefore is NOT subject to Corps regulatory jurisdiction.

Conversely, we have determined that the delineated eastern area (AECOS SP-2) is a wetland as we have confirmed the presence of all three (3) requisite wetland parameters. The October 30, 2008 wetland delineation report states that the proposed wastewater treatment system will "avoid the wetlands" (Page 1, ACOES, Inc., File 1179.doc). Should any work occur more than 15 feet eastward (down slope) of the remnant fishpond wall, a revised wetland delineation will need to be submitted and subsequently verified by the Corps of Engineers.

Enclosed with this letter is an approved jurisdictional determination (JD) form for the western upland area (AECOS SP-1 and SP-3). The approved JD is valid for a period of five (5) years from the date of this letter unless new information supporting a revision is provided to us before the expiration date. Additionally, a Notification of Administrative Appeal Options and

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Process and Request for Appeal form is provided for the approved jurisdictional determination (see section marked "Approved Jurisdictional Determination").

Nothing in this letter shall be construed as excusing you from compliance with other Federal, State, or local statutes, ordinances, or regulations that may affect any proposed work.

We appreciate your cooperation with the Corps of Engineers' Regulatory Program. If you have any questions concerning this determination or other questions regarding our Regulatory program, please contact Ms. Meris Bantilan-Smith at 808-438-7023 (Fax: 808-438-4060) or by electronic mail at: Meris.Bantilan-Smith@usace.army.mil . Please refer to file number POH-2009-067 in future correspondence regarding this parcel.

Sincerely,

for George P. Young, P.E.
Chief, Regulatory Branch

Enclosures

Copy Furnished (w/o encls):
Dr. Wendy Wiltse, U.S.E.P.A., Honolulu Branch, P.O. Box 50003, Honolulu, HI 96850

APPROVED JURISDICTIONAL DETERMINATION FORM
U.S. Army Corps of Engineers

This form should be completed by following the instructions provided in Section IV of the JD Form Instructional Guidebook.

SECTION I: BACKGROUND INFORMATION

A. REPORT COMPLETION DATE FOR APPROVED JURISDICTIONAL DETERMINATION (JD): June 3, 2009

B. DISTRICT OFFICE, FILE NAME, AND NUMBER: Honolulu District, POH-2009-067, Haena State Park Wetland Delineation

C. PROJECT LOCATION AND BACKGROUND INFORMATION:
State: Hawaii County/parish/borough: Kauai City: Haena
Center coordinates of site (lat/long in degree decimal format): Lat. 21.222957° **Pick List**, Long. -159.575005555° **Pick List**.
Universal Transverse Mercator: UTM Zone 4, NAD 83
Name of nearest waterbody: Un-named Stream

Name of nearest Traditional Navigable Water (TNW) into which the aquatic resource flows: Pacific Ocean
Name of watershed or Hydrologic Unit Code (HUC):
☒ Check if map/diagram of review area and/or potential jurisdictional areas is/are available upon request.
☐ Check if other sites (e.g., offsite mitigation sites, disposal sites, etc…) are associated with this action and are recorded on a different JD form.

D. REVIEW PERFORMED FOR SITE EVALUATION (CHECK ALL THAT APPLY):
☒ Office (Desk) Determination. Date: June 3, 2009
☐ Field Determination. Date(s): May 29, 2009

SECTION II: SUMMARY OF FINDINGS

A. RHA SECTION 10 DETERMINATION OF JURISDICTION.

There **Are no** "*navigable waters of the U.S.*" within Rivers and Harbors Act (RHA) jurisdiction (as defined by 33 CFR part 329) in the review area. [*Required*]
☐ Waters subject to the ebb and flow of the tide.
☐ Waters are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.
Explain:

B. CWA SECTION 404 DETERMINATION OF JURISDICTION.

There **Are no** "*waters of the U.S.*" within Clean Water Act (CWA) jurisdiction (as defined by 33 CFR part 328) in the review area. [*Required*]

1. **Waters of the U.S.**
   a. **Indicate presence of waters of U.S. in review area (check all that apply):** [1]
   ☐ TNWs, including territorial seas
   ☐ Wetlands adjacent to TNWs
   ☐ Relatively permanent waters[2] (RPWs) that flow directly or indirectly into TNWs
   ☐ Non-RPWs that flow directly or indirectly into TNWs
   ☐ Wetlands directly abutting RPWs that flow directly or indirectly into TNWs
   ☐ Wetlands adjacent to but not directly abutting RPWs that flow directly or indirectly into TNWs
   ☐ Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs
   ☐ Impoundments of jurisdictional waters
   ☐ Isolated (interstate or intrastate) waters, including isolated wetlands

   b. **Identify (estimate) size of waters of the U.S. in the review area:**
   Non-wetland waters: linear feet: width (ft) and/or acres.
   Wetlands: acres.

   c. **Limits (boundaries) of jurisdiction** based on: **1987 Delineation Manual**
   Elevation of established OHWM (if known):

2. **Non-regulated waters/wetlands (check if applicable):**[3]
   ☒ Potentially jurisdictional waters and/or wetlands were assessed within the review area and determined to be not jurisdictional.
   Explain: **The site did not meet the three requisite parameters as indicated in the 1987 Wetland Delineation Manual.**

[1] Boxes checked below shall be supported by completing the appropriate sections in Section III below.
[2] For purposes of this form, an RPW is defined as a tributary that is not a TNW and that typically flows year-round or has continuous flow at least "seasonally" (e.g., typically 3 months).
[3] Supporting documentation is presented in Section III.F.

SECTION III: CWA ANALYSIS

A. TNWs AND WETLANDS ADJACENT TO TNWs

The agencies will assert jurisdiction over TNWs and wetlands adjacent to TNWs. If the aquatic resource is a TNW, complete Section III.A.1 and Section III.D.1. only; if the aquatic resource is a wetland adjacent to a TNW, complete Sections III.A.1 and 2 and Section III.D.1.; otherwise, see Section III.B below.

1. **TNW**
   Identify TNW:

   Summarize rationale supporting determination:

2. **Wetland adjacent to TNW**
   Summarize rationale supporting conclusion that wetland is "adjacent":

B. CHARACTERISTICS OF TRIBUTARY (THAT IS NOT A TNW) AND ITS ADJACENT WETLANDS (IF ANY):

This section summarizes information regarding characteristics of the tributary and its adjacent wetlands, if any, and it helps determine whether or not the standards for jurisdiction established under *Rapanos* have been met.

The agencies will assert jurisdiction over non-navigable tributaries of TNWs where the tributaries are "relatively permanent waters" (RPWs), i.e. tributaries that typically flow year-round or have continuous flow at least seasonally (e.g., typically 3 months). A wetland that directly abuts an RPW is also jurisdictional. If the aquatic resource is not a TNW, but has year-round (perennial) flow, skip to Section III.D.2. If the aquatic resource is a wetland directly abutting a tributary with perennial flow, skip to Section III.D.4.

A wetland that is adjacent to but that does not directly abut an RPW requires a significant nexus evaluation. Corps districts and EPA regions will include in the record any available information that documents the existence of a significant nexus between a relatively permanent tributary that is not perennial (and its adjacent wetlands if any) and a traditional navigable water, even though a significant nexus finding is not required as a matter of law.

If the waterbody[4] is not an RPW, or a wetland directly abutting an RPW, a JD will require additional data to determine if the waterbody has a significant nexus with a TNW. If the tributary has adjacent wetlands, the significant nexus evaluation must consider the tributary in combination with all of its adjacent wetlands. This significant nexus evaluation that combines, for analytical purposes, the tributary and all of its adjacent wetlands is used whether the review area identified in the JD request is the tributary, or its adjacent wetlands, or both. If the JD covers a tributary with adjacent wetlands, complete Section III.B.1 for the tributary, Section III.B.2 for any onsite wetlands, and Section III.B.3 for all wetlands adjacent to that tributary, both onsite and offsite. The determination whether a significant nexus exists is determined in Section III.C below.

1. **Characteristics of non-TNWs that flow directly or indirectly into TNW**

   (i) **General Area Conditions:**
   Watershed size: **Pick List**
   Drainage area: **Pick List**
   Average annual rainfall: inches
   Average annual snowfall: inches

   (ii) **Physical Characteristics:**
   (a) Relationship with TNW:
   ☐ Tributary flows directly into TNW.
   ☐ Tributary flows through **Pick List** tributaries before entering TNW.

   Project waters are **Pick List** river miles from TNW.
   Project waters are **Pick List** river miles from RPW.
   Project waters are **Pick List** aerial (straight) miles from TNW.
   Project waters are **Pick List** aerial (straight) miles from RPW.
   Project waters cross or serve as state boundaries. Explain:

   Identify flow route to TNW[5]:
   Tributary stream order, if known:

[4] Note that the Instructional Guidebook contains additional information regarding swales, ditches, washes, and erosional features generally and in the arid West.
[5] Flow route can be described by identifying, e.g., tributary a, which flows through the review area, to flow into tributary b, which then flows into TNW.

(b) General Tributary Characteristics (check all that apply):

Tributary is:
- ☐ Natural
- ☐ Artificial (man-made). Explain:
- ☐ Manipulated (man-altered). Explain:

Tributary properties with respect to top of bank (estimate):
- Average width: feet
- Average depth: feet
- Average side slopes: **Pick List.**

Primary tributary substrate composition (check all that apply):
- ☐ Silts
- ☐ Sands
- ☐ Concrete
- ☐ Cobbles
- ☐ Gravel
- ☐ Muck
- ☐ Bedrock
- ☐ Vegetation. Type/% cover:
- ☐ Other. Explain:

Tributary condition/stability [e.g., highly eroding, sloughing banks]. Explain:
Presence of run/riffle/pool complexes. Explain:
Tributary geometry: **Pick List**
Tributary gradient (approximate average slope): %

(c) Flow:
Tributary provides for: **Pick List**
Estimate average number of flow events in review area/year: **Pick List**
Describe flow regime:
Other information on duration and volume:

Surface flow is: **Pick List.** Characteristics:

Subsurface flow: **Pick List**. Explain findings:
☐ Dye (or other) test performed:

Tributary has (check all that apply):
- ☐ Bed and banks
- ☐ OHWM[6] (check all indicators that apply):
  - ☐ clear, natural line impressed on the bank
  - ☐ changes in the character of soil
  - ☐ shelving
  - ☐ vegetation matted down, bent, or absent
  - ☐ leaf litter disturbed or washed away
  - ☐ sediment deposition
  - ☐ water staining
  - ☐ other (list):
  - ☐ the presence of litter and debris
  - ☐ destruction of terrestrial vegetation
  - ☐ the presence of wrack line
  - ☐ sediment sorting
  - ☐ scour
  - ☐ multiple observed or predicted flow events
  - ☐ abrupt change in plant community
- ☐ Discontinuous OHWM.[7] Explain:

If factors other than the OHWM were used to determine lateral extent of CWA jurisdiction (check all that apply):
- ☐ High Tide Line indicated by:
  - ☐ oil or scum line along shore objects
  - ☐ fine shell or debris deposits (foreshore)
  - ☐ physical markings/characteristics
  - ☐ tidal gauges
  - ☐ other (list):
- ☐ Mean High Water Mark indicated by:
  - ☐ survey to available datum;
  - ☐ physical markings;
  - ☐ vegetation lines/changes in vegetation types.

(iii) Chemical Characteristics:
Characterize tributary (e.g., water color is clear, discolored, oily film; water quality; general watershed characteristics, etc.).
Explain:
Identify specific pollutants, if known:

[6]A natural or man-made discontinuity in the OHWM does not necessarily sever jurisdiction (e.g., where the stream temporarily flows underground, or where the OHWM has been removed by development or agricultural practices). Where there is a break in the OHWM that is unrelated to the waterbody's flow regime (e.g., flow over a rock outcrop or through a culvert), the agencies will look for indicators of flow above and below the break.
[7]Ibid.

(iv) Biological Characteristics. Channel supports (check all that apply):
- ☐ Riparian corridor. Characteristics (type, average width):
- ☐ Wetland fringe. Characteristics:
- ☐ Habitat for:
  - ☐ Federally Listed species. Explain findings:
  - ☐ Fish/spawn areas. Explain findings:
  - ☐ Other environmentally-sensitive species. Explain findings:
  - ☐ Aquatic/wildlife diversity. Explain findings:

2. Characteristics of wetlands adjacent to non-TNW that flow directly or indirectly into TNW

(i) Physical Characteristics:

(a) General Wetland Characteristics:
Properties:
- Wetland size: acres
- Wetland type. Explain:
- Wetland quality. Explain:

Project wetlands cross or serve as state boundaries. Explain:

(b) General Flow Relationship with Non-TNW:
Flow is: **Pick List**. Explain:

Surface flow is: **Pick List**
Characteristics:

Subsurface flow: **Pick List**. Explain findings:
☐ Dye (or other) test performed:

(c) Wetland Adjacency Determination with Non-TNW:
- ☐ Directly abutting
- ☐ Not directly abutting
  - ☐ Discrete wetland hydrologic connection. Explain:
  - ☐ Ecological connection. Explain:
  - ☐ Separated by berm/barrier. Explain:

(d) Proximity (Relationship) to TNW
Project wetlands are **Pick List** river miles from TNW.
Project waters are **Pick List** aerial (straight) miles from TNW.
Flow is from: **Pick List.**
Estimate approximate location of wetland as within the **Pick List** floodplain.

(ii) Chemical Characteristics:
Characterize wetland system (e.g., water color is clear, brown, oil film on surface; water quality; general watershed characteristics; etc.). Explain:
Identify specific pollutants, if known:

(iii) Biological Characteristics. Wetland supports (check all that apply):
- ☐ Riparian buffer. Characteristics (type, average width):
- ☐ Vegetation type/percent cover. Explain:
- ☐ Habitat for:
  - ☐ Federally Listed species. Explain findings:
  - ☐ Fish/spawn areas. Explain findings:
  - ☐ Other environmentally-sensitive species. Explain findings:
  - ☐ Aquatic/wildlife diversity. Explain findings:

3. Characteristics of all wetlands adjacent to the tributary (if any)
All wetland(s) being considered in the cumulative analysis: **Pick List**
Approximately ( ) acres in total are being considered in the cumulative analysis.

For each wetland, specify the following:

Directly abuts? (Y/N)	Size (in acres)	Directly abuts? (Y/N)	Size (in acres)

Summarize overall biological, chemical and physical functions being performed: .

C. SIGNIFICANT NEXUS DETERMINATION

A significant nexus analysis will assess the flow characteristics and functions of the tributary itself and the functions performed by any wetlands adjacent to the tributary to determine if they significantly affect the chemical, physical, and biological integrity of a TNW. For each of the following situations, a significant nexus exists if the tributary, in combination with all of its adjacent wetlands, has more than a speculative or insubstantial effect on the chemical, physical and/or biological integrity of a TNW. Considerations when evaluating significant nexus include, but are not limited to the volume, duration, and frequency of the flow of water in the tributary and its proximity to a TNW, and the functions performed by the tributary and all its adjacent wetlands. It is not appropriate to determine significant nexus based solely on any specific threshold of distance (e.g. between a tributary and its adjacent wetland or between a tributary and the TNW). Similarly, the fact an adjacent wetland lies within or outside of a floodplain is not solely determinative of significant nexus.

Draw connections between the features documented and the effects on the TNW, as identified in the *Rapanos* Guidance and discussed in the Instructional Guidebook. Factors to consider include, for example:

- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to carry pollutants or flood waters to TNWs, or to reduce the amount of pollutants or flood waters reaching a TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), provide habitat and lifecycle support functions for fish and other species, such as feeding, nesting, spawning, or rearing young for species that are present in the TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to transfer nutrients and organic carbon that support downstream foodwebs?
- Does the tributary, in combination with its adjacent wetlands (if any), have other relationships to the physical, chemical, or biological integrity of the TNW?

Note: the above list of considerations is not inclusive and other functions observed or known to occur should be documented below:

1. **Significant nexus findings for non-RPW that has no adjacent wetlands and flows directly or indirectly into TNWs.** Explain findings of presence or absence of significant nexus below, based on the tributary itself, then go to Section III.D: .

2. **Significant nexus findings for non-RPW and its adjacent wetlands, where the non-RPW flows directly or indirectly into TNWs.** Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D: .

3. **Significant nexus findings for wetlands adjacent to an RPW but that do not directly abut the RPW.** Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D: .

D. DETERMINATIONS OF JURISDICTIONAL FINDINGS. THE SUBJECT WATERS/WETLANDS ARE (CHECK ALL THAT APPLY):

1. **TNWs and Adjacent Wetlands.** Check all that apply and provide size estimates in review area:
   - ☐ TNWs: linear feet width (ft), Or, acres.
   - ☐ Wetlands adjacent to TNWs: acres.

2. **RPWs that flow directly or indirectly into TNWs.**
   - ☐ Tributaries of TNWs where tributaries typically flow year-round are jurisdictional. Provide data and rationale indicating that tributary is perennial: .
   - ☐ Tributaries of TNW where tributaries have continuous flow "seasonally" (e.g., typically three months each year) are jurisdictional. Data supporting this conclusion is provided at Section III.B. Provide rationale indicating that tributary flows seasonally: .

   Provide estimates for jurisdictional waters in the review area (check all that apply):
   - ☐ Tributary waters: linear feet width (ft).
   - ☐ Other non-wetland waters: acres.
     Identify type(s) of waters: .

3. **Non-RPWs[8] that flow directly or indirectly into TNWs.**
   - ☐ Waterbody that is not a TNW or an RPW, but flows directly or indirectly into a TNW, and it has a significant nexus with a TNW is jurisdictional. Data supporting this conclusion is provided at Section III.C.

   Provide estimates for jurisdictional waters within the review area (check all that apply):
   - ☐ Tributary waters: linear feet · width (ft).
   - ☐ Other non-wetland waters: acres.
     Identify type(s) of waters: .

4. **Wetlands directly abutting an RPW that flow directly or indirectly into TNWs.**
   - ☐ Wetlands directly abut RPW and thus are jurisdictional as adjacent wetlands.
     - ☐ Wetlands directly abutting an RPW where tributaries typically flow year-round. Provide data and rationale indicating that tributary is perennial in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW: .
     - ☐ Wetlands directly abutting an RPW where tributaries typically flow "seasonally." Provide data indicating that tributary is seasonal in Section III.B and rationale in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW: .

   Provide acreage estimates for jurisdictional wetlands in the review area: acres.

5. **Wetlands adjacent to but not directly abutting an RPW that flow directly or indirectly into TNWs.**
   - ☐ Wetlands that do not directly abut an RPW, but when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisidictional. Data supporting this conclusion is provided at Section III.C.

   Provide acreage estimates for jurisdictional wetlands in the review area: acres.

6. **Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs.**
   - ☐ Wetlands adjacent to such waters, and have when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisdictional. Data supporting this conclusion is provided at Section III.C.

   Provide estimates for jurisdictional wetlands in the review area: acres.

7. **Impoundments of jurisdictional waters.**[9]
   As a general rule, the impoundment of a jurisdictional tributary remains jurisdictional.
   - ☐ Demonstrate that impoundment was created from "waters of the U.S.," or
   - ☐ Demonstrate that water meets the criteria for one of the categories presented above (1-6), or
   - ☐ Demonstrate that water is isolated with a nexus to commerce (see E below).

E. ISOLATED [INTERSTATE OR INTRA-STATE] WATERS, INCLUDING ISOLATED WETLANDS, THE USE, DEGRADATION OR DESTRUCTION OF WHICH COULD AFFECT INTERSTATE COMMERCE, INCLUDING ANY SUCH WATERS (CHECK ALL THAT APPLY):[10]

- ☐ which are or could be used by interstate or foreign travelers for recreational or other purposes.
- ☐ from which fish or shellfish are or could be taken and sold in interstate or foreign commerce.
- ☐ which are or could be used for industrial purposes by industries in interstate commerce.
- ☐ Interstate isolated waters. Explain: .
- ☐ Other factors. Explain: .

Identify water body and summarize rationale supporting determination: .

---

[8] See Footnote # 3.
[9] To complete the analysis refer to the key in Section III.D.6 of the Instructional Guidebook.
[10] **Prior to asserting or declining CWA jurisdiction based solely on this category, Corps Districts will elevate the action to Corps and EPA HQ for review consistent with the process described in the Corps/EPA *Memorandum Regarding CWA Act Jurisdiction Following Rapanos*.**

Provide estimates for jurisdictional waters in the review area (check all that apply):
☐ Tributary waters: linear feet width (ft).
☐ Other non-wetland waters: acres.
Identify type(s) of waters: .
☐ Wetlands: acres.

F. NON-JURISDICTIONAL WATERS, INCLUDING WETLANDS (CHECK ALL THAT APPLY):
☐ If potential wetlands were assessed within the review area, these areas did not meet the criteria in the 1987 Corps of Engineers Wetland Delineation Manual and/or appropriate Regional Supplements.
☐ Review area included isolated waters with no substantial nexus to interstate (or foreign) commerce.
☐ Prior to the Jan 2001 Supreme Court decision in "*SWANCC*," the review area would have been regulated based solely on the "Migratory Bird Rule" (MBR).
☐ Waters do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction. Explain: .
☐ Other: (explain, if not covered above): .

Provide acreage estimates for non-jurisdictional waters in the review area, where the sole potential basis of jurisdiction is the MBR factors (i.e., presence of migratory birds, presence of endangered species, use of water for irrigated agriculture), using best professional judgment (check all that apply):
☐ Non-wetland waters (i.e., rivers, streams): linear feet width (ft).
☐ Lakes/ponds: acres.
☐ Other non-wetland waters: acres. List type of aquatic resource: .
☐ Wetlands: acres.

Provide acreage estimates for non-jurisdictional waters in the review area that do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction (check all that apply):
☐ Non-wetland waters (i.e., rivers, streams): linear feet, width (ft).
☐ Lakes/ponds: acres.
☐ Other non-wetland waters: acres. List type of aquatic resource: .
☐ Wetlands: acres.

SECTION IV: DATA SOURCES.

A. SUPPORTING DATA. Data reviewed for JD (check all that apply - checked items shall be included in case file and, where checked and requested, appropriately reference sources below):
☒ Maps, plans, plots or plat submitted by or on behalf of the applicant/consultant:A wetland delineation for a comfort station individual wastewater treatment system modification at Haena State Park, OCtober 30, 2008, AECOS, Inc..
☒ Data sheets prepared/submitted by or on behalf of the applicant/consultant.
☐ Office concurs with data sheets/delineation report.
☒ Office does not concur with data sheets/delineation report.
☒ Data sheets prepared by the Corps: Site Visit was conducted by Meris Bantilan-Smth. 2 delineation sheets were prepared for the west end of the site.
☐ Corps navigable waters' study: .
☐ U.S. Geological Survey Hydrologic Atlas: .
☐ USGS NHD data.
☐ USGS 8 and 12 digit HUC maps.
☐ U.S. Geological Survey map(s). Cite scale & quad name: .
☐ USDA Natural Resources Conservation Service Soil Survey. Citation: .
☐ National wetlands inventory map(s). Cite name: .
☐ State/Local wetland inventory map(s): .
☐ FEMA/FIRM maps: .
☐ 100-year Floodplain Elevation is: (National Geodectic Vertical Datum of 1929)
☐ Photographs: ☐ Aerial (Name & Date): .
or ☐ Other (Name & Date): .
☐ Previous determination(s). File no. and date of response letter: .
☐ Applicable/supporting case law: .
☐ Applicable/supporting scientific literature: .
☐ Other information (please specify): .

NOTIFICATION OF ADMINISTRATIVE APPEAL OPTIONS AND PROCESS AND REQUEST FOR APPEAL

Applicant: State of Hawaii DLNR		File Number POH-2009-067	Date: 15 Jun 2009
Attached is:			See Section below
	INITIAL PROFFERED PERMIT (Standard Permit or Letter of permission)		A
	PROFFERED PERMIT (Standard Permit or Letter of permission)		B
	PERMIT DENIAL		C
X	APPROVED JURISDICTIONAL DETERMINATION		D
	PRELIMINARY JURISDICTIONAL DETERMINATION		E

SECTION I - The following identifies your rights and options regarding an administrative appeal of the above decision. Additional information may be found at http://usace.army.mil/inet/functions/cw/cecwo/reg or Corps regulations at 33 CFR Part 331.

A: INITIAL PROFFERED PERMIT: You may accept or object to the permit.

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Permit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.
- OBJECT: If you object to the permit (Standard or LOP) because of certain terms and conditions therein, you may request that the permit be modified accordingly. You must complete Section II of this form and return the form to the district engineer. Your objections must be received by the district engineer within 60 days of the date of this notice, or you will forfeit your right to appeal the permit in the future. Upon receipt of your letter, the district engineer will evaluate your objections and may: (a) modify the permit to address all of your concerns, (b) modify the permit to address some of your objections, or (c) not modify the permit having determined that the permit should be issued as previously written. After evaluating your objections, the district engineer will send you a proffered permit for your reconsideration, as indicated in Section B below.

B: PROFFERED PERMIT: You may accept or appeal the permit

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Permit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.
- APPEAL: If you choose to decline the proffered permit (Standard or LOP) because of certain terms and conditions therein, you may appeal the declined permit under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

C: PERMIT DENIAL: You may appeal the denial of a permit under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

D: APPROVED JURISDICTIONAL DETERMINATION: You may accept or appeal the approved JD or provide new information.

- ACCEPT: You do not need to notify the Corps to accept an approved JD. Failure to notify the Corps within 60 days of the date of this notice, means that you accept the approved JD in its entirety, and waive all rights to appeal the approved JD.
- APPEAL: If you disagree with the approved JD, you may appeal the approved JD under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

E: PRELIMINARY JURISDICTIONAL DETERMINATION: You do not need to respond to the Corps regarding the preliminary JD. The Preliminary JD is not appealable. If you wish, you may request an approved JD (which may be appealed), by contacting the Corps district for further instruction. Also you may provide new information for further consideration by the Corps to reevaluate the JD.

SECTION II - REQUEST FOR APPEAL or OBJECTIONS TO AN INITIAL PROFFERED PERMIT

REASONS FOR APPEAL OR OBJECTIONS: (Describe your reasons for appealing the decision or your objections to an initial proffered permit in clear concise statements. You may attach additional information to this form to clarify where your reasons or objections are addressed in the administrative record.)

ADDITIONAL INFORMATION: The appeal is limited to a review of the administrative record, the Corps memorandum for the record of the appeal conference or meeting, and any supplemental information that the review officer has determined is needed to clarify the administrative record. Neither the appellant nor the Corps may add new information or analyses to the record. However, you may provide additional information to clarify the location of information that is already in the administrative record.

POINT OF CONTACT FOR QUESTIONS OR INFORMATION:

If you have questions regarding this decision and/or the appeal process you may contact:	If you only have questions regarding the appeal process you may also contact:
Meris Bantilan-Smith, (808) 438-7701 U.S. Army Corps of Engineers, Honolulu District CEPOH-EC-R, Bldg 230 Fort Shafter, HI 96858-5440	Thom Lichte (808) 438-0397 U.S. Army Corps of Engineers CEPOD-RBT, Bldg 525 Fort Shafter, HI 96858-5440

RIGHT OF ENTRY: Your signature below grants the right of entry to Corps of Engineers personnel, and any government consultants, to conduct investigations of the project site during the course of the appeal process. You will be provided a 15 day notice of any site investigation, and will have the opportunity to participate in all site investigations.

Signature of appellant or agent.	Date:	Telephone number:

A wetland delineation for a new comfort station project at Hā'ena State Park, Kaua'i.[1]

October 30, 2008 **_DRAFT_** *AECOS* No. 1179

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Introduction

On May 27, 2008, an inspection was made by AECOS biologists of an area of low ground to the east of a comfort station (restroom facility) under construction on parcel TMK: (4) 5-9-08: 01, at Hā'ena State Park on the north shore of Kaua'i (Fig. 1). The purpose of the visit was to establish whether or not—and if so, then precisely where—a wetland existed here so that plans for the comfort station leach field would avoid the wetlands. The visit coincided with a survey team (Esaki Surveying & Mapping, Inc.) and the location of three wetland soil test pits and seven ("A" through "G") marking flags were established immediately after the biologists completed their work.

Site Description

Hā'ena State Park is located at the very end of State Rte. 56 (Kūhiō Highway) on Kaua'i in Hā'ena. The park occupies the last section of coastal plain extending along Kaua'i's northern coast. Beyond, to the west, the mountainous terrain drops steeply into the sea as a *pali* (cliff). This cliff extends along the inland side of the road through the park. Limahuli Valley lies inland to the south, its stream crossing the coastal plain along the eastern boundary of the state park.

The inland portion of the coastal plain within the state park is a lowland lying between the pali (and the road) and coastal dunes. Parts of this lowland are clearly wetlands based upon vegetation. Indeed, portions are developed into pondfields or *lo'i* in which *kalo* (taro; *Colocasia esculenta*) is being farmed (Fig. 2). Further, the

[1] This report was prepared for Strategic Solutions, Inc. to be used as needed for permitting/ compliance for the Hā'ena State Park Comfort Station Improvements. This report will become part of the public record for the permitting process.

subject area is shown by the National Wetlands Inventory (NWI) to have a wetland present (PFO3C[2]; USFWS, 2008). Although the majority of the existing wetland area is open, and maintained in that state for agricultural purposes, the western end supports more dense vegetation, in particular a dense area of *hau* (*Hibiscus tiliaceus*) and a closed canopy forest of mostly false *kamani* or tropical almond (*Terminalia catappa*) and Java plum (*Syzygium cuminii*). Therefore, the primary question becomes precisely where is the western edge (end of wetland closest to the construction project) of this wetland.

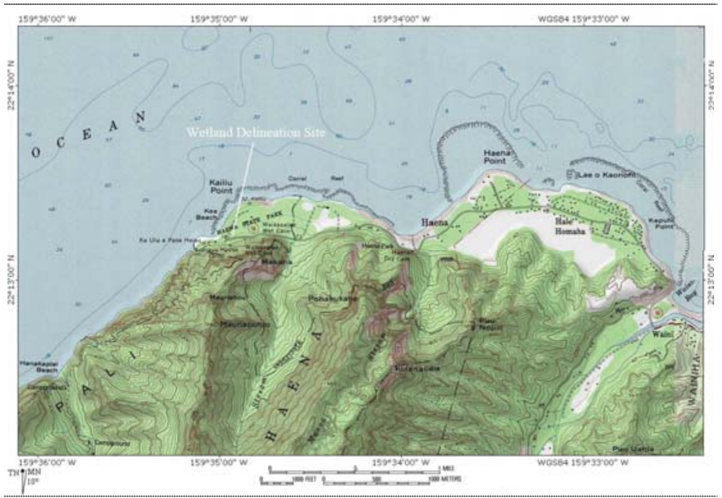


Figure 1. Location of wetland delineation site at Hāʻena State Park, Kauaʻi.

Methods

This wetland delineation was completed by Eric Guinther and Susan Burr of *AECOS* Inc. Methodology followed the official delineation manual (ACOE, 1987). Soil descriptions utilized Munsell soil color charts (Munsell, 1994). The wetland status of identified plants comes from Reed (1988) as required, although we point out that this source is botanically out of date (see Puttock and Imada, 2004). Plant species not listed (NL) in Reed are counted as upland (UPL) plants.

[2] PFO3C = Palustrine, broad-leaved evergreen forest, seasonally flooded wetland.

For this effort, a total of three soil pits were dug along a transect extending from the forested uplands (1179-SP-3 and 1179-SP-1) to an area of mostly grasses and some sedges (1179-SP-2) lying between the false *kamani*/Java plum forest and the *hau* grove seen in Fig. 2. Standing water was observed within the *hau*, so this area was considered wetland without closer inspection.

Figure 2. View of *kalo lo'i* at Hāʻena State Park, looking west towards the project area (within dense forest, center background).

Wetland Delineation Results

The first observation area and first soil pit (*AECOS* 1179-SP-1) were undertaken within the forest, in an area of false *kamani* trees with little understory present due to the deep shade. A few vines (golden pothos or *Epipremnum pinnatum 'Aureum'*) occur running up the trees and growing across the ground. The pit was dug to a depth of 8 inches (21 cm) without encountering saturated soil or free water. However, the low chroma of the soil suggests a hydric soil.

We then moved further out towards the hau stand, developing a test pit (*AECOS* 1179-SP-2) in an open area of grass (*Paspalum conjugatum*) and dayflower (*Commelina diffusa*) between the false *kamani* forest and the *hau*. This soil was clearly hydric at the surface (10YR 3/1) and standing water was present nearby within the *hau*.

A third soil pit (1179-SP-3) was developed inland of the first and roughly 2 m (8 ft) behind a low line of boulders thought to be part of an old wall. The ground here was dominated by pathos vine, wedelia (*Sphagneticola trilobata*), and tree seedlings; the upper story vegetation was mostly large false *kamani* and Java plum trees. The soil resembled that seen in the other two pits, with hydric tendencies. However, here the vegetation was clearly upland. Further, evidence of flooding in the area in the form of litter deposits of mostly *Terminalia* seeds constitutes a strong hydrology indicator. The upper extent of this wrack was against the base of the line of boulders, excluding 1179-SP-3 but including 1179-SP-1 in the wetland.

Conclusions

The surveyed location within Hā'ena State Park does contain a wetland more or less as indicated on the soil survey (Foote, et at., 1972) and NWI maps. In the project area, this wetland is jurisdictional within a boundary that closely coincides with remnants of a former, presumably ancient, fishpond wall. This broken line of boulders also corresponds to a high water line for the larger basin. The wetland may not extend fully up to the wall for the reason that the forest area supports an "upland" vegetation. However, this designation is a technicality based upon the requirements of the process as established by ACOE (1987). Logically, the area is dominated by a tree not considered (or previously misidentified) by Reed (1988) but now regarded as a facultative wetland species (FAC; Puttock & Imada, 2004). Therefore, it is a logical conclusion that the wetland extends into this forest and up to the wall. The scattered remnants of a former wall coincide with a modest slope change. The wall and change in slope were utilized to place the 7 marking flags shown plotted in Fig. 3 and presenting our interpretation of the wetland boundary in the project vicinity.

No areal extent for this wetland was calculated because the intent of the comfort station project is to design around (away from) the wetland boundary as delineated and not enter or alter the wetland in any way.

References

Foote, D. E., et al. 1972. *Soils survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii*. U.S. Department of Agriculture, Soil Conservation Service.

Munsell® Color. 1994. *Munsell soil color charts. Revised edition*. Macbeth Div. of Kollmorgan Instruments Corp., New Windsor, NY.

Puttock, C. F., and C. Imada. 2004. Wetland status list for Hawaiian plants. Final report for U.S. Fish and Wildlife Service, Honolulu.

Reed, P. B. J. 1988. National list of plant species that occur in wetlands: Hawaii (Region H). Biological Report 88(26.13): 88 pp.

U.S. Army Corps of Engineers (ACOE). 1987. *Corps of Engineers Wetlands Delineation Manual*. Vol. Tech. Rept. Y-87-1. Environmental Laboratory, Dept. of the Army, Waterways Experiment Station, Corps of Engineers.

U.S. Fish and Wildlife Service (USFWS). 2008. Wetlands Geodatabase, available online at http://wetlandsfws.er.usgs.gov/NWI/index.html (last visited October 30, 2008)

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Haena State Park, Kaua'i Applicant/Owner: State of Hawai'i Investigator: Guinther/Burr UTM:			Date: May 27, 2008 County: Kaua'i State: Hawai'i
Do Normal Circumstances exist on the site?	Yes ☒	No ☐	Community ID:
Is the site significantly disturbed (Atypical Situation)?	Yes ☐	No ☒	Transect ID: No. 1
Is the area a potential Problem Area? (If needed, explain on reverse side.)	Yes ☐	No ☒	Plot ID: *AECOS* 1179-SP-1

VEGETATION

	Dominant Plant Species	Stratum	Indicator		Other Plant Species	Stratum	Indicator
1.	*Terminalia catappa*	T	NL	1.	*Epipremnum pinnatum* *'Aureum'*	V	NL
2.				2.			
3.				3.			
4.				4.			
5.				5.			
6.				6.			
7.				7.			
8.				8.			

Percent of Dominant Species that are OBL, FACW, or FAC (excluding FAC-). 0%

Remarks: Heavily shaded, monotypic stand of false kamani that extends into the upland, where additional tree species occur (see *AECOS* SP-3) . This tree is misidentified in Reed (1988) as *Terminalia carolinensis*, a species not recorded from Hawai'i.

HYDROLOGY

☐ Recorded Data (Describe in Remarks):
- ☐ Stream, Lake, or Tide Gauge
- ☐ Aerial Photographs
- ☐ Other

☒ No Recorded Data Available

Field Observations

Depth of Surface Water: n/a (cm)

Depth to Free Water in Pit: >21 (cm)

Depth to Saturated Soil: >21 (cm)

Wetland Hydrology Indicators:

Primary Indicators:
- ☐ Inundated
- ☐ Saturated in Upper 12 inches
- ☐ Water Marks
- ☐ Drift Lines
- ☐ Sediment Deposits
- ☒ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required)
- ☐ Oxidized Root Channels in Upper 12 Inches
- ☐ Water-Stained Leaves
- ☐ Local Soil Survey Data
- ☐ FAC Neutral Test
- ☒ Other (Explain in Remarks)

Remarks: Dense drift area of false kamani seeds mark high water mark and occur along inside edge of old fishpond wall.

SOILS

Map Unit Name
(Series and Phase): ______________________

Drainage Class: ______________
Field Observations
Confirmed Mapped Type? Yes ☐ No ☐

Taxonomy (Subgroup): ______________________

Profile Description:

Depth (cm)	Horizon	Matrix Colors (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance / Size / Contrast	Texture, Concretions, Structure, etc.
0 - 2	O	black			organic matter
2 - 7	A	10YR 2/2 and ??	none		clay loam
7 – 19	B	10YR 3/3	7.5YR 4/4	40%; fine, distinct	clay loam
19 - 21	B	10YR 3/2	7.5YR 4/4	25%; medium, distinct	clay loam
			7.5YR 3/1	25%; medium, faint	

Hydric Soil Indicators:

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in Surface Layer in Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (Explain in Remarks)

Remarks: Maps to "MZ" or marsh, surrounded by Mokuleia fine sandy loam (Young, et al., 1979).

Keaukaha soils have a 20 cm (8 in) organic layer consisting of very dark brown (10YR 2/2) muck, which overlays pahoehoe lava.

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes ☐ No ☒
Wetland Hydrology Present? Yes ☒ No ☐
Hydric Soils Present? Yes ☒ No ☐

Is this Sampling Point Within a Wetland? Yes ☒ No ☐

Remarks: Indentified on NWI maps (USFWS, 1984); conditions at survey somewhat dry for late wet season.

Although *Terminalia catappa* is not listed in Reed (1988) and therefore by default an upland species, this conclusion cannot be reasonably supported given the hydrology and soils at this soil pit location; a more useful version of the Hawaii plant wetland status codes (Puttock & Imada, 2004) lists T. catappa as FAC.

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Haena State Park, Island of Kaua'i
Applicant/Owner: State of Hawai'i
Investigator: Guinther/Burr
UTM:

Date: May 27, 2008
County: Kaua'i
State: Hawai'i

Do Normal Circumstances exist on the site? Yes ☒ No ☐
Is the site significantly disturbed (Atypical Situation)? Yes ☐ No ☒
Is the area a potential Problem Area? Yes ☐ No ☒
(If needed, explain on reverse side.)

Community ID:
Transect ID: No. 1
Plot ID: *AECOS* 1179-SP-2

VEGETATION

Dominant Plant Species	Stratum	Indicator	Other Plant Species	Stratum	Indicator
1. *Paspalum conjugatum*	H	FAC+	1. *Cyperus javanicus*	H	FACW
2. *Commelina diffusa*	H	FACW	2. *Psidium guajava*	T	FACU
3.			3.		
4.			4.		
5.			5.		
6.			6.		
7.			7.		
8.			8.		

Percent of Dominant Species that are OBL, FACW, or FAC (excluding FAC-). 100%

Remarks: In open area between false kamani forest and hau forest, the latter with standing water on surface.

HYDROLOGY

☐ Recorded Data (Describe in Remarks):
- ☐ Stream, Lake, or Tide Gauge
- ☐ Aerial Photographs
- ☐ Other

☒ No Recorded Data Available

Field Observations

Depth of Surface Water: n/a (cm)

Depth to Free Water in Pit: >17 (cm)

Depth to Saturated Soil: >17 (cm)

Wetland Hydrology Indicators:
Primary Indicators:
- ☐ Inundated
- ☐ Saturated in Upper 12 inches
- ☐ Water Marks
- ☐ Drift Lines
- ☐ Sediment Deposits
- ☒ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required)
- ☐ Oxidized Root Channels in Upper 12 Inches
- ☐ Water-Stained Leaves
- ☐ Local Soil Survey Data
- ☐ FAC Neutral Test
- ☐ Other (Explain in Remarks)

Remarks: Soil moist throughout, but not saturated

SOILS

Map Unit Name (Series and Phase):
Taxonomy (Subgroup):

Drainage Class:
Field Observations
Confirmed Mapped Type? Yes ☐ No ☒

Profile Description:

Depth (cm)	Horizon	Matrix Colors (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance / Size / Contrast	Texture, Concretions, Structure, etc.
0 – 9	A	10YR 3/1	none		sandy clay loam
9 - 17	B	7.5YR 4/4	7.5YR 4/1	5%; horizontal bedding evident	sandy clay loam

Hydric Soil Indicators:

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in Surface Layer in Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (Explain in Remarks)

Remarks: Reducing conditions observed in top layer (0-9") by positive α, α diprydil test. Keaukaha soils have a 20 cm (8 in) organic layer consisting of very dark brown (10YR 2/2) muck, which overlays pahoehoe lava.

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes ☒ No ☐
Wetland Hydrology Present? Yes ☒ No ☐
Hydric Soils Present? Yes ☒ No ☐

Is this Sampling Point Within a Wetland? Yes ☒ No ☐

Remarks: Survey point is within an ancient fishpond.

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Ha'ena State Park, Kaua'i
Applicant/Owner: State of Hawai'i
Investigator: Guinther/Burr
UTM:

Date: May 27, 2008
County: Kaua'i
State: Hawai'i

	Yes	No
Do Normal Circumstances exist on the site?	☒	☐
Is the site significantly disturbed (Atypical Situation)?	☐	☒
Is the area a potential Problem Area? (If needed, explain on reverse side.)	☐	☒

Community ID:
Transect ID:
Plot ID: *AECOS* 1179-SP-3

VEGETATION

	Dominant Plant Species	Stratum	Indicator		Other Plant Species	Stratum	Indicator
1.	*Epipremnum pinnatum 'aureum'*	V	NL	1.	*Xanthosoma roseum*	H	NL
2.	*Terminalia cattapa*	T	NL	2.	*Carica papaya*	H	NL
3.	*Sphagneticola trilobata*	H	FACU	3.	*Shefflera actinophylla*	T	UPL
4.	*Syzygium cuminii*	T	FACU	4.			
5.				5.			
6.				6.			
7.				7.			
8.				8.			

Percent of Dominant Species that are OBL, FACW, or FAC (excluding FAC-). 0%

Remarks: Reed (1988) misidentifies the false kamani tree in Hawai'i as *Terminalia carolinensis*, a species that does not occur here.

HYDROLOGY

☐ Recorded Data (Describe in Remarks):
- ☐ Stream, Lake, or Tide Gauge
- ☐ Aerial Photographs
- ☐ Other

☒ No Recorded Data Available

Field Observations

Depth of Surface Water: n/a (cm)

Depth to Free Water in Pit: >21 (cm)

Depth to Saturated Soil: >21 (cm)

Wetland Hydrology Indicators:
Primary Indicators:
- ☐ Inundated
- ☐ Saturated in Upper 12 inches
- ☐ Water Marks
- ☐ Drift Lines
- ☐ Sediment Deposits
- ☐ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required)
- ☐ Oxidized Root Channels in Upper 12 Inches
- ☐ Water-Stained Leaves
- ☐ Local Soil Survey Data
- ☐ FAC Neutral Test
- ☐ Other (Explain in Remarks)

Remarks: Upslope of former fishpond wall

SOILS

Map Unit Name (Series and Phase):
Taxonomy (Subgroup):

Drainage Class:
Field Observations
Confirmed Mapped Type? Yes ☐ No ☐

Profile Description:

Depth (cm)	Horizon	Matrix Colors (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance / Size / Contrast	Texture, Concretions, Structure, etc.
0 – 3	A	10YR 3/1	none		sandy loam
3 - 21	B	10YR 3/6	10YR 3/2	40%; medium, distinct	sandy loam

Hydric Soil Indicators:

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in Surface Layer in Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (Explain in Remarks)

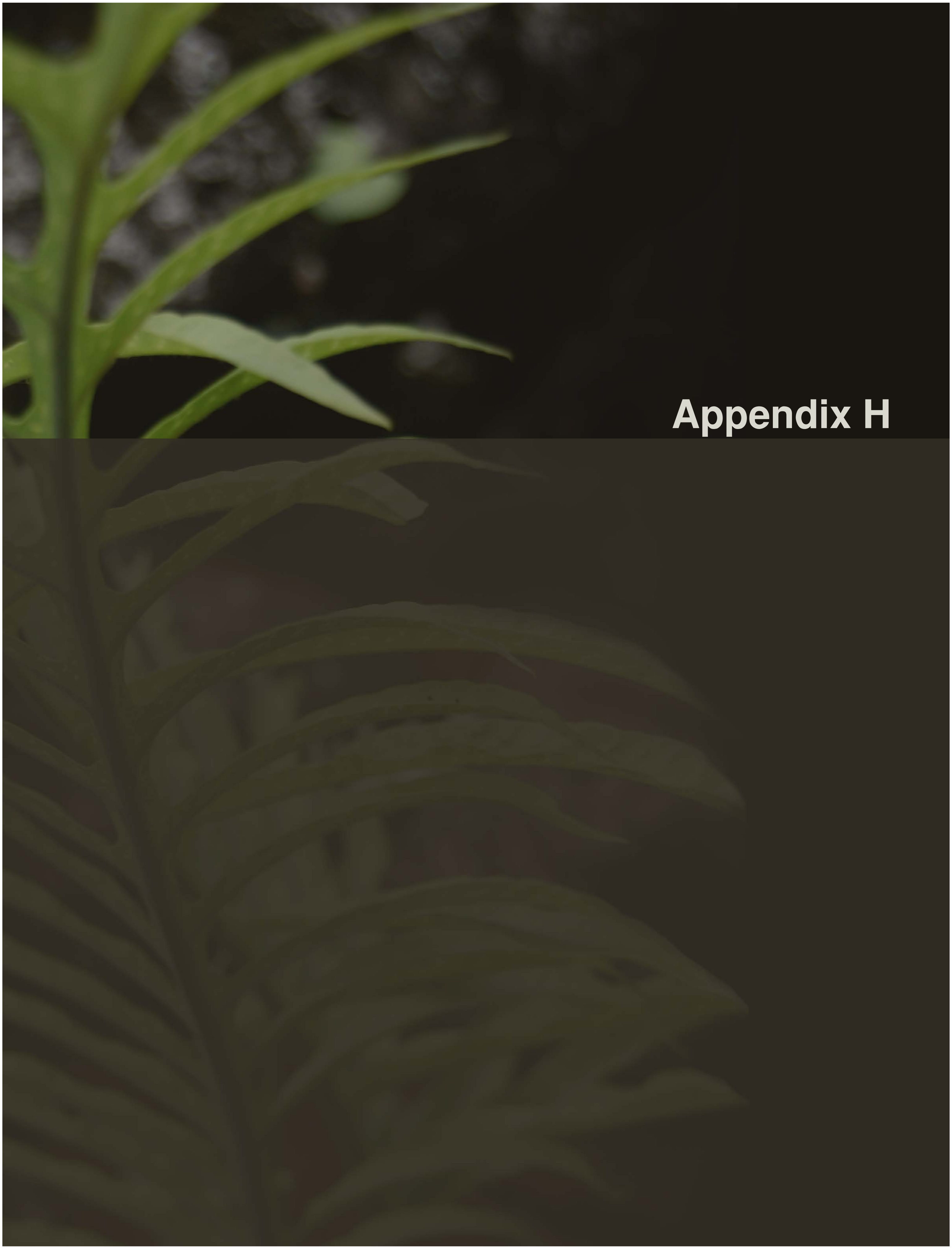
Remarks: Keaukaha soils have a 20 cm (8 in) organic layer consisting of very dark brown (10YR 2/2) muck, which overlays pahoehoe lava.

WETLAND DETERMINATION

	Yes	No
Hydrophytic Vegetation Present?	☐	☒
Wetland Hydrology Present?	☐	☒
Hydric Soils Present?	☒	☐

Is this Sampling Point Within a Wetland? Yes ☐ No ☒

Remarks:



Appendix H

Rockfall Hazard Assessment
Haena State Park
Kauai, Hawaii

Prepared for

State of Hawaii
Department of Land and Natural Resources
Division of State Parks
1151 Punchbowl Street, Room 310
Honolulu, Hawaii 96813

Prepared by

AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawaii 96813

June 2013

OVERVIEW

AECOM Technical Services, Inc. (AECOM) has prepared this rockfall assessment for the State property within Haena State Park along the mauka side of Kuhio Highway in accordance with Federal Highway Administration (FHWA) publications and construction industry standards. The purpose of the assessment is to evaluate rockfall potentials and hazards and to recommend rockfall mitigation methods best suited for this site. It is AECOM's opinion that it is impossible to speculate with great certainty as to when any of the rockfall areas referenced in this report could result in an actual rockfall event; however, it is possible to identify the areas that show a potential for rockfall hazard.

This rockfall study was performed in two consecutive phases: a) geological survey of the site and rockfall hazard identification, and b) engineering planning study of the rockfall condition and development of preliminary rockfall protection design alternatives and cost estimates. During the geological survey phase, areas with potential for rockfall or landslide were identified and site-specific descriptions were obtained. The geological conditions of the site and the key rockfall features are presented in a report format including color photographs. The engineering planning phase identifies engineering solutions in terms of alternative designs for reducing potentials of rockfall hazards. A preliminary construction cost estimate is provided for each alternative design. All work is based on the research data and the recommended procedures by FHWA, United States Department of Transportation, and the engineering and construction standards accepted by the industry.

Many rockfall features and many recent rockfall activities were found during field investigation. Some of the recent rockfalls occurred right next to and ended on the Kuhio Highway close to the Wet Cave (Wai a Kanaloa). The area around the Wet Cave (Wai a Kanaloa) is the most hazardous rockfall area because: 1) many rockfall features exist there; 2) very high probability for rockfalls to reach the roadway or Wet Cave (Wai a Kanaloa); and 3) almost constant presence of visitors in this area. The Wet Cave (Wai a Kanaloa) area is rated rockfall hazard Class A entailing a high hazard rating. Rockfalls are less likely to reach the roadway or beach at other places.

The annual probability of loss of life from rockfall along Kuhio Highway and the beach within Haena Park is estimated at 6.4×10^{-4}, higher than the recommended tolerable level of 10^{-5} for general public. Therefore rockfall mitigation is recommended for Haena Park to reduce rockfall risk to park users.

The recommended permanent engineering mitigation design alternative for Haena Park is a combination of rockfall impact fence and anchored wire mesh system due to its effectiveness, and least disturbance to environment, with a cost of 9.8 million dollars and a construction period of eight months.

For temporary rockfall mitigation design, scaling is recommended due to its ease of construction, least disturbance to environment, and cost-effectiveness in rockfall hazard reduction, with a cost of $750,000 and a construction period of four months to scale the high hazard area around the two Wet Caves and all the identified boulder sites in this report. An additional 1.5 million dollars and a construction period of six months are needed to scale other areas. Only rocks that are likely to reach the roadway or other protected structures need to be scaled.

However, it has been noted that the North Shore and Haena communities would not support any disturbance and potential devastation to the sacred mountains at Haena caused by rockfall mitigation and construction. Consequently, there are two other plans at work addressing the long term and short term concerns. The long term plan is to divert the public traffic away from the high rockfall zones. This would be accomplished by closing the highway to both vehicular and on-foot public travelers while redirecting them through walkways that are built in the safe rockfall zones. This is part of a master planning process that the State is currently working on with the public. For the short term mitigation solution and in the interim, AECOM has proposed demolition and stabilization of some of the larger rocks (a total of 4 to 6 rocks) along the base of the mountain near the areas of the Wet caves. This work will be implemented using basic tools such as rock scaling bars and airbags. Once these rocks are dislodged, they would be brought to rest in a stable location along the foothills. All dislodged rocks are planned to be left at the site. The cost of this effort has been estimated at about $400,000 and a construction period of about three weeks.

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Acronyms and Abbreviations

AGS	Australian Geomechanics Society
CRSP	Colorado Rockfall Simulation Program
FHWA	Federal Highway Administration
ft.	feet/foot
GPS	global positioning system
lf	linear feet
mph	miles per hour
RHRS	Rockfall Hazard Rating System
USDOT	United States Department of Transportation

Section 1.0

Introduction

1.0 INTRODUCTION

Faced with potential for rockfalls on the mauka side of Kuhio Highway at Haena State Park, the Department of Land and Natural Resources, State of Hawaii, tasked AECOM Technical Services, Inc. (AECOM) to perform a study of the present rockfall condition for the site (Figure 1-1). AECOM geotechnical engineers and geologists performed the field investigation using visual means and methods. Rockfall locations identified in this report are based on coordinates shown on a hand-held global positioning system (GPS) unit with +/- 30 ft accuracy under normal condition. These identified sites are representative samples of potentially hazardous rocks. Similar types of rocks may exist along the project site which were not identified and documented in this report. Topographic surveying and sub-surface investigation were not a part of the scope of this study. The specific conditions described in this report pertain to those present at the time of field investigation.

1.1 SCOPE OF SERVICES

The scope of services included the following tasks: (1) conduct field reconnaissance; (2) assess and delineate the falling rock hazards; (3) identify and articulate options to mitigate the potential hazard; (4) identify and articulate the risks associated with each option; (5) identify products required for each option; (6) identify locations (in Hawaii if applicable) where the options have been implemented; (7) provide budgetary cost estimates for work required under each option; and (8) identify experienced contractors qualified to perform the work.

1.2 IMPLEMENTATION PLAN

The project was implemented in two phases, as follows:

1. Geological survey of the site and rockfall hazard identification:

   AECOM performed a visual assessment of the geological formation and rock outcroppings along accessible areas of the mountain slope.

   A geological report was prepared to identify the key features of the site geology and to locate rock outcroppings including GPS readings and color photography. The study methodology is based on applying suitable methods recognized by the Federal Highway Administration (FHWA), United States Department of Transportation (USDOT), and the prevailing construction standards used in the industry.

2. Engineering planning study of the rockfall condition and development of preliminary rockfall protection design and cost estimates:

   The AECOM team performed an engineering study for identifying alternative mitigation procedures which ultimately led to prescribing of a recommended methodology based on accepted engineering practice and sound economics to reduce rockfall hazards.

   A budgetary cost estimate was provided for each design option.

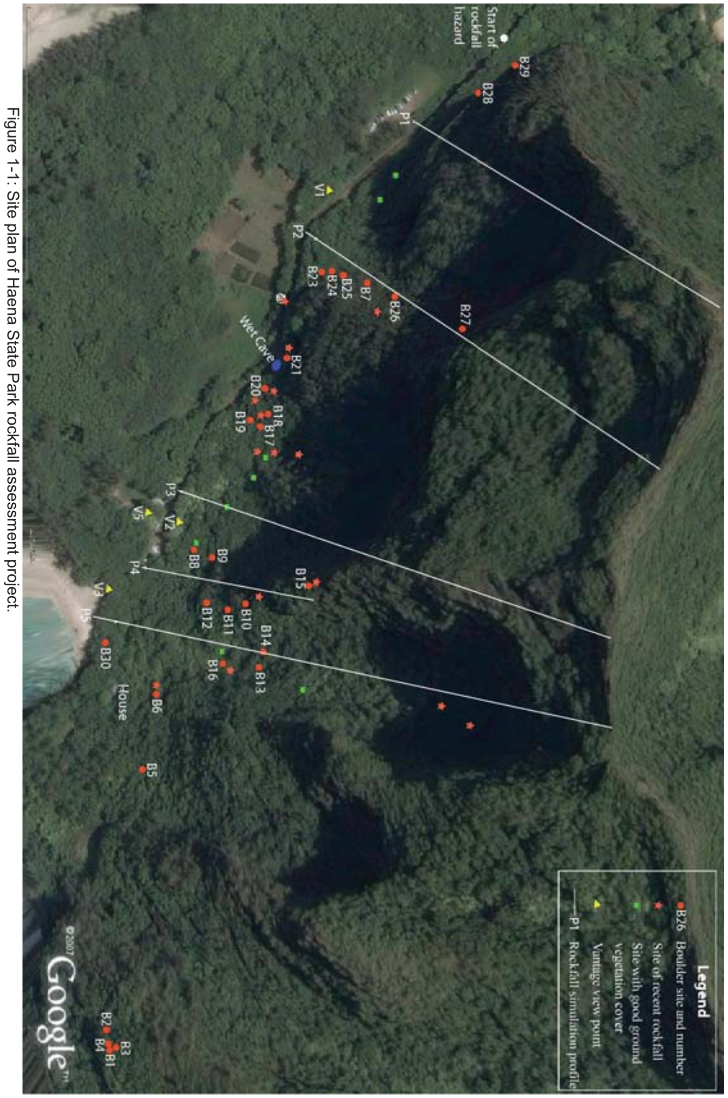


Figure 1-1: Site plan of Haena State Park rockfall assessment project.

Section 2.0

Geological Survey of the Site and Rockfall Hazard Identification

2.0 GEOLOGICAL SURVEY OF THE SITE AND ROCKFALL HAZARD IDENTIFICATION

2.1 Rock Formations–Foundation of Rockfall

Knowing local geology knowledge is essential to understanding the potential hazards of rockfall events and the associated mitigation methods.

The island of Kauai consists of a single shield volcano, which is deeply eroded and partly veneered with much later volcanics. The rock formation exposed at Haena State Park belongs to the Napali Formation (or Napali Member), the oldest exposed shield volcano formation above ocean water (Stearns 1985; MacDonald et al. 1983). Talus, formed by fallen rocks piled against the high cliffs, is another major rock formation exposed at the project site.

The Napali Formation consists of mainly basaltic lava flows with two morphology types: 'a'a and pahoehoe. 'A'a flows are formed by dense (low volatile content) and viscous lava. As the viscous lava flows, it constantly shears apart its top crust formed by cooling to produce the top rough and jagged clinkers. At the front of a'a flows, the top clinkers–carried along by the flowing lava like on a conveyor belt–tumble down and are buried by the advancing lava over them, forming the bottom clinkers. A typical 'a'a flow unit, therefore, consists of three layers: the top and bottom clinker layers and the middle interior. Vesicles in the middle interior are commonly stretched or of irregular shapes. Due to differential erosions–the fast erosion of the weak, very vesicular, and poorly cemented clinkers and the slow erosion of the dense interior, a'a interiors are often overhang and prone to rockfall.

Pahoehoe flows are formed by fluidal lava (low viscosity) with high volatile content. Consequently, pahoehoe flows commonly are thin characterized by smooth, billowy, hummocky, or ropy surfaces and contain large amount of spherical vesicles. Pahoehoe flows are essentially tunnel or tube lava flows: once crusted over on the surface due to cooling, the fluidal lava is less likely to shear apart its crust and thenceforth flows within a tunnel or tube of its own making. A main feeding channel or lava tube, usually thick, is typically associated with a pahoehoe flow unit.

2.2 Weathering and Erosion Processes–Cause of Rockfall

Weathering and erosion are chiefly responsible in creating rockfall.

Several natural mechanisms contribute to the alteration and breakdown of rocks. Mechanical weathering represents breaking up of rocks by physical disintegration without changing their chemical composition. Chemical weathering involves an alteration in chemical composition and the formation of new minerals. Examples of mechanical or physical weathering are stream and wave erosion, the wedging action of growing plant roots and stems, or the fragmentation of rock faces caused by enlargement of fractures due mainly to gravity. Clay minerals and hydrated iron oxides are typical products of chemical weathering. Due to high temperature and rainfall and abundant vegetation, conditions for chemical weathering are nearly optimum at the Haena State Park site.

Breaking up of the rock by mechanical weathering greatly aids chemical weathering because it increases the area of rock surface exposed to chemical action. Chemical weathering, in return, reinforces mechanical weathering. For example, chemical weathering normally increases the volume of weathered rocks as compared to the original volume of the unweathered rock, setting up stress between the outer more weathered and inner less weathered portions, and causing the rock to break apart. The mutual reinforcement of chemical and physical weathering effects is an ongoing process, the degree and rate of which will largely determine the stability of rock in the area.

'A'a flows are especially prone to boulder rockfall due to their differential erosion. The thick and dense interiors of 'a'a flows are relatively resistant to weathering due to their large thickness and low permeability (low porosity). The clinkers, on the other hand, are rapidly eroded away by both chemical and mechanical weathering. Consequently, overhangs of thick 'a'a interiors are seen almost at every 'a'a flow outcrop. These overhangs are unstable because: (1) the top and bottom supporting layers of the overhangs are poorly cemented and often deeply weathered clinkers; (2) the dense interiors have columnar joints formed naturally by the thermal contraction of lava during cooling; (3) overhangs exert extra stresses on vertical joints and fractures that may increase over time, enlarging the fracture and/or joint spaces. Because it is unlikely for the interior and the clinkers to have similar weathering rates, the only natural way to eliminate a'a interior overhangs is through rock falls or slides. Once dislodged, boulders of the dense interior could roll far due to their large potential energy (large size) and the focus of the energy (without breaking up into small pieces of rocks).

Massive pahoehoe flows (main feeding channels) embedded in thin pahoehoe flows behave similarly as 'a'a interiors. Massive pahoehoe flows are relatively resistant to weathering due to the lack of internal bedding, low permeability, and large thickness. Thin pahoehoe flows, on the other hand, are prone to weathering due to their thin bedding and large amount of vesicles. The piling style of thin pahoehoe in which small oval toes stacked together with little welding-in-between creates adverse geologic structure. Although thin pahoehoe layers themselves are much less prone to boulder rockfall as they easily splinter into small and often flat pieces, their fast differential erosion, however, leads to the overhang of their main feeding channel that could create spectacular rockfall events.

Both a'a and pahoehoe flows are subject to jointing and fracturing where focused weathering occurs. Fracturing and jointing in basalt flows are most commonly initiated as contraction cracks during cooling of lavas. Joints and fractures are enlarged by weathering and gravitational stresses.

Spheroidal weathering is a common form of weathering in which concentric shells of progressively weathered material form around a core of less weathered basalt. Because edges and corners of fractured basalt are exposed to weathering through two or more surfaces, the increased weathering there results in rounding of blocks. Spheroidal weathering produces spherical rocks that could roll easily on a slope.

Over-steepened talus slopes consisting of soil and boulders are prone to rockfall. Rainfalls induce the erosion of soil materials, leaving behind loose and overhanging boulders. During exceptionally heavy rains when the quantity and speed of surface runoff reach certain limits under which the cohesion and gravity of the soil material can be overcome, great quantities of material can be eroded away in relatively a short period of time.

2.3 PRECIPITATION–TIMING OF ROCKFALL

Water does not only promote weathering but also a determinant factor in the timing of rockfall events. Due to hydraulic pressure and erosion, rockfall events tend to occur more frequently during or after heavy rains in Hawaii.

The average yearly rainfall for Haena State Park is quite high at about 122 inches per year according to data at rainfall station PH Wainiha 1115 about 1.7 miles away with similar elevation. The precipitation data were taken from the Hawaii State Climate Office at website: http://lumahai.soest.hawaii.edu/Hsco/ppt.htm. The weather station information was taken from the National Climatic Data Center at website: http://www.ncdc.noaa.gov/oa/climate/-surfaceinventories.html#A.

2.4 ROCKFALL HAZARD RATING SYSTEM

A rockfall mitigation procedure begins with an understanding of the structural geology and relative orientation of the discontinuities of a slope, the water run-off condition, and the site geometry. To assess potential rockfall hazards, the FHWA and the DOT have sponsored extensive research to develop a series of rockfall mitigation methods and a systematic procedure for rating rockfall

conditions. The results of this research were presented in a series of publications and guidelines *Rockfall Hazard Mitigation Methods* (Publication No. FHWA SA-93-085, March 1994) and *Rockfall Hazard Rating System* (Publication No. FHWA SA-93-057, November 1993). These manuals introduce a multitude of up-to-date techniques and materials to mitigate each condition, hence providing a sense of uniformity during assessment, design, and maintenance. The basic concept behind the DOT/FHWA Rockfall Hazard Rating System is summarized below.

Rockfall rating groups the hazard conditions into three classes, as described below:

- Class A — High estimated potential for rockfall on adjacent property(ies) with high historical rockfall activity. A Class A rating means that the chances of rock falling in a site is moderate to high, and that when the rockfall occurs, it will certainly reach adjacent property(ies). An example of a Class A condition is where rocks on the cut slope overhang the adjacent property(ies) and in areas, between the rockfall property and adjacent property(ies), where little or no rock catchment ditch is present.
- Class B —Moderate estimated potential for a rock to fall on adjacent property(ies) with moderate historical rockfall activity. As the rockfall risk is reduced, a Class B rating indicates that although a rockfall is probable, the chances of it reaching the adjacent properties are low to moderate. A possible scenario for Class B is a condition where a rockfall from the slope is clearly possible, and the catchment ditch is large enough to prevent most of the rocks from reaching the adjacent property(ies).
- Class C — Low estimated potential for rockfall on adjacent property(ies) with low historical rockfall activity. Class C rating pertains to a condition in which there is a low chance for a rockfall event, but should one occur, there is low to no chance for the rocks to reach other properties.

To evaluate a rockfall condition for a given property, certain criteria must be evaluated. These criteria are identified below:

- Slope height
- Ditch or catchment effectiveness
- Structural condition, Case One slopes (movement along discontinuities)
- Rock friction
- Structural condition, Case Two slopes (differential erosion or oversteepening leads to rockfall)
- Difference in erosion rates
- Volume of rockfall event
- Climate and the presence of water on slope
- Rockfall history
- Slope topography

Slope Height evaluates the risk associated with the vertical height of a slope. Slope height represents the highest elevation from which a rock could roll down the slope. This value is reasonably estimated from existing topographic maps, through use of a GPS unit, or from trigonometric relationships. High slopes are associated with high rockfall hazard because they have more materials available for rockfall and higher potential energy for rock acceleration. A larger rockfall potential energy is associated with an increased hazard.

The slopes at Haena State Park are high, at places over 1000 ft.

Ditch Effectiveness estimates the effectiveness of a catchment ditch or zone in restricting falling rocks from reaching adjacent property(ies). The risk related to a rockfall situation varies based on how effectively a catchment ditch or zone can avert the rocks from reaching the adjacent property(ies). The risk of rocks reaching other property(ies) is lower where a good catchment is in place, regardless of the volume of rock that has fallen. Conversely, the risk heightens where there is limited or no catchment available to stop the falling rocks.

Rockfall catchment varies along the project site. Portions of the mauka side of the Kuhio Highway at Haena State Park have relatively wide flat area with dense trees, providing almost adequate rockfall catchment. Other portions, however, have narrow or no flat areas, providing little rockfall catchment.

Structural Condition. For the purpose of the rockfall assessment, the geologic conditions of slopes are evaluated based on two distinct cases. Where both rockfall cases are present, the condition that is more severe should be considered.

Case 1. Structural Condition represents slopes for which discontinuities, bedding planes, and joints are the dominant features. Movement within the discontinuities of the slope is the major cause of rockfall for the Case 1 category. "Movement occurs along these joints where the resistance to movement is significantly less than the intact strength of the rock itself. When the joints are oriented adversely to the slope, the potential for rockfall is greater. Adverse joints are those that singularly or in combination with other joints make planar, circular, block, wedge or topping failures kinematically possible" (Pierson and van Vickle 1993, p. 49).

Rockfall movement along structural joints is controlled by the roughness of the joint planes. The degree of roughness ranges from rough and irregular to slickensided. "Friction along a joint, bedding plane, or other discontinuity is governed by the macro and micro roughness of surfaces. Macro roughness is the degree of undulation of the joint relative to the direction of possible movement. Micro roughness is the texture of the surface. On slopes where the joints contain hydrothermally altered or weathered material, movement has occurred causing slickensides or fault gouge to form, or the joints are open or filled with water, the rockfall potential is greater" (Pierson and van Vickle 1993, p. 52).

Case 2. This case represents slope conditions in which differentially eroded rock units and over-steepened slopes are dominant features. Over-steepening of slopes and unsupported rock overhangs increase the risk of rockfall. As described in the RHRS manual, "Rockfall is commonly caused by erosion that leads to a loss of support either locally or throughout a slope. The types of slopes that may be susceptible to this condition are layered units containing more easily erodible units that undermine more durable rock; talus slopes; highly variable units, such as conglomerates, and mudflows, that weather differentially, allowing resistant rocks and blocks to fall; and rock/soil slopes that weather allowing rocks to fall as the soil matrix material is eroded" (Pierson and van Vickle 1993, p. 55).

Where the slope is composed of different rock/soil materials, which exhibit significant differences in composition and characteristics, the rate of erosion may vary within different layers and zones. Progress of soil erosion under these conditions could result in loss of support of portions of the slope, increasing the risk for rockfall.

Block Size or Volume of Rockfall Event is evaluated based on individual blocks of rock or a volume of rocks of various sizes. "Larger blocks or volumes of falling rock produce more total kinetic energy and greater impact force than smaller events… the larger the blocks or volume the greater the hazard created…" (Pierson and van Vickle 1993, p.62).

During field investigations, both large and small boulders were identified within this property posing potential hazard.

Climate and Presence of Water on Slope. This category evaluates the effects of climate including precipitation, and the presence of water on the slope surface. "Water … contributes to the weathering and movement of rock materials and a reduction in overall slope stability. This category evaluates the amounts of precipitation …" (Pierson and van Vickle 1993, p. 65).

Generally a rainfall of 122 inches per year at the site is considered high.

Rockfall History at a site is an important indicator of future rockfall activities. Sites with a history of frequent rockfall are more likely to experience future rockfall events. The magnitude of historical rockfalls is also an indicator of future rockfall behavior at a site.

During site investigation, recent rockfall activities were apparent, some of them occurred right adjacent to Kuhio Highway.

Based on the above rating criteria, the rockfall section at the mauka side of Kuhio Highway at Haena State Park consists of both Class A and Class B rockfall ratings.

2.5 ROCKFALL COMPUTER SIMULATION

Rockfall is initiated by unbalanced forces as a result of gravity, weathering, erosion, excavation, fracture development, hydraulic pressure, plant or ice wedging, seismic or blasting vibration, or impact by moving objects. After initiation, the fate of rockfall depends on initial momentum, elevation, steepness and roughness of slope, slope material, and the shape and size of the falling rocks. The elevation and size determine potential energy and the shape, slope, and slope material determine the potential acceleration of rockfall.

The Colorado Rockfall Simulation Program (CRSP) version 4.0 (Jones et al. 2000), jointly developed by Colorado School of Mines, Colorado Department of Transportation, and Colorado Geological Survey, simulates rocks tumbling down a slope. The program is based on mathematical models, probability factors, and many rockfall experiments. CRSP can predict the statistical distribution of speed and bouncing height and is a guide and reference for recommending and designing rockfall mitigation. The model takes into account slope profile, rebound and friction characteristics of the slope, and rotational energy of the rocks. The program, together with its values for normal coefficient of restitution (R_n) and the tangential coefficient of frictional resistance (R_t), has been calibrated by many rockfall events here in Kauai. The model is one of the most widely used and is the recommended tool for the geologist and engineer in analyzing and mitigating rockfall hazards.

CRSP simulations are used to approximate the bouncing height, velocity, kinetic energy, and traveling distance of possible rockfalls. The simulation profiles (cross sections) are based on field measurements taken during investigation. The shape of each boulder is assumed spherical with a 4-foot (ft.) diameter, similar to the large boulders found on the slope. Because CRSP does not include the effect of trees, slope roughness was increased to simulate the effect of tree trunks in stopping falling rocks as dense trees exist at the project site. For each assumed slope profile and boulder, the program mathematically rolls the same boulder down the same slope profile one thousand times and each time it mathematically produces a new slope roughness resulting in a new traveled path by that boulder. It would then issue a percentage for the number of times the hypothetical boulder reaches the end of the run and the jumping height and speed of the boulder at each location of the profile.

Rockfall simulations were performed for five slope profiles on the mauka side of Kuhio Highways at Haena State Park (Figure 1-1). Due to the high elevation and difficulty in access, the top slope profiles were obtained from Google Earth Pro. The bottom of the slope profiles were measured using a measuring tape and a clinometer.

Figure 2-1 shows the simulation results for profile P1 from the gate of the secondary parking lot to the mountain peak (Figure 1-1). A high rock cliff is about 140 feet away from the paved road of Kuhio

Highway, and a relatively flat catchment area exists between the cliff and the road (Figure 1-1 and Figure 2-1). Based on results of this mathematical simulation, about 3% rockfalls reach the road, with a maximum bouncing height of 0.4 foot at the road position (See Appendix A for detailed simulation information). This rockfall section represented by profile P1 would entail Class B rockfall rating.

Figure 2-2 shows the simulation results for profile P2. Unlike profile P1, profile P2 has a long and steep talus slope leading to a high rock cliff (Figure 1-1 and Figure 2-1). About 63% of simulated rockfalls originated from the top of the mountain are anticipated to reach the road, with a maximum bouncing height of 9 feet at the road position (See Appendix A for detailed simulation information). This rockfall section represented by profile P2 would entail Class A rockfall rating.

Figure 2-3 shows the simulation results for profile P3 at the start of the beaching parking lot (Figure 1-1). Profile P3 has a relatively flat catchment area and a steep talus slope before a high rock cliff (Figure 1-1 and Figure 2-3). About 4% of simulated rockfalls originated from the top of the mountain are anticipated to reach the road, with a maximum bouncing height of 1.6 feet at the road position (See Appendix A for detailed simulation information). This rockfall section represented by profile P3 would entail Class B rockfall rating.

The Wet Cave (Wai a Kanaloa) exists between profiles P2 and P3, in between locations of boulders B21 and B20 shown in Figure 1-1. Here high rock cliff is right next to the paved road. Most, if not all, rockfalls would reach the road. This rockfall section including the Wet Cave (Wai a Kanaloa) is considered Class A rockfall rating.

Figure 2-4 shows the simulation results for profile P4 at the start of the Kalalau trail (Figure 1-1). Profile P4 has a relatively flat catchment area and then a short steep talus slope before a ridge (Figure 1-1 and Figure 2-4). About 0.5% of simulated rockfalls originated from the top of the mountain reach the road, with little or no bouncing at the road position (See Appendix A for detailed simulation information). This rockfall section represented by profile P4 would entail Class B rockfall rating.

Figure 2-5 shows the simulation results for profile P5 starting from the most populated beach area (Figure 1-1). Profile P5 has some relatively flat catchment areas and a long talus slope before a high ridge (Figure 1-1 and Figure 2-5). Profile P5 crosses the Kalalau trail which helps to stop falling rocks due to its depression formed by erosion along the trail. No simulated rockfalls originated from the top of the mountain would reach the beach area (See Appendix A for detailed simulation information). Rockfalls started from the steep slope right next to the beach, however, could reach the beach area. This rockfall section represented by profile P5 would entail Class B rockfall rating.

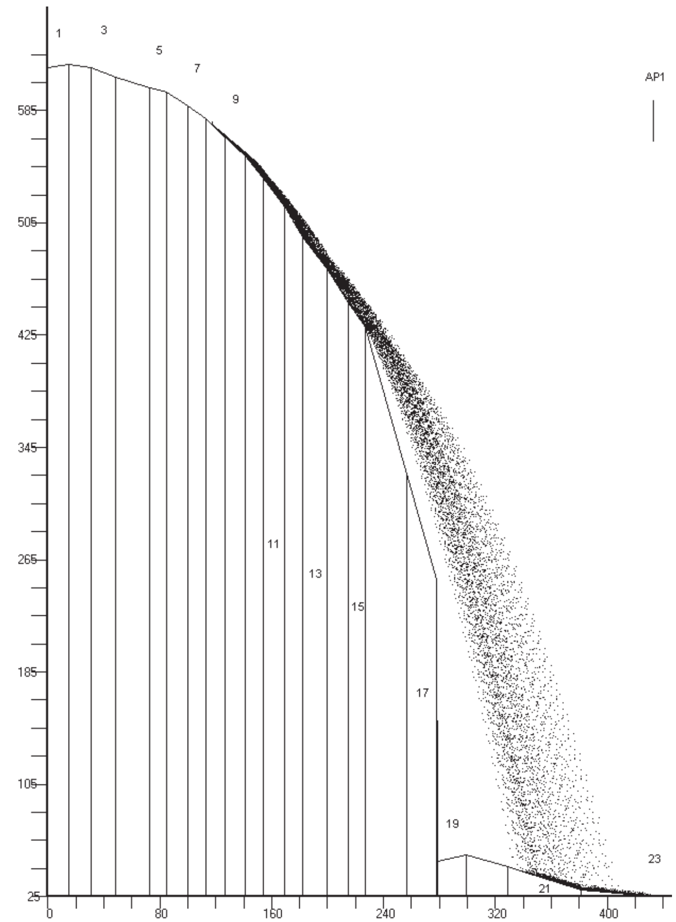


Figure 2-1: Rockfall simulation results for profile P1.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1 is analysis points at road position. The numbers (1, 3, 5, …, 23) are slope section references. Upper slope profile was obtained from Google Earth Pro and lower slope profile was measured. About 3% rockfalls reach the road, with a maximum bouncing height of 0.4 foot. See Appendix A for detailed simulation information.

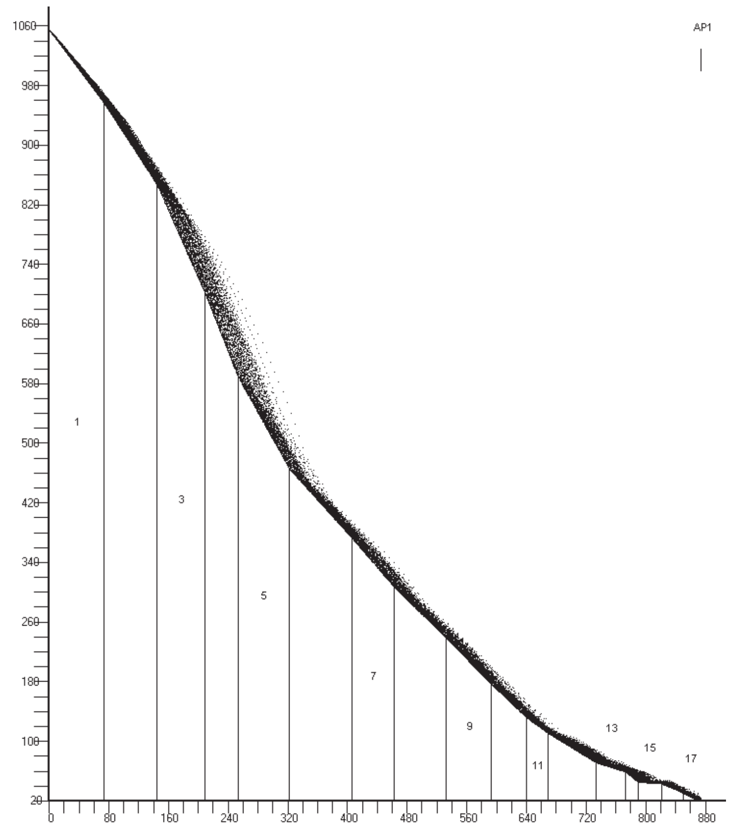


Figure 2-2: Rockfall simulation results for profile P2.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1 is analysis points at road position. The numbers (1, 3, 5, …, 17) are slope section references. Upper slope profile was obtained from Google Earth Pro and lower slope profile was measured. About 63% rockfalls reach the road, with maximum bouncing height of 9 feet. See Appendix A for detailed simulation information.

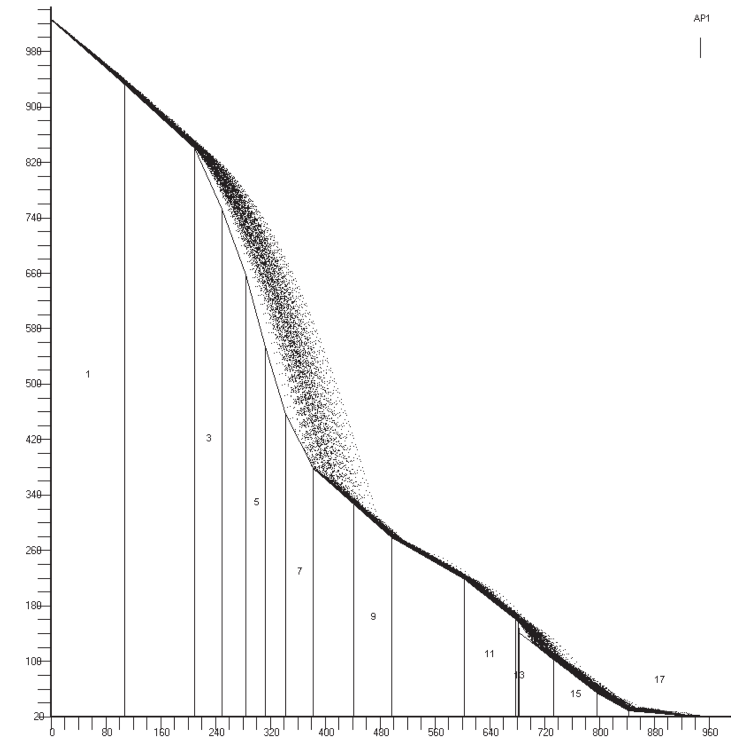


Figure 2-3: Rockfall simulation results for profile P3.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1 is analysis points at road position. The numbers (1, 3, 5, …, 17) are slope section references. Upper slope profile was obtained from Google Earth Pro and lower slope profile was measured. About 4% rockfalls reach the road, with maximum bouncing height of 1.6 feet. See Appendix A for detailed simulation information.

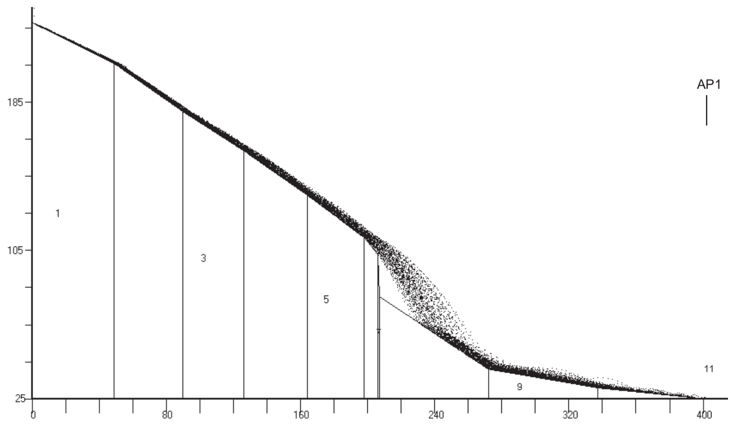


Figure 2-4: Rockfall simulation results for profile P4.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1 is analysis points at road position. The numbers (1, 3, 5, …, 11) are slope section references. Upper slope profile was obtained from Google Earth Pro and lower slope profile was measured. About 0.5% rockfalls reach the road, with maximum bouncing height of 0.0 foot. See Appendix A for detailed simulation information.

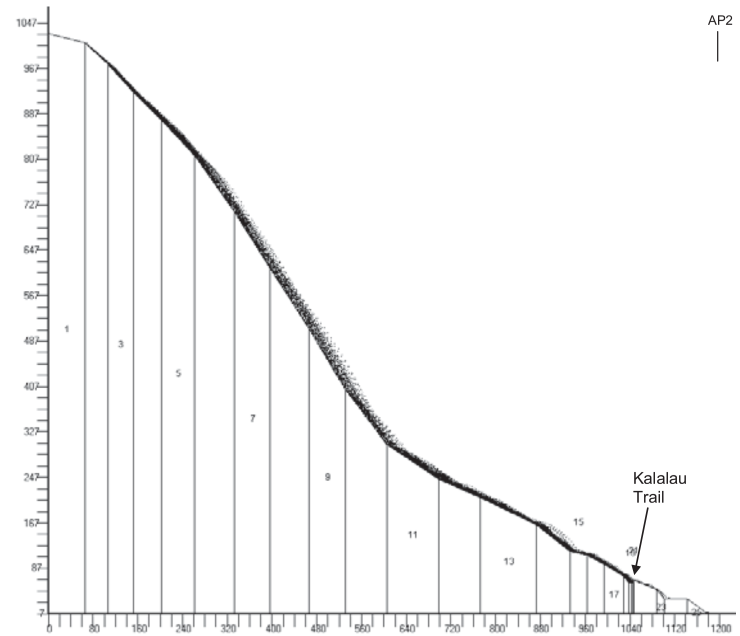


Figure 2-5: Rockfall simulation results for profile P5.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP2 is analysis point at beach positions, respectively. The numbers (1, 3, 5, …, 25) are slope section references. Upper slope profile was obtained from Google Earth Pro and lower slope profile was measured. No simulated rockfalls reach the beach position. See Appendix A for detailed simulation information.

2.6 Rockfall Sites and Potential Rockfall Hazards at Haena State Park

Due to the time-consuming nature of rappelling and safety issues regarding high mountains and the requirement of this planning study, the high cliffs and high ridge tops were only observed from a distance where they could be viewed from nearby vantage points.

Three factors determine the hazard level of potential rockfall outcrops: how likely they are going to fall (chance of rockfall); once they fall, how likely they are going to hit the target to be protected (chance of hitting target); and how large their size or volume (rockfall size or volume) would be.

For chance of rockfall, the following four categories are considered:

Category 1: Imminent potential for rockfall (could fall anytime). There are no visible signs of competent support and the rocks could fall any time. Observed rock characteristics include but not limited to: 1) loose boulders or completely separated rocks lacking toe and interlocking support and sitting on planes dipping out of slope with dipping angles significantly greater than friction angles; 2) rounded loose boulders sitting on steep soil slope with little embedment and weakened soil support that is subjected to great potential for further erosion; 3) overhang with opened release joints without observed competent interlocking; 4) loose boulders or fractured rocks sitting in a position that is at or very close to toppling or losing balance; 5) failing key supporting stones.

Category 2: Short term potential for rockfall. There are visible signs of support that will diminish relatively quickly with time (within several to a dozen years. Time scale is used symbolically and should not be understood or interpreted as actual time length) but nonetheless most likely prevents immediate rockfall at present. Loose boulders or fractured rocks have short term rockfall potential when having one or more of the following characters: 1) supported by soil or mixture with soil that is being subjected to rapid erosion; 2) supported by old, dying, or dead vegetation; 3) supported by interlocking that is unlocking due to continuously opening fractures; 4) weakening key supporting stones that show signs of stress like sliding and fracturing; 5) in the process of making small-scale adjustments through local rotating or sliding towards a position of eventual rockfall.

Category 3: Medium term potential for rockfall. There are visible signs of stable support that prevent rockfall at present and diminish within medium length of time period (within dozens of years). The boulders or rock outcrops are currently in a stable position but are working their way to eventual rockfall due to stress, erosion, weathering, root wedging, hydraulic pressure, and other de-stabilizing forces.

Category 4: Long term potential for rockfall. There are visible signs of solid support that will diminish within a long period of time (up to or more than a hundred years). De-stabilizing forces will take many years to develop new rockfall features.

Categories in between the above four categories are also used. For example, Category 1.5 simply indicates the chance of rockfall is between Category 1 and Category 2.

Representative rock outcrops, their sizes, locations, and categories are listed in Table 2-1 and their relative locations are plotted in Figure 1-1.

Photo 2-1 shows round boulder on steep slope at B1. Photo 2-2 shows highly fractured and weathered steep slope with many loose rocks at B3, with a recent rockfall source. Photo 2-3 shows an overhanging and standing boulder with large opened back fracture at B4. Photo 2-4 shows a completely overhanging boulder with steep back fracture dipping out of slope at B5. Photo 2-5 shows loose boulders on talus slope at B7. Photo 2-6 shows root wedging that enlarged fractures at B12. Photo 2-7 shows a recent fallen boulder at B14. Photo 2-8 shows recent fallen boulders with fresh impact marks on the trees. Photo 2-9 shows old impact marks on a tree and stopped boulders. Photo 2-10 shows a rock perched on tree branches at B17. Photo 2-11 shows a recent rockfall boulder, with fresh impact marks and tree barks on it, on steep slope with potential for further fall at B18. Photo 2-12 shows an overhanging boulder partly supported by rotten tree roots at B19. Photo 2-13 shows an overhang loose boulder on steep slope at B19. Photo 2-14 shows a loose boulder on steep slope at B20 above Kuhio Highway. Photo 2-15 shows rocks stopped by a tree just above Kuhio Highway at B21. Photo 2-16 shows recent rockfall boulders and fresh impact marks on trees at B21. Photo 2-17 shows recent rockfall boulders perched on tree roots and fresh impact marks on trees at B21. Photo 2-18 shows the source of the recent rockfall at B21. Photo 2-19 shows an overhanging fractured rock with potential for wedge failure at B21. Photo 2-20 shows fractured and overhanging rocks at B21. Photo 2-21 shows an opened columnar joint of a dike at B21. Photo 2-22 shows a major fracture separating a small ridge from the main rock slope at B21. Photo 2-23 shows overhanging and fractured rocks at B23. Photo 2-24 shows a protruding rock sitting on a steep fracture dipping out of slope at B25. Photo 2-25 shows an overhanging loose rock sitting on top of a ledge at B26. Photo 2-26 shows overhanging loose boulders on a steep talus slope just above a very popular beach area at B30. Photo 2-27. Overhanging loose boulders on a steep talus slope at B30.

Photo 2-28 shows an overhanging fractured rock on a high cliff face (photo taken from vantage point V1). Photo 2-29 shows an overhanging and fractured block on top of a high cliff face (photo taken from vantage point V2). Photo 2-30 shows a major fracture separating a large block on a high rock cliff (photo taken from vantage point V2). The block dropped a little distance as indicated by the shifts of major layers across the fracture. Photo 2-31 shows a recent rockfall source and a large overhanging rock with back fractures (photo taken from vantage point V2). Photo 2-32 shows an overhanging portion of a high cliff (photo taken from vantage point V3). Photo 2-33 shows loose boulders perched on a steep ridge (photo taken from vantage point V1). Photo 2-34 shows an overhanging large bolder on the very top of a high slope (photo taken from vantage point V5). Photo 2-35 shows the thick lava flow layer on the very top of the high slopes (photo taken from vantage point V5).

Table 2-1: Representative Identified Potential Rockfall Outcrops at Haena State Park, Kauai.

Location	Category	Size	Number of rocks	Latitude (°)	Longitude (°)
B1	1.5	4 x 3 x 2.6	1	22.21842	-159.58562
B2	2.5	25 x 22 x 15	1	22.21852	-159.58552
B3	2.5	3 x 2 x 1.7	1	22.21840	-159.58553
B4	1.5	8 x 8 x 6	1	22.21845	-159.58558
B5	1	7 x 7 x 3.7	1	22.21943	-159.58398
B6	3	2 x 1 x 0.5	1	22.21970	-159.58347
B7	2.5	4.2 x 3 x 3	1	22.22028	-159.57973
B8	3	4 x 4 x 3.5	2	22.22015	-159.58233
B9	3	3.5 x 2.2 x 1.8	1	22.21998	-159.58228
B10	2.5	3 x 1.2 x 4	2	22.21955	-159.58238
B11	3	2.5 x 1.8 x 3.8	1	22.21963	-159.58252
B12	2	1.5 x 1.2 x 2	1	22.21980	-159.58258
	2.5	3.5 x 3 x 3	1		
B13	2.5	3 x 3.8 x 3	2	22.21918	-159.58270
B14	2	6 x 7 x 3.5	1	22.21923	-159.58258
B15	3	3 x 1.8 x 4	1	22.21925	-159.58195
B16	3	3.3 x 1.8 x 1.7	1	22.21942	-159.58287
B17	2	2 x 1.2 x 1.2	1	22.22030	-159.58118
B18	2	2.5 x 1.9 x 1.2	1	22.22032	-159.58107
	2	2 x 3 x 1.8	2		
	3	8 x 11 x 8	1		
B19	2.5	3 x 5 x 7	1	22.22040	-159.58118
B20	2	2 x 2 x 2	2	22.22047	-159.58090
B21	2	6 x 8 x 3	1	22.22047	-159.58058
	2.5	2 x 1.7 x 2	2		
	3	30 x 60 x 20	1		
B23	1.5	5 x 5 x 2	1	22.22067	-159.57982
B24	2	4 x 3.8 x 3.7	1	22.22060	-159.57977
B25	2	3 x 12 x 10	1	22.22050	-159.57975
B26	2	1.7 x 0.8 x 2	1	22.22002	-159.57975
B27	2.5	2.5 x 1.4 x 1.4	1	22.21942	-159.57990
B28	3	3 x 1.5 x 1	1	22.22035	-159.57825
B29	1.5	2 x 3 x 1	2	22.22027	-159.57790
B30	1	2 x 1.8 x 2	3	22.22028	-159.58343

Note: Size is length × height × depth; Latitude and Longitude are in NAD 83.

2.7 ROCKFALL RISK ESTIMATION FOR THE HAENA STATE PARK SITE

The risk estimation of rockfalls and landslides involves the integration of their frequency and consequences. Because the United States has yet to develop a guideline for rockfall and landslide risk management, the guideline developed by the Australian Geomechanics Society (AGS) that has been used by many countries is used as a reference (AGS 2000).

For loss of life, the risk can be calculated from:

$$R_{(DI)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where $R_{(DI)}$ is the risk (annual probability of loss of life (death)); $P_{(H)}$ is the annual probability of the hazardous events (the landslides or rockfalls); $P_{(S:H)}$ is the probability of spatial impact by the hazard (e.g. probability of landslides impacting structures (locations) taking into account travel distance); $P_{(T:S)}$ is the temporal probability (e.g. probability of the structure being occupied); $V_{(D:T)}$ is the vulnerability (probability of loss of life of individuals given the impacts).

For existing slopes, the suggested tolerable risk for loss of life is 10^{-4} for persons most at risk and 10^{-5} for average persons; for new slopes, the suggested tolerable risk for loss of life is 10^{-5} for persons most at risk and 10^{-6} for average persons (AGS 2000).

For property, the risk can be calculated from:

$$R_{(Prop)} = P_{(H)} \times P_{(S:H)} \times V_{(Prop:S)} \times E$$

Where $R_{(Prop)}$ is the risk (annual loss of property value); $P_{(H)}$ is the annual probability of the hazardous event; $P_{(S:H)}$ is the probability of spatial impact by the hazard (i.e. of the landslide impacting the property, taking into account the travel distance) and for vehicles, for example, the temporal probability; $V_{(Prop:S)}$ is the vulnerability of the property to the spatial impact (proportion of property value lost); E is the element at risk (e.g. the value or net present value of the property).

A full risk analysis involves consideration of all landslide and rockfall hazards for the site and all the elements at risk. Unless extensive geotechnical testing and observations over a very long period are available, this risk calculation depends heavily on the estimator's experience and availability of data and is meant only as a first order approximation.

To estimate the rockfall risk or annual loss of life, we use $P_{(H)} = 0.5$ (one major rockfall every two years along the 3050 ft long rockfall section); $P_{(S:H)}$ = 14% * 15 ft. / 3050 = 0.00069, namely 14% rockfalls reach or pass the road (average of the five rockfall simulation profiles) and each rockfall impacts 15 ft width (car length) of the 3050 ft width; $P_{(T:S)}$ = 3050 ft / 5280 ft per mile / 15 mph / 24 hour * 1550 vehicle per day * 2.5 persons each vehicle = 6.22, and $V_{(D:T)} = 0.3$ as vehicles are likely not to be buried by a rockfall (AGS 2000). Therefore the annual probability of loss of life at this site of the road is 0.5 * 0.00069 * 6.22 * 0.3 = 6.4×10^{-4}, higher than the recommended tolerable level of 10^{-5} for general public. Rockfall mitigation is recommended for Haena State Park to reduce rockfall risk to park users. If the park is limited to 900 visitors per day with the visitors walking on the highway along the rockfall section (from the main parking to the beach), we have $P_{(T:S)}$ = 3050 ft / 5280 ft per mile / 2.5 mph / 24 hour * 900 = 8.66 (assuming walking speed at 2.5 mph) and $V_{(D:T)} = 0.35$ (increased fatality without the protection from vehicles), and the annual probability of loss of life at this site is 0.5 * 0.00069 * 8.66 * 0.35 = 1.0×10^{-3}. Calculated rockfall risk would increase significantly if visitors spend time at the two wet caves.

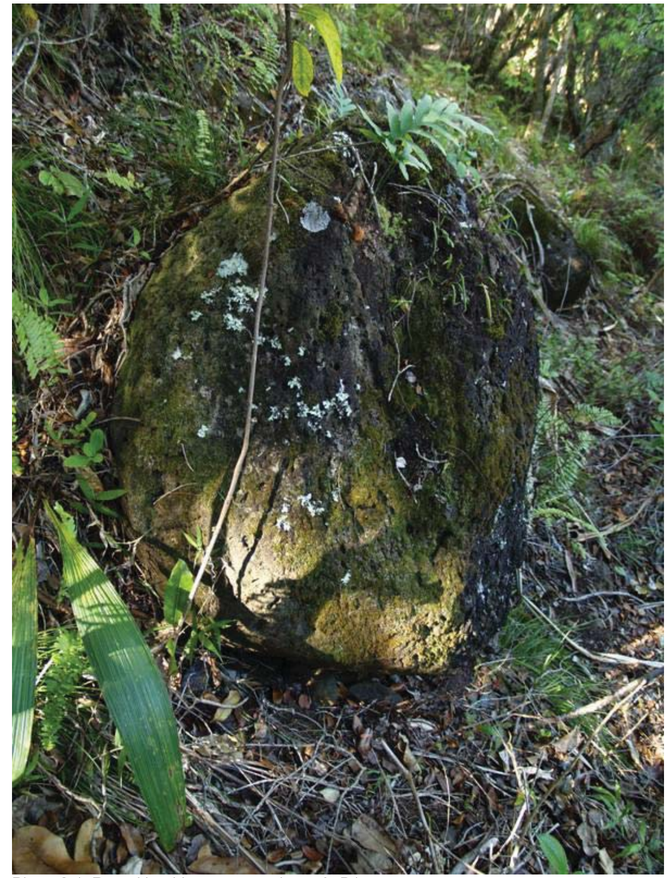


Photo 2-1. Round boulder on steep slope. At B1.

Photo 2-2. Highly fractured and weathered steep slope with many loose rocks. At B3. The foreground is a recent rockfall source.

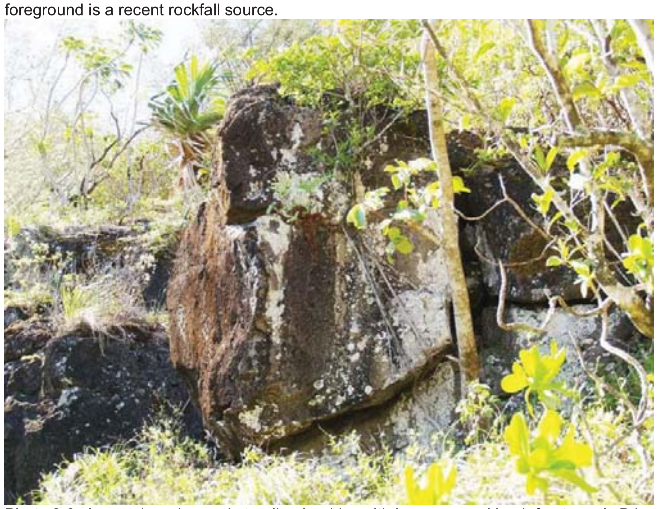


Photo 2-3. An overhanging and standing boulder with large opened back fracture. At B4.

Photo 2-4. A completely overhanging boulder with steep back fracture dipping out of slope. At B5.

Photo 2-5. Loose boulders on talus slope. At B7.

Photo 2-6. Root wedging enlarged fractures. At B12.

Photo 2-7. A recent fallen boulder. At B14.

Photo 2-8. Recent fallen boulders. Notice the fresh impact marks on the trees.

Photo 2-9. Old impact marks on the tree and stopped boulders.

Photo 2-10. A rock perched on tree branches. At B17.

Photo 2-11. A recent rockfall boulder on steep slope with potential for further fall. Notice the fresh impact marks and tree barks on the boulder. At B18.

Photo 2-12. An overhanging boulder partly supported by rotten tree roots. At B19.

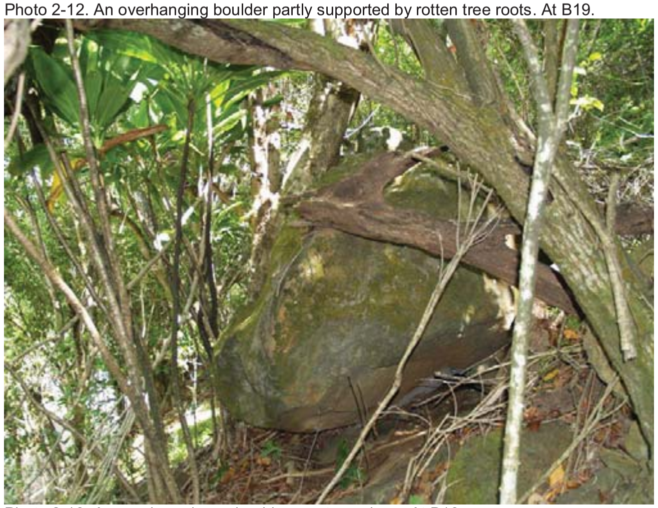


Photo 2-13. An overhang loose boulder on steep slope. At B19.

Photo 2-14. A loose boulder on steep slope. Notice Kuhio Highway down below. At B20.

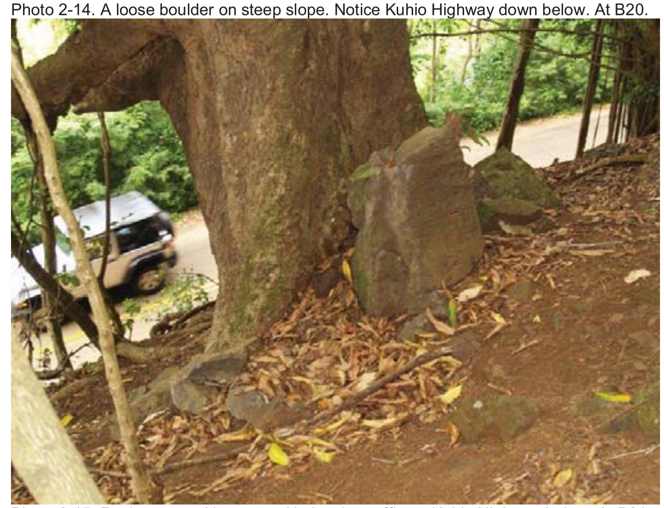


Photo 2-15. Rocks stopped by a tree. Notice the traffic on Kuhio Highway below. At B21.

Photo 2-16. Recent rockfall boulders and fresh impact marks on trees (pointed by the arrows). Notice Kuhio Highway below. At B21.

Photo 2-17. Recent rockfall boulders perched on tree roots and fresh impact marks on trees (pointed by the arrows). Notice Kuhio Highway below. At B21.

Photo 2-18. The source (pointed by the arrow) of the recent rockfall. At B21.

Photo 2-19. An overhanging fractured rock (pointed by the arrow) with potential for wedge failure. Notice fractured rocks on the cliff face at left of the photo. At B21.

Photo 2-20. Fractured and overhanging rocks. At B21.

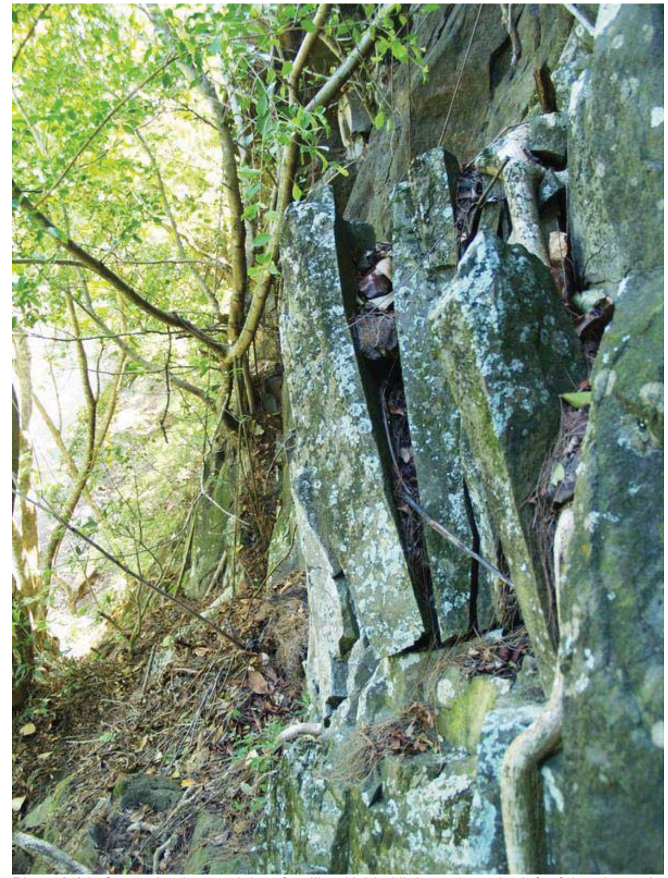


Photo 2-21. Opened columnar joint of a dike. Kuhio Highway is at the left of the photo. At B21.

Photo 2-22. A major fracture (pointed by the arrows) separates a small ridge (left of photo) from the main rock slope. At B21.

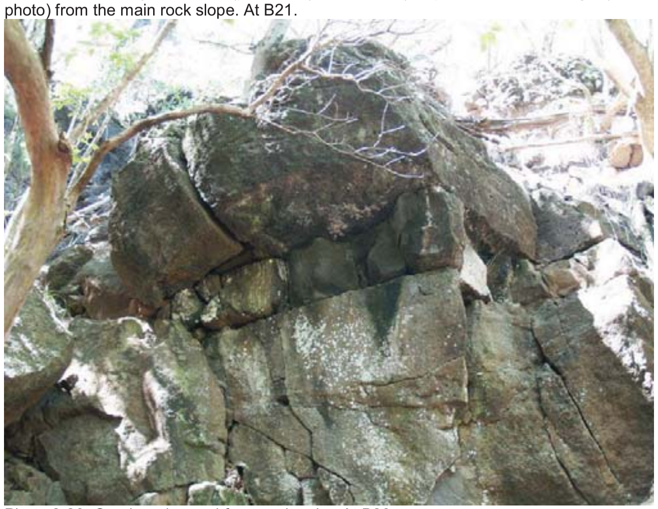


Photo 2-23. Overhanging and fractured rocks. At B23.

Photo 2-24. Overhanging rocks with wildly opened back fracture . At B24.

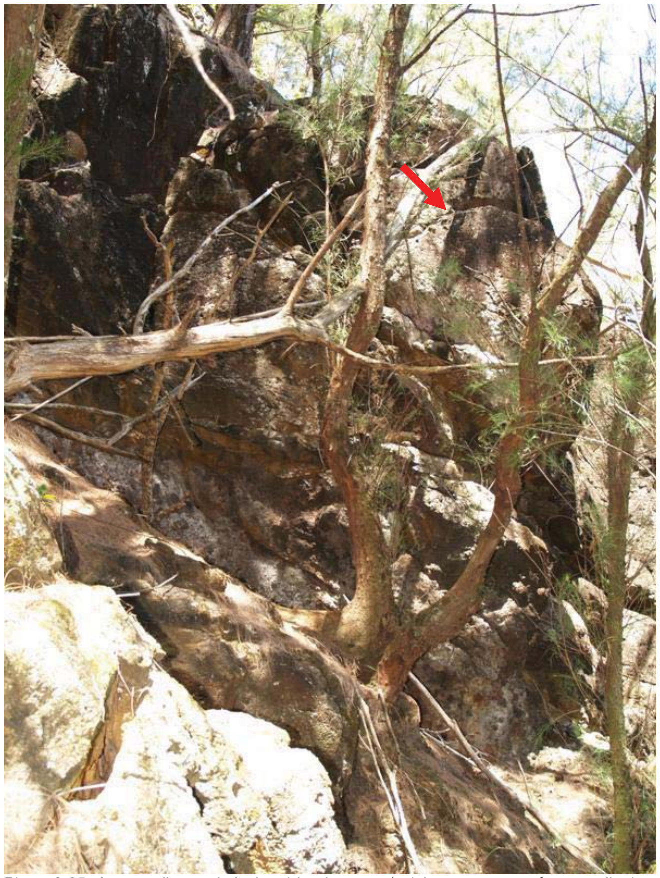


Photo 2-25. A protruding rock (pointed by the arrow) sitting on a steep fracture dipping out of slope. At B25.

Photo 2-26. An overhanging loose rock (pointed by the arrow) sitting on top of a ledge. At B26.

Photo 2-27. Overhanging loose boulders on a steep talus slope. The upper left corner of the photo is a very popular beach area. At B30.

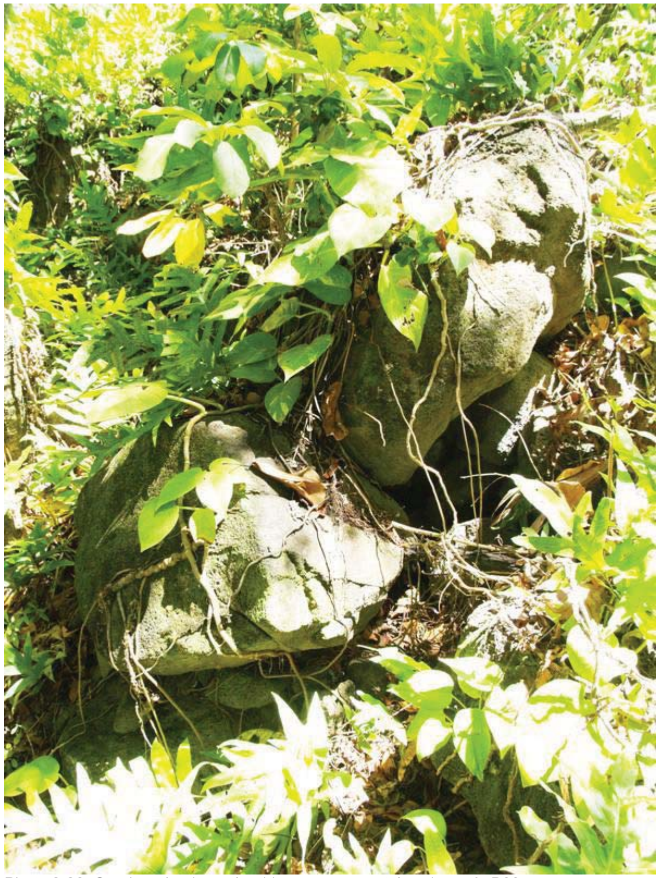


Photo 2-28. Overhanging loose boulders on a steep talus slope. At B30.

Photo 2-29. An overhanging fractured rock (pointed by the arrows) on a high cliff face (photo taken from vantage point V1).

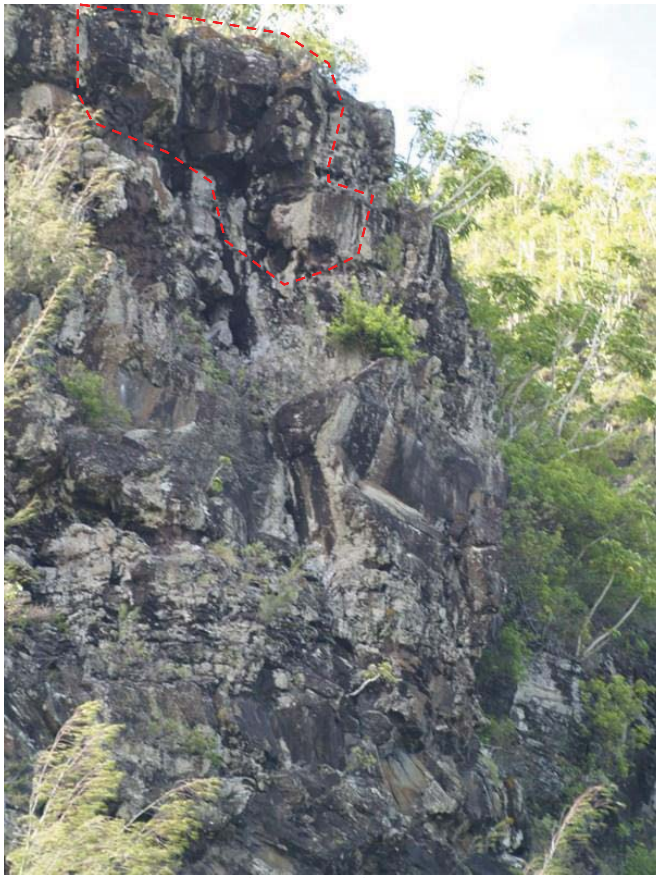


Photo 2-30. An overhanging and fractured block (indicated by the dashed lines) on top of a high cliff face (photo taken from vantage point V2).

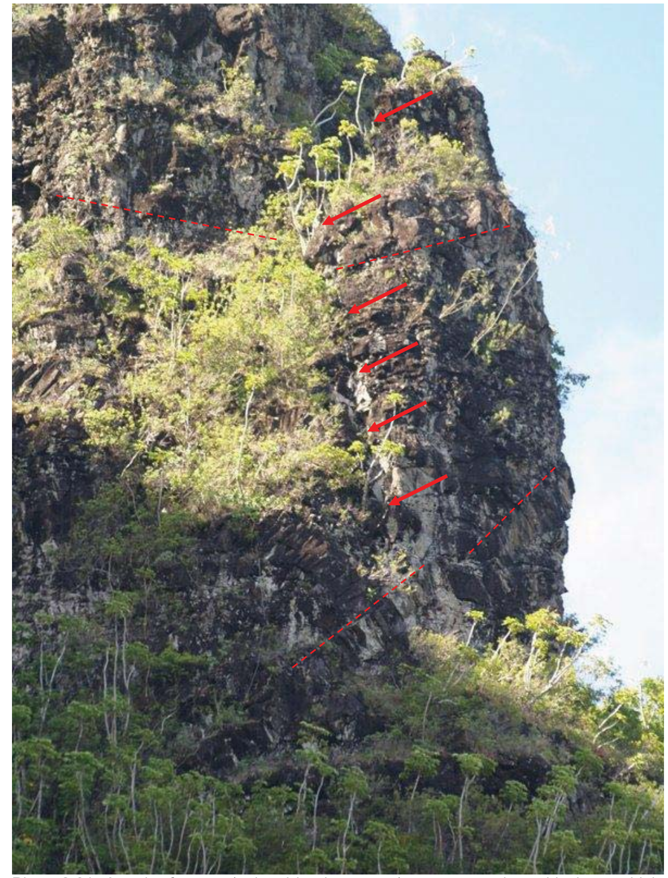


Photo 2-31. A major fracture (pointed by the arrows) separates a large block on a high rock cliff. The block dropped a little distance as indicated by the shifts of major layers across the fracture (the top dashed lines indicate a thick lava flow layer and the bottom dashed lines indicate a dike) (photo taken from vantage point V2).


Photo 2-32. A recent rockfall source (pointed by the arrows) and a large overhanging rock with back fractures (indicated by the dashed lines) (photo taken from vantage point V2).

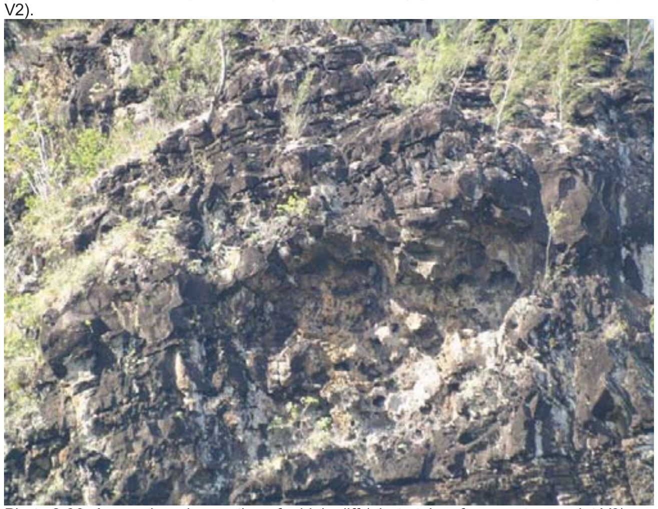


Photo 2-33. An overhanging portion of a high cliff (photo taken from vantage point V3).


Photo 2-34. Loose boulders perched on a steep ridge (photo taken from vantage point V1).


Photo 2-35. An overhanging large bolder (pointed by the arrow) on the very top of a high slope (photo taken from vantage point V5).

Photo 2-36. The thick lava flow layer on the very top of the high slopes (photo taken from vantage point V5).

2.8 Supplemental Rockfall Computer Simulation

To meet the design requirement of the master planning of Haena State Park, rockfall computer simulations were performed for six additional slope profiles (N0, N1, N2, N3, N4, and N5, see Figure 2-6) on both sides of simulation profile P2.

Contour maps with limited control points, like Google Earth Pro and regular survey maps, invariably smooth slope profiles and adversely impact rockfall simulation. For example, there are many very high and near vertical cliff faces at Haena State Park but none could be found in Google Earth Pro. Small rockfall launching benches and pads are also missing in Google Earth Pro due to its smoothing. Rockfall simulation based on contour maps with limited control points should be regarded only as a first order approximation. Site measurement has to be made for more accurate rockfall simulations. For very long slope profiles with emphasis at slope bottoms, however, it does not make much difference whether the top slopes are measured on site or obtained from contour maps.

To overcome the smoothing of contour maps for this supplemental rockfall simulation, the high and steep top slope profiles were estimated using a laser range finder and a clinometer to catch major cliff faces and launching benches and pads. Only those major cliff faces that were visible at advantageous view points at slope bottom were measured using the laser range finder. Both the direct and horizontal distances to both cliff top and bottom were measured for each major cliff face. Gentler slopes between major cliff faces were constrained by their slope angle estimated using the clinometer and the height and distances of two adjacent major cliff faces. Bottom slope profiles were directly measured using a tape and a clinometer.

Figure 2-7 shows the simulation results for profile N0 (Figure 2-6). A small launching pad existed on top of the bottom major cliff (Figure 2-7). Based on results of this mathematical simulation, about 81%, 38%, and 0.0% simulated rockfalls reach mauka edge, makai edge, and 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 18 ft, 1.5 ft, and 0.0 ft, respectively. 8.7% and 3.4% simulated rockfalls passed the points at 20 ft and 30 ft down the makai edge of the paved road, respectively. See Appendix A for detailed simulation information. If without the small launching pad, the maximum jumping height at the mauka edge of the paved road would be only 2.1 ft (compared to the 18.3 ft), with other results very similar to the above.

Figure 2-8 shows the simulation results for profile N1. A small launching pad existed on top of the bottom major cliff (Figure 2-8). Based on results of this mathematical simulation, about 100%, 65%, and 5.6% simulated rockfalls reach mauka edge, makai edge, and 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 150 ft, 116 ft, and 4.7 ft, respectively. 4.0% and 0.5% simulated rockfalls passed the points at 64 ft and 94 ft down the makai edge of the paved road, respectively. See Appendix A for detailed simulation information. If without the small launching pad, about 98%, 60%, and 4.8% simulated rockfalls reach mauka edge, makai edge, and 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 102 ft, 61 ft, and 1.0 ft, respectively. 1.6% simulated rockfalls passed the point at 74 ft down the makai edge of the paved road. See Appendix A for detailed simulation information.

Figure 2-9 shows the simulation results for profile N2. Profile N2 passes the upper wet cave (Waiakapalae). Based on results of this mathematical simulation, about 100%, 17%, and 0.3% simulated rockfalls reach the upper Wet Cave (Waiakapalae), the mauka edge, and the point 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 166 ft, 2.3 ft, and 0.3 ft, respectively. 3.4% simulated rockfalls passed the point 5 ft down the makai edge of the paved road. See Appendix A for detailed simulation information.

Figure 2-10 shows the simulation results for profile N3. Based on results of this mathematical simulation, about 100%, 100%, and 40% simulated rockfalls reach mauka edge, makai edge, and 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 96 ft, 77 ft, and 20 ft, respectively. 5.7% and 2.3% simulated rockfalls passed the points at 89 ft and 99 ft down the makai edge of the paved road, respectively. See Appendix A for detailed simulation information.

Figure 2-11 shows the simulation results for profile N4. Based on results of this mathematical simulation, about 100%, 94%, and 14% simulated rockfalls reach the lower Wet Cave (Wai a Kanaloa), mauka edge, and the point 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 159 ft, 106 ft, and 0.7 ft, respectively. 2.7% and 0.0% simulated rockfalls passed the points at 74 ft and 94 ft down the makai edge of the paved road, respectively. See Appendix A for detailed simulation information.

Figure 2-12 shows the simulation results for profile N5. Based on results of this mathematical simulation, about 84%, 9%, and 0% simulated rockfalls reach mauka edge, makai edge, and 60 ft down the makai edge of the paved road, respectively, with a maximum bouncing height of 5.7 ft, 0.7 ft, and 0.0 ft, respectively. 1.4% simulated rockfalls passed the point at 36 ft down the makai edge of the paved road. See Appendix A for detailed simulation information.

The results of these additional rockfall computer simulations were summarized in Figure 2-6, with the 0% line indicating no simulated rockfalls pass the location indicated by the lines, and the 5% line indicating five percent of simulated rockfalls pass the location indicated by the lines. Figure 2-13 shows rockfall simulation results with minimum mitigation measures in place. Notice the change of the 0% line and 5% line in Figure 2-13 compared to in Figure 2-6. A drainage/catchment ditch or a low wall can be designed along or down slope of the 0% line in Figure 2-13 to stop rockfalls from going any further. Figure 2-14 shows the drainage/catchment ditch mitigation option where a drainage/catchment ditch is installed along the 0% line in Figure 2-13. Figure 2-15 shows the drainage ditch and elevated path mitigation option where a drainage ditch is installed right along the roadway to stop most falling rocks and the elevated height of the path to stop the remaining falling rocks.

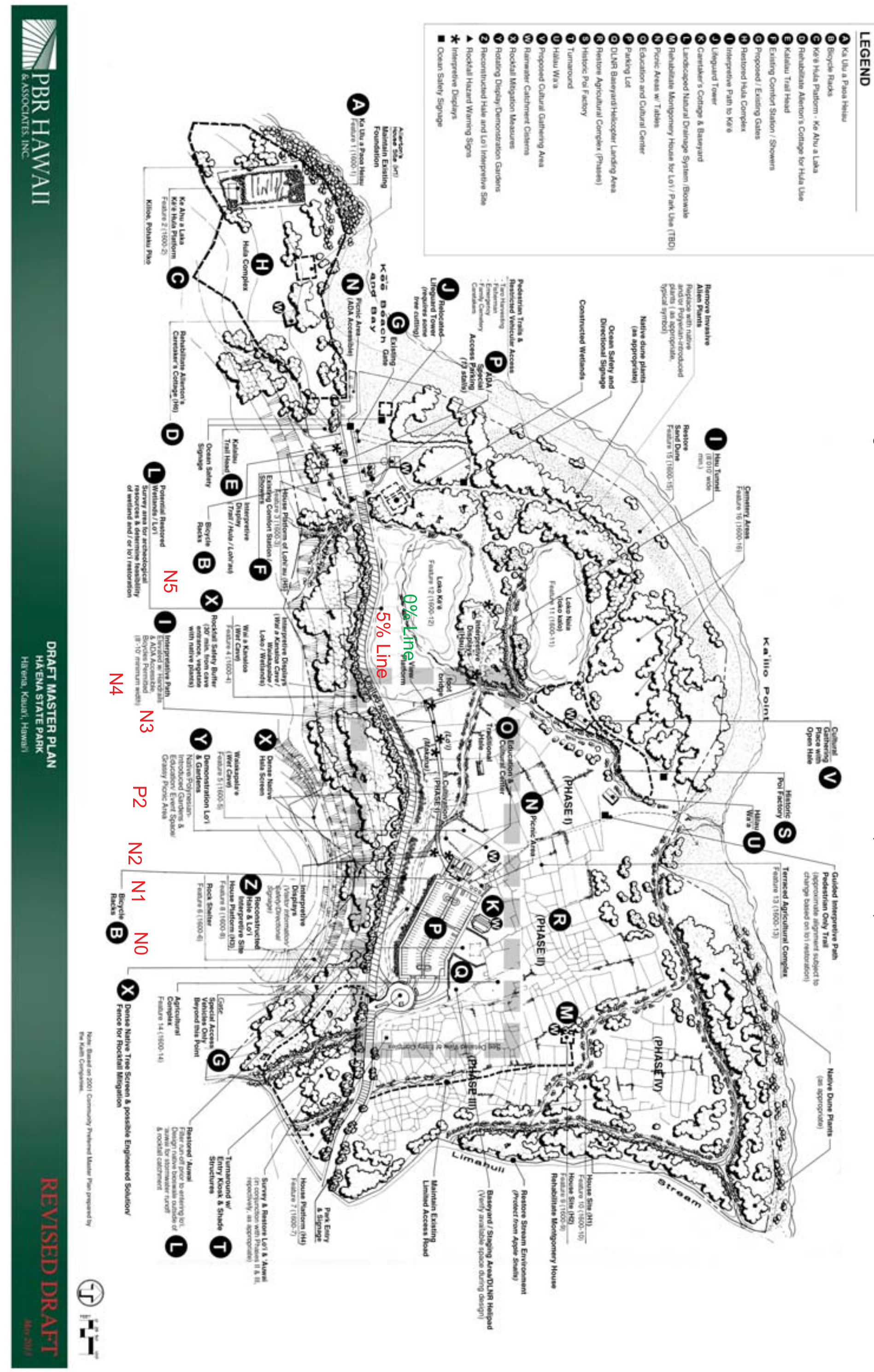


Figure 2-6: Additional Rockfall Simulation Profiles (N0 to N5) and the 5% and 0% Rockfall Reach Lines

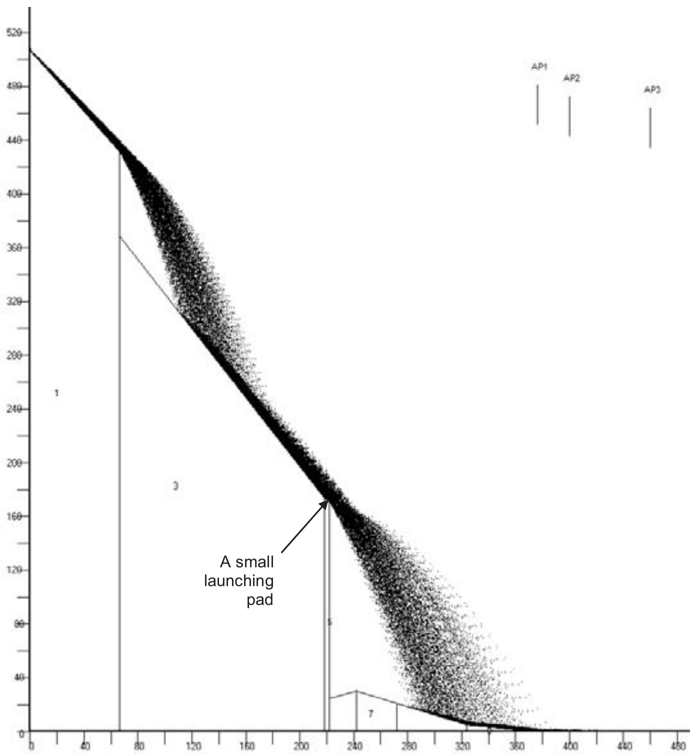


Figure 2-7: Rockfall simulation results for profile N0.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the mauka edge, makai edge, and 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 81%, 38%, and 0% rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 18.3 ft, 1.5 ft, and 0 ft, respectively. See Appendix A for detailed simulation information. If without the small launching pad indicated in the above figure, the maximum jumping height at AP1 would be 2.1 ft, with other results very similar to the above.

June 2013 Haena State Park Rockfall Study Supplemental Simulation

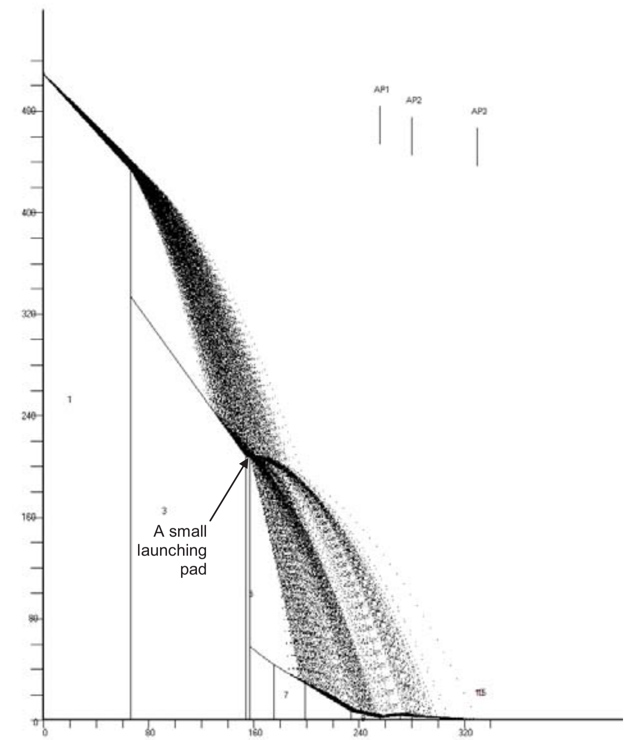


Figure 2-8: Rockfall simulation results for profile N1.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the mauka edge, makai edge, and 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 100%, 65%, and 5.6% simulated rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 150 ft, 116 ft, and 4.7 ft, respectively. If without the small launching pad, about 98%, 60%, and 4.8% simulated rockfalls reach AP1, AP2, and Ap3, respectively, with a maximum bouncing height of 102 ft, 61 ft, and 1.0 ft, respectively. See Appendix A for detailed simulation information.

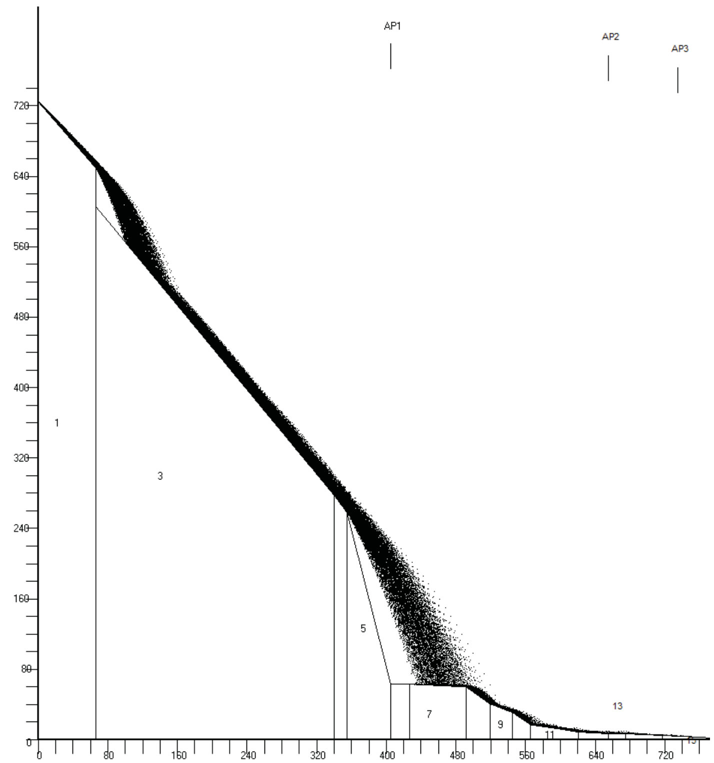


Figure 2-9: Rockfall simulation results for profile N2.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the upper wet Cave (Waiakapalae), the mauka edge, and the point 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 100%, 17%, and 0.3% simulated rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 166 ft, 2.3 ft, and 0.3 ft, respectively. See Appendix A for detailed simulation information.

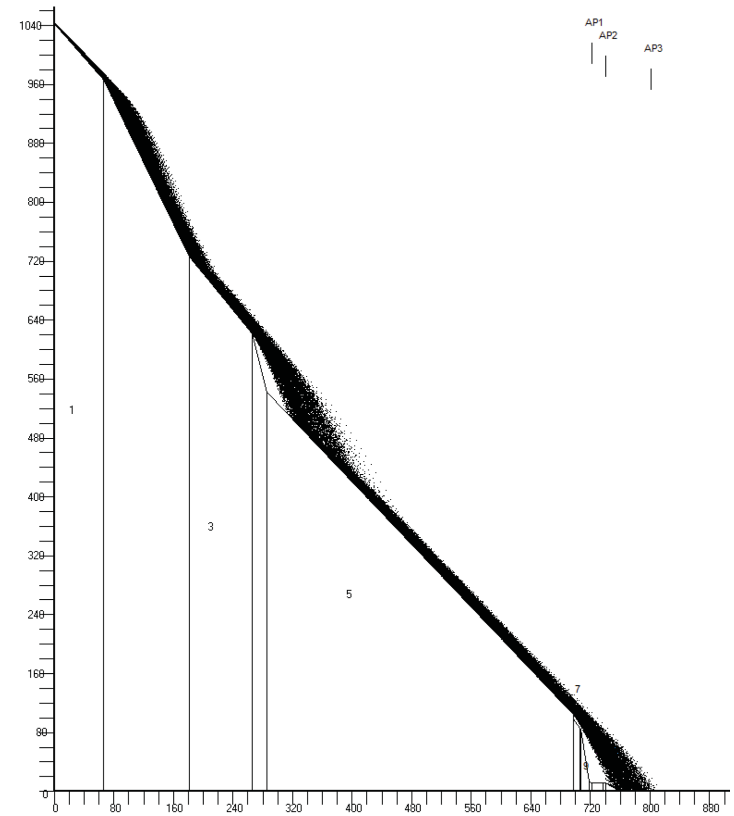


Figure 2-10: Rockfall simulation results for profile N3.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the mauka edge, makai edge, and 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 100%, 100%, and 40% simulated rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 96 ft, 77 ft, and 20 ft, respectively. See Appendix A for detailed simulation information.

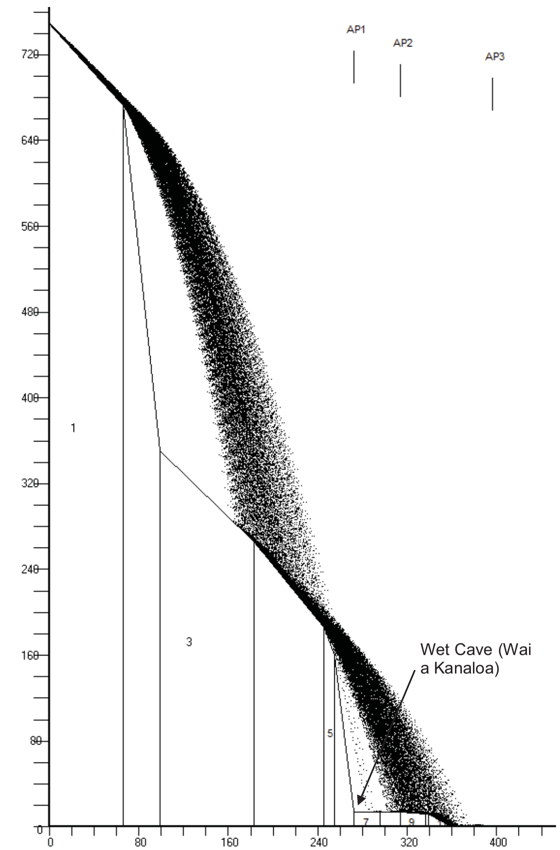


Figure 2-11: Rockfall simulation results for profile N4.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the lower wet Cave (Wai a Kanaloa), the mauka edge, and the point 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 100%, 94%, and 14% simulated rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 159 ft, 106 ft, and 0.7 ft, respectively. See Appendix A for detailed simulation information.

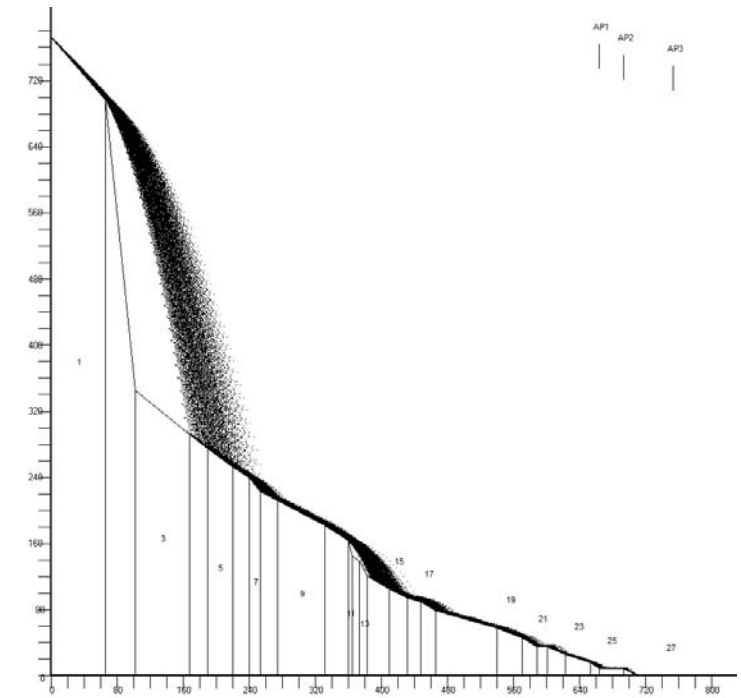


Figure 2-12: Rockfall simulation results for profile N5.

Vertical axis is elevation (foot) and horizontal axis is distance from rockfall source (foot). Each small dot represents the position of a boulder during rockfall. AP1, AP2, and Ap3 are analysis points at the mauka edge, makai edge, and 60 ft down the makai edge of the paved road. The numbers (1, 3, 5, 7…) are slope section references. Upper slope profile was estimated using a laser range finder and a clinoment and lower slope profile was measured. About 84%, 9%, and 0% simulated rockfalls reach analysis points AP1, AP2, and AP3, respectively, with a maximum bouncing height of 5.7 ft, 0.7 ft, and 0.0 ft, respectively. See Appendix A for detailed simulation information.

Figure 2-13: Rockfall Simulation Results with Minimum Mitigation Measures in Place

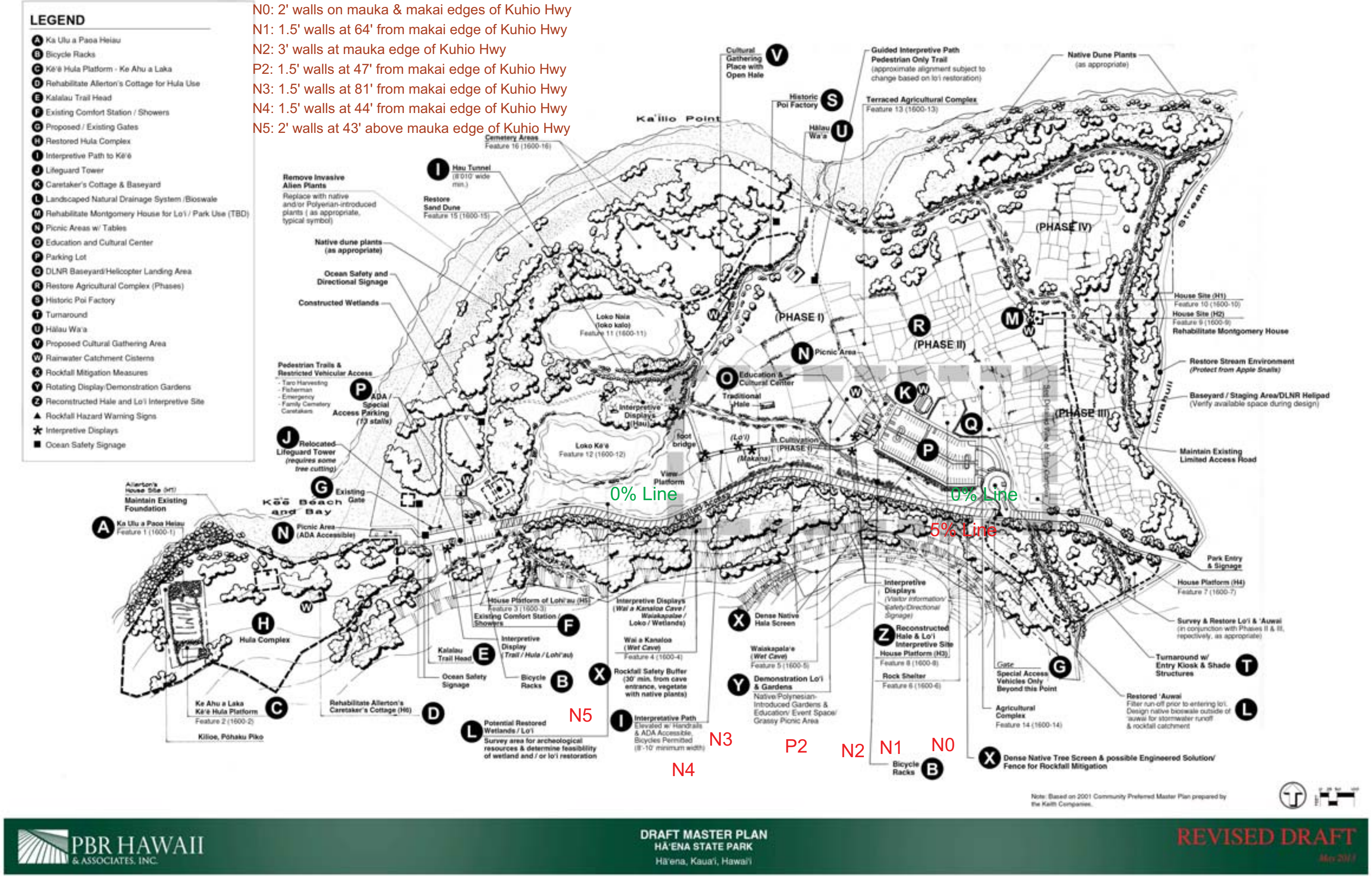
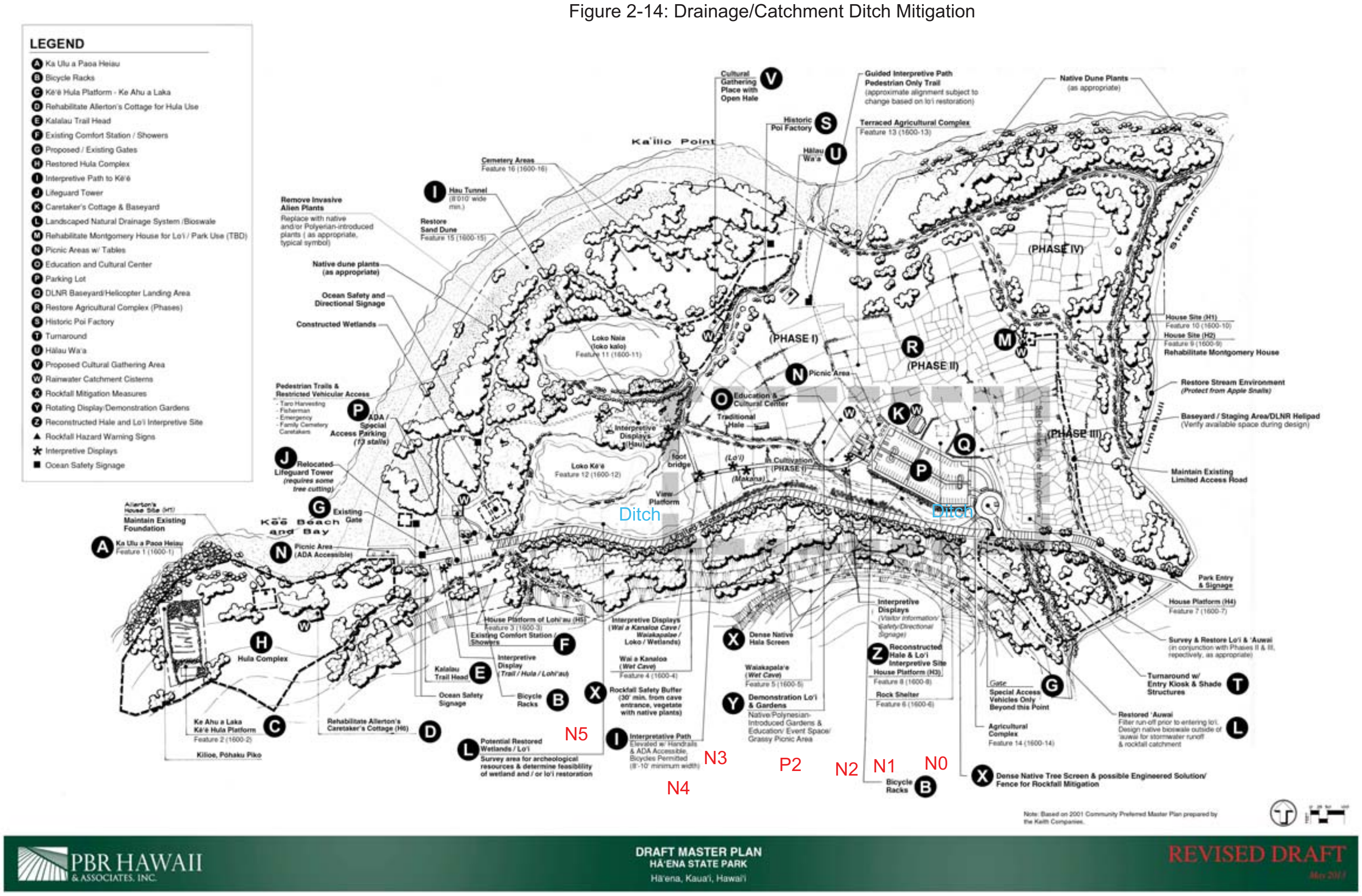


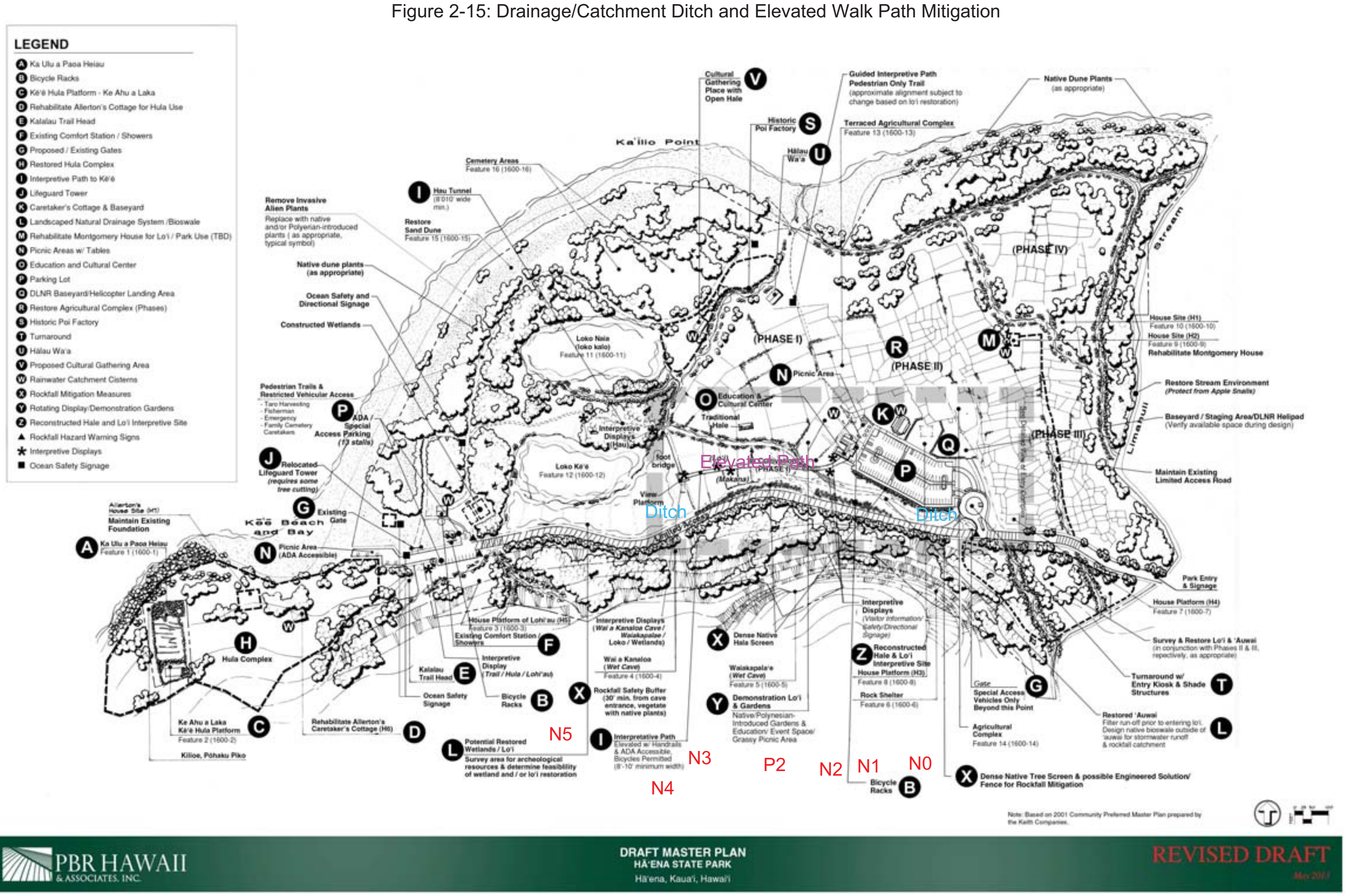
Figure 2-14: Drainage/Catchment Ditch Mitigation



Section 3.0

Engineering Planning Study

Figure 2-15: Drainage/Catchment Ditch and Elevated Walk Path Mitigation



3.0 ENGINEERING PLANNING STUDY

3.1 ROCKFALL ENGINEERING MITIGATION METHODS

This section provides typical narratives and schematic drawings for engineered rockfall mitigation solutions. These solutions are among the most widely used rockfall mitigation methods in the industry.

There are two general ways of approaching engineering mitigation solutions: permanent and temporary. Permanent mitigation solutions provide high level of protection against falling rocks for the entire site with the intent to remain effective for many years (the design life of the system used). The first six mitigation methods described below, from wire mesh drape system to retaining wall, are permanent design alternatives. Temporary design alternatives usually provide emergency or cost-effective rockfall hazard reduction, usually do not provide full hazard protection coverage of a rockfall site, and may need to be re-visited or repeated periodically as new rockfall features develop. The use of temporary methods must be based strictly on the results of a risk management process initiated by the owner of the project. Temporary methods are preferred by property owners when there is a need for emergency rockfall hazard reduction, permanent mitigation is cost prohibitive, or funding for permanent mitigation is not available. Scaling of rocks described below is a temporary rockfall mitigation method.

1. DESIGN ALTERNATIVE NO. 1- WIRE MESH DRAPE SYSTEM

Design Alternative No. 1 provides for the installation of wire mesh or ringnet drape system over entire slope that could send falling rocks to roadways or other protected structures. As shown in Figure 3-1, the draped wire mesh or ringnet should be anchored at the top of the slope and extend to the bottom. Falling debris are restrained behind the drape. Debris would be deposited into a small catchment area at the base.

This design alternative requires periodic inspection and maintenance. The mesh should be inspected for corrosion and damage from falling debris. Steel components may need to be repaired or replaced. Rockfall debris should be cleared from behind the mesh and from the catchment area.

The main benefit of this design alternative is that the mesh covering offers a high level of rockfall protection. This system can be installed in places where limited catchment area prevents the use of other systems like the rockfall impact fence and catchment ditch zone. This system is cost effective for small slopes with limited catchment area. The drawbacks of this design alternative are visual impact and the high initial construction cost.

Wire mesh drape system is not suitable for Haena State Park: 1) it is cost-prohibitive at a cost of 206.5 million dollars (see Appendix B for cost estimate) and a construction time of 8 months, and 2) although vegetation would grow through mesh openings, portions of the mesh covering bare rocks may become visible creating an aesthetic drawback.

2. DESIGN ALTERNATIVE NO. 2- ANCHORED WIRE MESH SYSTEM

Design Alternative No. 2 provides for the installation of anchored wire mesh over the entire slope that could otherwise send falling rocks onto roadways or other protected structures. After cleaning, scaling and leveling, the terrain surface is covered by a high strength steel wire mesh and tensioned with pre-installed anchors typically spaced 8 to 10 feet apart throughout the coverage area, as shown in Figure 3-2. The anchors pull the mesh tightly against the slope. This system is designed to prevent rockfalls by restraining the loose material in place. If the slope has large scale landslide potential, the anchors can be designed to stabilize the slope.

This design alternative requires periodic inspection and some maintenance where required. As with all anchored wire mesh systems, the steel components must be inspected for signs of corrosion, fatigue, and damage. Parts may require repair or replacing if damaged.

The benefit of using this design alternative is that it stabilizes slope and restrains loose material in place. The wire mesh held tightly against the slope improves soil retention and vegetation growth for a natural green appearance making the wire mesh virtually invisible. The system can be integrated to accommodate trees and other existing slope features. Furthermore, this system requires no catchment zone, and therefore can be installed practically at any area where other mitigation systems are ineffective. The drawbacks of this alternative are high initial construction cost and that the area beneath the wire mesh becomes unusable.

Anchored wire mesh system is not suitable for Haena State Park: 1) it is cost-prohibitive at a cost of 340.4 million dollars (see Appendix B for cost estimate) and a construction time of about 12 months, and 2) although vegetation grows through mesh openings, the mesh could become visible where covering rock outcrops. This may be unacceptable for a State park that is renowned for its natural beauty.

3. DESIGN ALTERNATIVE NO. 3- IMPACT FENCE SYSTEM

Impact fence system provides for the installation of a rockfall impact fence along the shoulder or toe of slope to intercept rolling rocks from upslope (see Figure 3-3). The fence provides blanket rockfall protection for large areas. The system can be designed to absorb various levels of energy and jumping heights produced from falling rocks for specific site conditions.

This design alternative requires periodic maintenance to repair the fence. Braking elements need to be checked and replaced, if necessary, after each major impact. Rocks embedded in the fence should be removed.

Large slopes can be mitigated with a single fence installed at the base thus making this design alternative beneficial. The main drawback is the catchment area required. Sites with launching features or little shoulder room may require widening or realignment to accommodate the fence. Additional drawbacks include periodic maintenance costs and some visual impact.

Impact fence system is suitable for most areas of Haena State Park with a cost of 8.6 million dollars (see Appendix B for cost estimate) and a construction time of about 6 months. The impact fence will mostly be hidden from view by trees and other vegetation so its adverse aesthetic impact is limited.

4. DESIGN ALTERNATIVE NO. 4- COMBINATION IMPACT FENCE AND DRAPE OR ANCHORED WIRE MESH SYSTEM

This alternative is a combination of Design Alternative No. 2 and No. 3. It includes installation of a rockfall impact fence in strategic locations to intercept falling rocks and a draped or anchored wire mesh system over steep slopes that are right next to protected structures with no catchment zone in between for the installation of an impact fence (see Figure 3-4). The fence would provide blanket rockfall protection intercepting rolling rocks from upslope, and the anchored wire mesh system would inhibit rockfalls just above protected structures.

This system is most beneficial for areas with limited shoulder having high continuous natural slopes. The drawback is the higher construction cost and some visual impact.

Impact fence and anchored wire mesh system is suitable for Haena State Park with a cost of 9.8 million dollars (see Appendix B for cost estimate) and construction time of about 9 months. The impact fence will mostly be hidden from view by trees and other vegetation so its adverse aesthetic impact is limited. The anchored wire mesh system is mainly installed at the area around the Wet Cave (Wai a Kanaloa) where high steep cliffs are right next to roadway and popular visitor areas.

5. DESIGN ALTERNATIVE NO. 5- CATCHMENT DITCH

Design Alternative No. 5 provides for the construction of a catchment ditch along the shoulder, as shown by Figure 3-5. The ditch should be designed based on site conditions to provide adequate catchment zone. Roads with little shoulder width will require partial cutting of the slope or realignment of the road in order to accomplish the designed effects.

This design alternative requires low maintenance. The ditch should be cleared of rockfall debris periodically.

This design alternative is beneficial because large slopes can be mitigated with a single catchment ditch along the base. Also, the ditch improves drainage capacity. The drawback is associated with the large catchment zone area and rock excavation required. Additionally, existing utilities along the shoulder may require modification or relocation.

Catchment ditch is suitable for Haena State Park with a cost of 6.8 million dollars (see Appendix B for cost estimate) and a construction time of about 8 months. An anchored wire mesh system is needed at the area around the Wet Cave (Wai a Kanaloa) where high steep cliffs are right next to roadway and popular visitor areas with no room for a catchment ditch. Impact fences may be needed in locations where a catchment ditch is not effective in intercepting falling rocks. The position and dimension of the catchment ditch should be verified by rockfall simulation at each location.

6. DESIGN ALTERNATIVE NO. 6- ROADWAY REALIGNMENT

Design alternative No. 6 provides for construction of a new realigned roadway parallel to the existing road where the existing roadway is too close to the mountain. The new roadway will be constructed on the makai side of the existing road using fill material and mechanically stabilized earth (MSE) walls as necessary. The existing road will be used as a rock catchment area. An impact protection fence will be installed in areas where the new road is still in close proximity to the rockfall path. This design alternative requires some ground excavation and backfilling. With the roadway pushed away from the mountain side, the access to the caves could easily become limited for public safety and hazard control.

The construction cost to realign the roadway and installation of the necessary safety features is estimated at $15.5 M (see Appendix B for cost estimate) with a construction time of about 12 months.

The benefits of this design alternative include low maintenance, longevity, and simplicity and effectiveness of design. The drawback is increased construction costs. This design alternative is very suitable for Haena State Park.

7. DESIGN ALTERNATIVE NO. 7- ROCK SCALING (TEMPORARY FIX)

During scaling, rock outcrops that are ready to fall are removed from the slope by using hands, prying bars, and hydraulic jacks or airbags for large rocks. Scaling is most cost-effective when there are no structures to be protected at the base of the slope where the scaled rocks are allowed to run down the slope freely. The only significant structure at Haena State Park is the paved road surface which, if damaged during scaling, can be easily repaired by patching the impact holes made by scaled rocks. Alternatively, metal plates or other road covers can be used to reduce damage to the paved road at additional cost.

After a thorough scaling, the rockfall hazard is generally maintained at a low level for quite a few years because the geological processes associated with natural production of rockfalls are generally slow requiring many years to generate a rock outcrop that is ready to fall. Exceptions, however, exist. For example, if a new water channel develops on a steep soft soil slope with embedded boulders, new rockfall hazards will be created after almost every surface runoff. The slopes at Haena State Park consist of nearly horizontal lava flow layers with limited weathering and talus slopes with limited fine or soil material. The geological processes associated with natural production of rockfalls at Haena State Park are reasonably slow.

The steep slopes around the Wet Cave (Wai a Kanaloa) are the most hazardous at Haena State Park and should be scaled first. The area around Profile P2, which is close to both wet caves, has the highest percentage of potential rockfalls anticipated to reach the roadway and should be scaled first. The other areas have low percentage (less than 5%) of rockfalls reaching roadway or beach and should be scaled if additional funding is available. The cost of scaling is $750,000 for two crews of three scalors each crew to work for 75 days (daily cost $10,000) to scale the wet caves' area and above, and the identified boulder sites (B1 to B30). Scaling of large rocks in other areas that have a reasonable chance of reaching roadway or beach or other structures is recommended if additional funding is available, with an estimated additional cost at 1.5 million dollars.

During rock scaling operation, it is highly recommended that the contractors' scope of work is directed and validated on site by geologists or engineers experienced in rock scaling.

7. OTHER MITIGATION METHODS

There are many other rockfall mitigation methods. Rock demolition, bolting, cable lashing, pedestal support, and local netting can be used independently or in combination with other mitigation methods. High-cost methods like constructing concrete canopy, or elevated roadways above rock fallout zones can also be used if specific conditions that warrant the high costs.

3.2 RECOMMENDED ROCKFALL MITIGATION DESIGN AT HAENA STATE PARK

Design for the mitigation alternatives are based on factors such as public safety, least impact to the environment, construction cost, and sound engineering principles. The recommendations were provided to develop preliminary construction cost data used to establish project development and funding. The final remedial design may vary from the preliminary design based on other factors including detailed rockfall protection characteristics, land acquisitions, community needs, environmental issues, cultural considerations, aesthetics, and local politics.

For permanent rockfall mitigation design, the combination of impact fence and anchored wire mesh system is recommended due to its effectiveness, and least disturbance to environment with a cost of about 9.8 million dollars and a construction period of eight months.

For temporary rockfall mitigation design, scaling is recommended due to its ease of construction, least disturbance to environment, and cost effectiveness in rockfall hazard reduction, with a cost of $750,000 and a construction period of four months to scale the high hazard areas around both Wet Caves and the identified boulder sites. It should be noted that rock scaling is a temporary solution and should only be used to reduce rockfall potentials. For an engineered rockfall protection methodology any of the permanent mitigation methods may be considered. An additional 1.5 million dollars and a construction period of six months are needed to scale the remaining other areas. Only rocks that are likely to reach the roadway or other protected structures will be scaled.

It has been noted that the North Shore and specifically the Haena communities have been resistive to any disturbance and potential devastation to the sacred mountains at Haena brought about as the result of any rockfall mitigation and construction. Consequently, there are various other plans being drawn up in cooperation with the community in terms of long term and short term mitigation for rockfall protection in this area. The long term plan is to divert the public traffic away from the high rockfall zones. This would be accomplished by closing the highway to both vehicular and on-foot public travelers while redirecting them through walkways that are built in the safe rockfall zones. This is part of a master planning process that the State is currently working on with the public. The proposed facilities and pathways for the master planning of Haena State Park are outside of rockfall reach zones (Figure 2-6). To further increase rockfall protection, the proposed pathways can be elevated by 2 ft (Figure 3-6) and the proposed parking lot can be fronted at mauka side by a drainage\catchment ditch with 2 ft depth (Figure 3-7), as suggested by the simulations shown in Figure 2-13, Figure 2-14, and Figure 2-15. The cost of such improvements would vary depending on a number of factors including the topographic survey, soil condition, ground water levels, cultural interests, and so on, and is best to remain for determination during design phase.

For the short term mitigation solution and in the interim, we are proposing demolition and stabilization of some of the larger rocks (a total of 4 to 6 rocks) along the base of the mountain near the areas of the Wet caves. The way this procedure has been proposed is to remove each unstable rock using rock scaling bars or airbags only. Once these rocks are dislodged, they should be brought to rest in a stable location along the foothills. All dislodged rocks are planned to be left at the site. The cost of this effort has been estimated at about $400,000 and a construction period of about three weeks.

3.3 Similar Rockfall Projects and Experienced Contractors

A rockfall protection fence and roadway realignment method was used at Waimea Bay in June 2000 to protect Kamehameha Highway from potential rockfalls and at the Old Puunui Quarry site to protect residents from the upslope boulders. The special rockfall protection fence was designed and manufactured by GeoBrugg. Rockfall catchment ditch, rock demolition, bolting, and cable netting have been performed in various locations on Oahu including at Waimea Bay, at Makapuu during a major scaling and netting of the mountain slopes, and at Lalea of Hawaii Kai. The recently completed Kailua Road project used a combination of rockfall impact fence, both draped and anchored mesh systems, rockfall catchment ditch, rock scaling, rock bolting, local netting, and cable lashing. The latest major scaling operation performed in Hawaii was the scaling of 130 bunkers at Waikele. Tens of thousands of boulders, some of them over ten tons, were scaled from the slopes above the bunkers. A large number of boulders were scaled easily by hand, reflecting their high rockfall potential.

The following general contractors are among those who have been involved with rock scaling/demolition/bolting and/or rockfall fence/net/ditch installation in Hawaii:

- High Tech Rockfall Construction
- AIS Construction
- Prometheus Construction
- Royal Contracting Co. Ltd.
- Kiewit Pacific Co.
- Good Fellow Brothers, Inc.

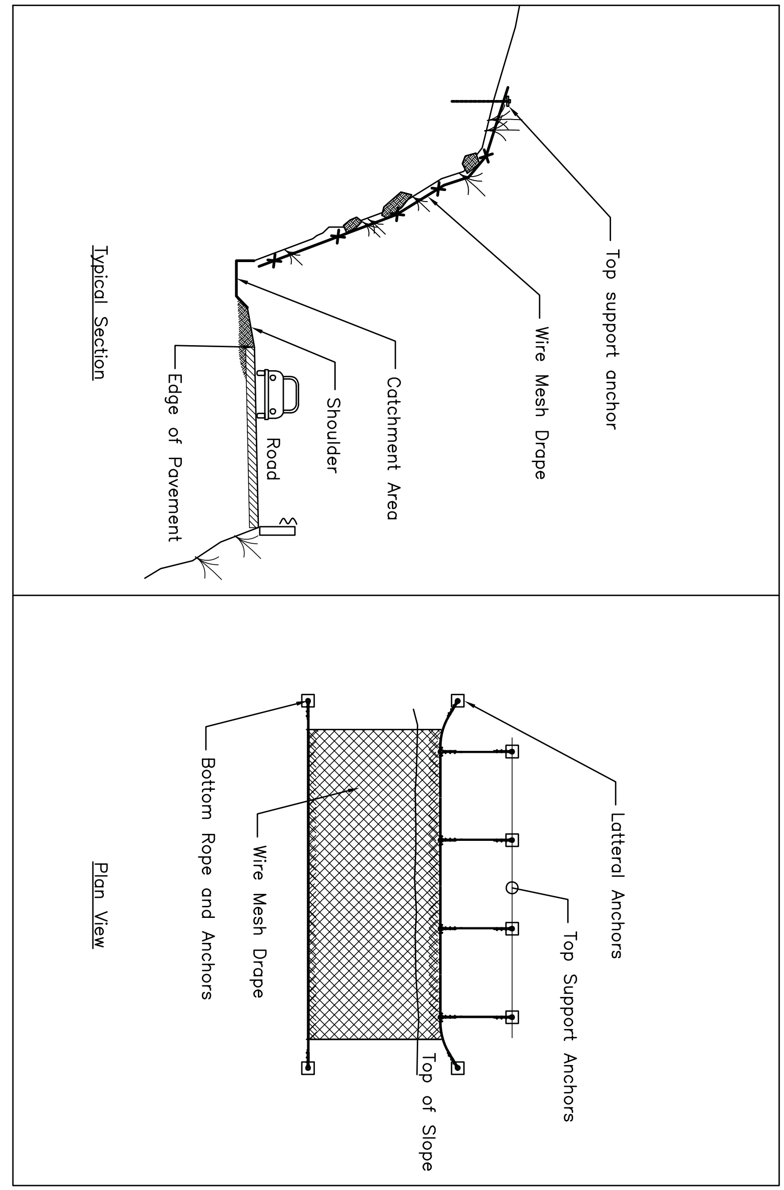


Figure 3-1
Design Alternative No. 1
Wire Mesh Drape System

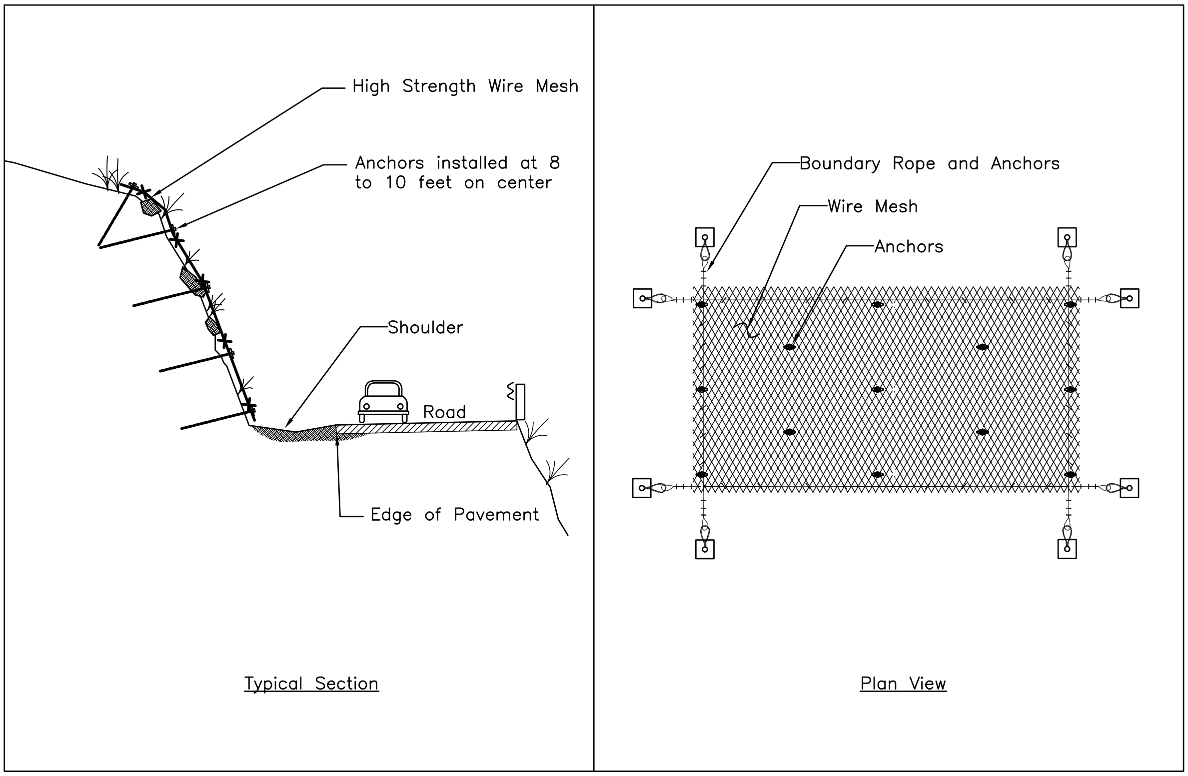


Figure 3-2
Design Alternative No. 2
Anchored Wire Mesh

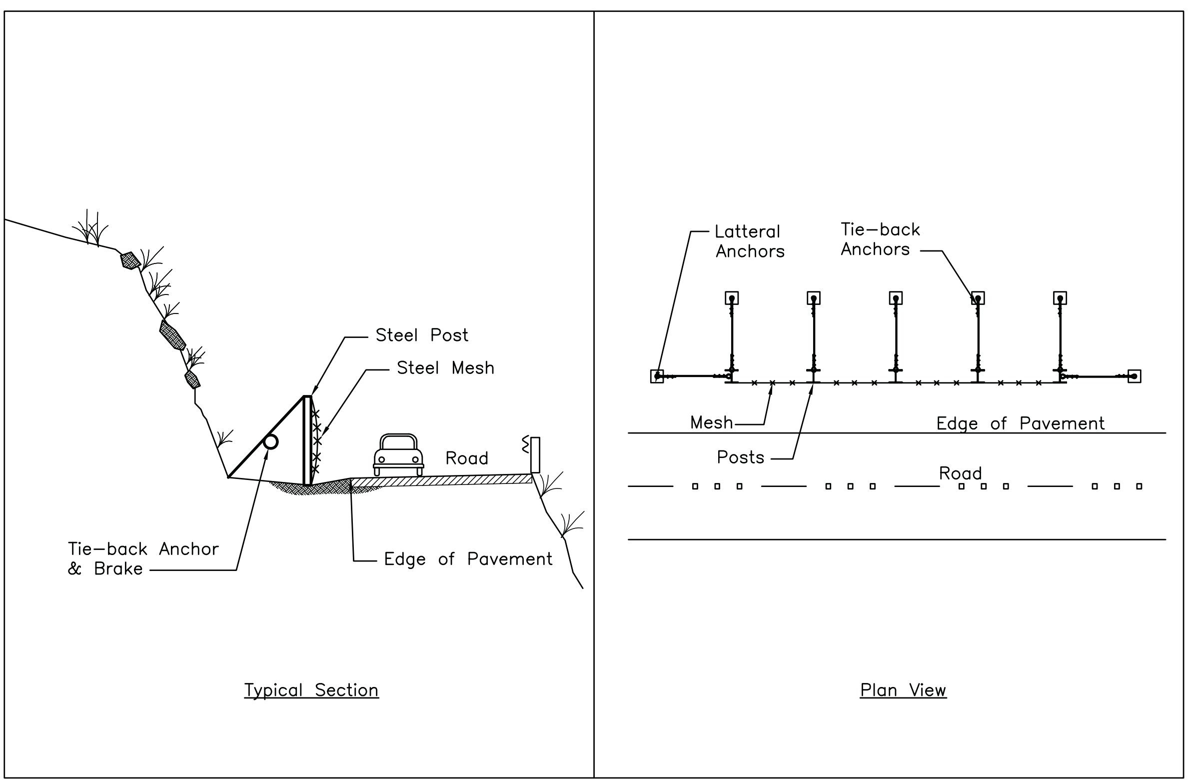


Figure 3-3
Design Alternative No. 3
Impact Fence System

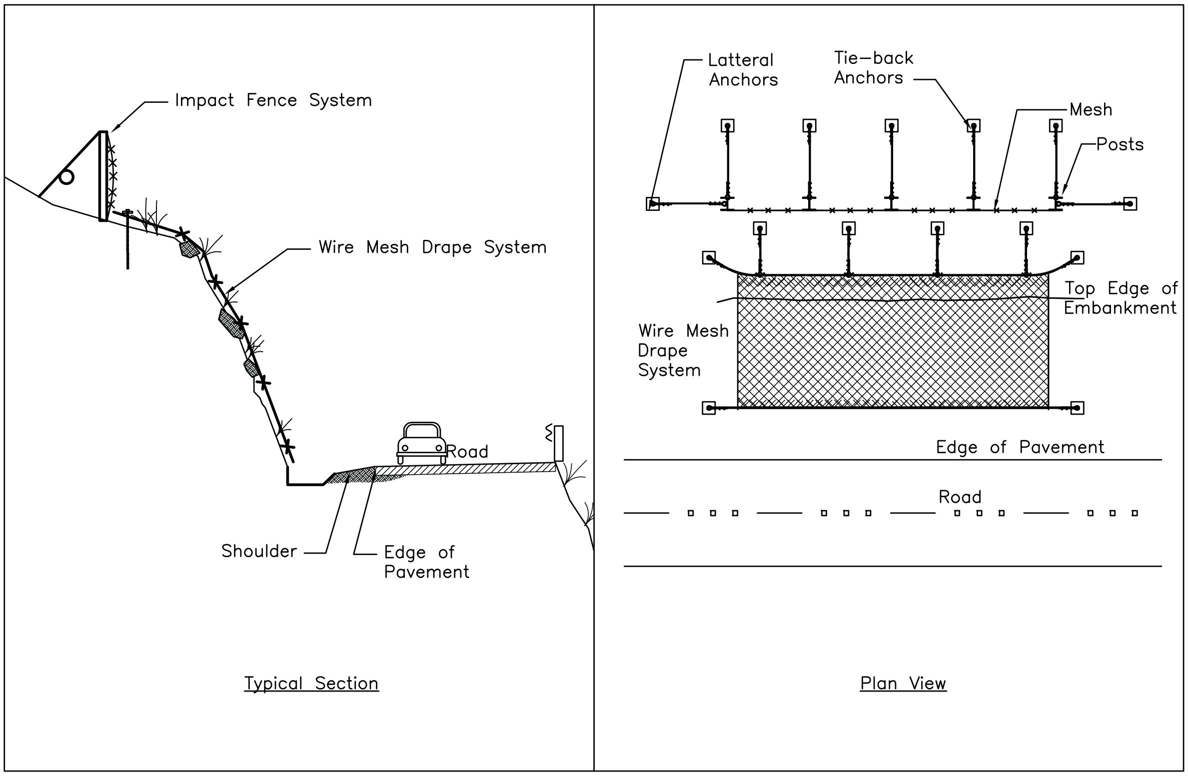


Figure 3-4
Design Alternative No. 4
Combination Impact Fence & WIre Mesh Drape

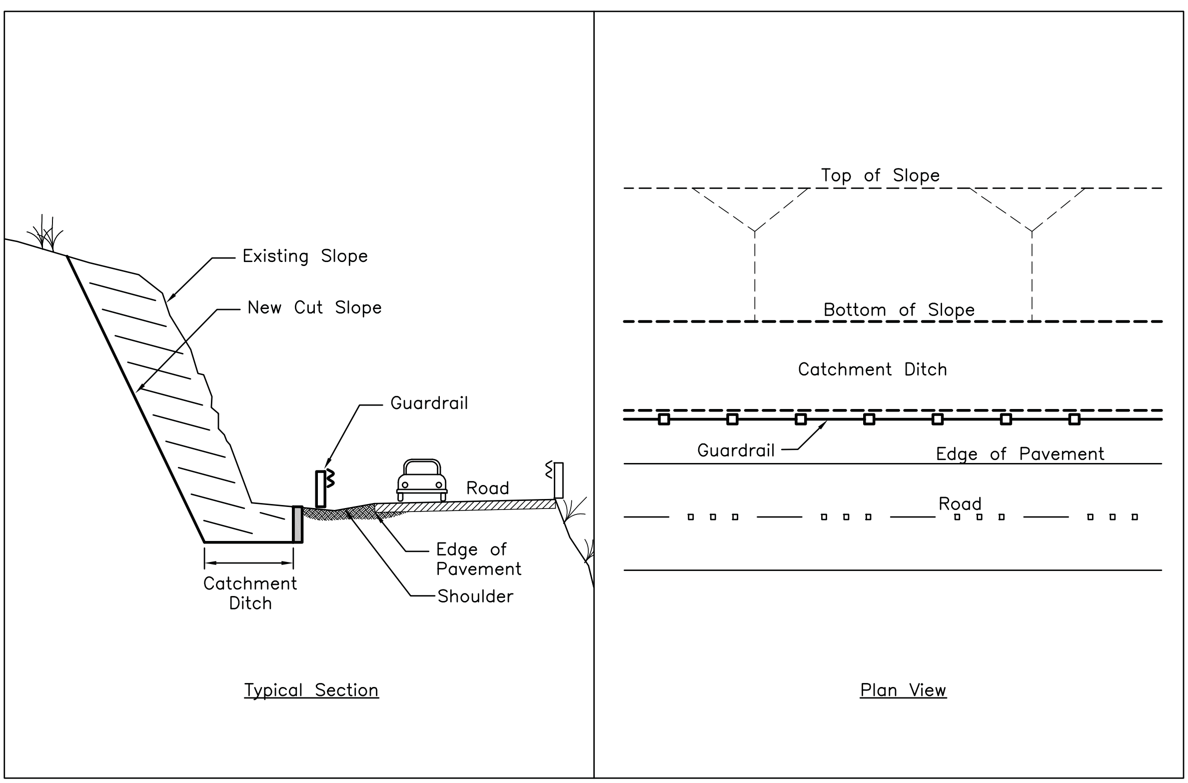
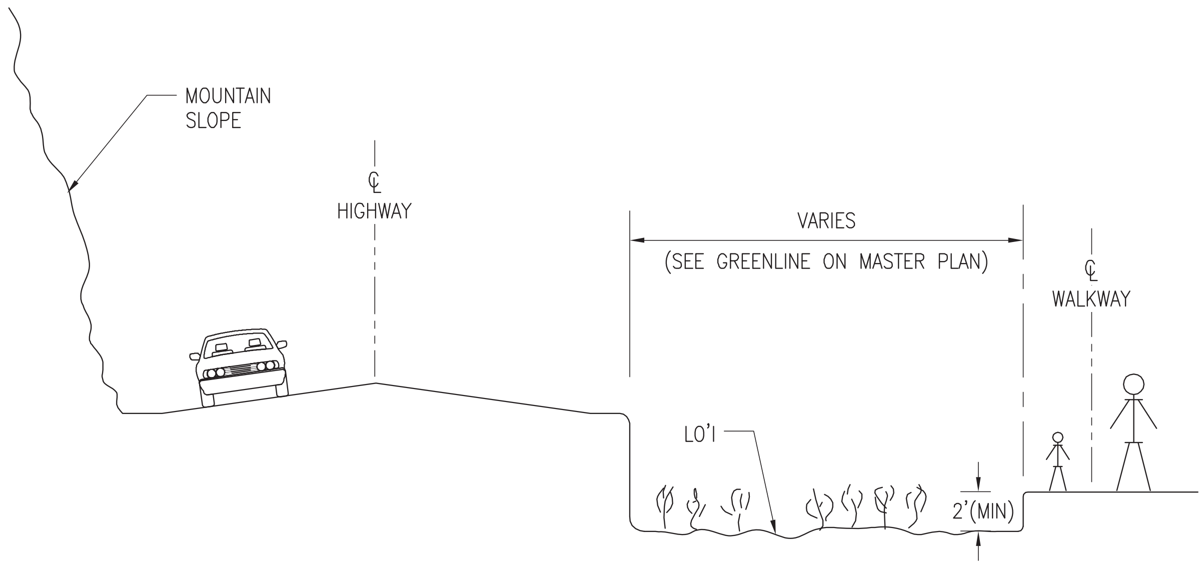


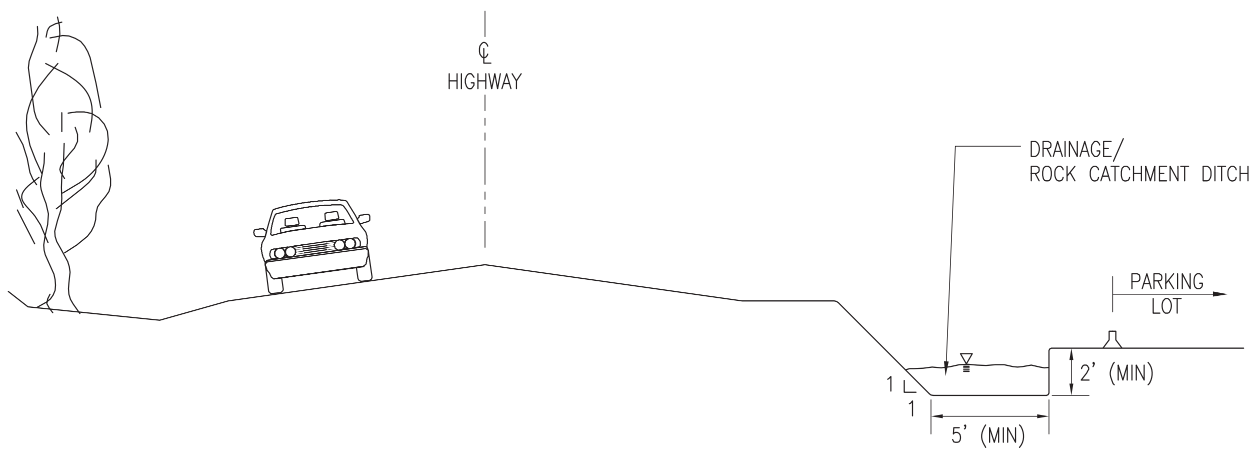
Figure 3-5
Design Alternative No. 5
Catchment Ditch



SCHEMATIC SECTION AT LO'I

NOT TO SCALE

Figure 3-6
Elevated Walkway



SCHEMATIC SECTION @ PARKING LOT

NOT TO SCALE

Figure 3-7
Drainage\Catchment Ditch at Parking Lot

4.0 REFERENCES

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Appendix A
Rockfall Simulation Data

Rockfall simulation input and output data for profile P1

CRSP Input File -L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G185 m.bmp

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 23
Analysis Point 1 X-Coordinate: 433
Analysis Point 2 X-Coordinate:
Analysis Point 3 X-Coordinate:
Initial Y-Top Starting Zone Coordinate: 575
Initial Y-Base Starting Zone Coordinate: 575

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	616	15	618
2	.8	.8	.2	15	618	31	616
3	.8	.8	.2	31	616	48	609
4	.8	.8	.2	48	609	73	601
5	.8	.8	.2	73	601	85	598
6	.8	.8	.2	85	598	100	588
7	.8	.8	.2	100	588	113	579
8	.8	.8	.2	113	579	127	566
9	.8	.8	.2	127	566	141	553
10	.8	.8	.2	141	553	154	537
11	.8	.8	.2	154	537	169	517
12	.8	.8	.2	169	517	182	495
13	.8	.8	.2	182	495	200	472
14	.8	.8	.2	200	472	215	448
15	.8	.8	.2	215	448	227	431
16	.8	.8	.2	227	431	257	326
17	.8	.8	.2	257	326	278	251
18	1.5	.8	.2	278	251	279	50
19	1.5	.8	.2	279	50	299	55
20	1.5	.8	.2	299	55	329	46
21	1.5	.8	.2	329	46	381	30
22	1.5	.8	.2	381	30	433	25
23	1.5	.8	.2	433	25	434	25

CRSP Simulation Specifications: Used with L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G185 m.bmp

Total Number of Rocks Simulated: 200
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec

Starting Cell Number: 1
Ending Cell Number: 23
Rock Density: 145 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G185 m.bmp

Analysis Point 1: X = 433, Y = 25

Total Rocks Passing Analysis Point: 7

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	11.79	16246	0.27
75%	14.67	25104	1.26
90%	17.27	33072	2.14
95%	18.83	37855	2.67
98%	20.57	43223	3.26

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 21.12	Maximum: .41	Maximum: 45403
Average: 11.79	Average: .29	Average: 16246
Minimum: 8.48	G. Mean: .27	Std. Dev.: 13119
Std. Dev.: 4.27	Std. Dev.: 1.45	

Remarks:

CRSP Data Collected at End of Each Cell - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G185 m.bmp

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	No rocks	past end of cell			
2	No rocks	past end of cell			
3	No rocks	past end of cell			
4	No rocks	past end of cell			
5	No rocks	past end of cell			
6	No rocks	past end of cell			
7	No rocks	past end of cell			
8	22	18	1.42	1	0

9	32	27	2.01	3	0
10	43	37	3.44	6	2
11	55	44	4.1	8	3
12	63	54	5.08	14	6
13	73	54	7.3	11	3
14	80	62	7.13	17	7
15	81	65	7.35	19	7
16	107	87	9.6	81	59
17	126	104	10.93	126	84
18	127	105	10.99	325	282
19	145	121	12.19	286	219
20	173	146	13.94	229	124
21	173	55	64.11	94	11
22	21	12	4.27	0	0
23	16	10	3.59	1	0

CRSP Rocks Stopped Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G185 m.bmp

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0

320 To 330 ft	0
330 To 340 ft	5
340 To 350 ft	11
350 To 360 ft	14
360 To 370 ft	16
370 To 380 ft	12
380 To 390 ft	37
390 To 400 ft	38
400 To 410 ft	29
410 To 420 ft	20
420 To 430 ft	11
430 To 434 ft	0

Rockfall simulation input and output data for profile P2

CRSP Input File -L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G187.bmp

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 18
Analysis Point 1 X-Coordinate: 874
Analysis Point 2 X-Coordinate:
Analysis Point 3 X-Coordinate:
Initial Y-Top Starting Zone Coordinate: 1055
Initial Y-Base Starting Zone Coordinate: 1055

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	1055	74	957
2	.8	.8	.2	74	957	144	848
3	.8	.8	.2	144	848	209	702
4	.8	.8	.2	209	702	253	590
5	.8	.8	.2	253	590	322	466
6	.8	.8	.2	322	466	406	373
7	.8	.8	.2	406	373	462	308
8	.8	.8	.2	462	308	532	239
9	.8	.8	.2	532	239	593	177
10	.8	.8	.2	593	177	640	132
11	.8	.8	.2	640	132	669	111
12	1.5	.8	.2	669	111	734	71
13	1.5	.8	.2	734	71	773	59
14	1.5	.8	.2	773	59	790	45
15	1.5	.8	.2	790	45	821	43
16	1.5	.8	.2	821	43	851	31
17	1.5	.8	.2	851	31	870	20
18	1.5	.8	.2	870	20	874	20

CRSP Simulation Specifications: Used with L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G187.bmp

Total Number of Rocks Simulated: 200
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 18
Rock Density: 145 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G187.bmp

Analysis Point 1: X = 874, Y = 20

Total Rocks Passing Analysis Point: 127

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	18.55	51397	0.33
75%	27.36	101360	4.93
90%	35.28	146299	9.08
95%	40.04	173278	11.56
98%	45.38	203558	14.35

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 67.31	Maximum: 8.91	Maximum: 450329
Average: 18.55	Average: .9	Average: 51397
Minimum: 2.87	G. Mean: .33	Std. Dev.: 73997
Std. Dev.: 13.05	Std. Dev.: 6.82	

Remarks:

CRSP Data Collected at End of Each Cell - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G187.bmp

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	68	55	5.4	12	4
2	102	77	11.34	25	9
3	135	107	17.08	75	27
4	155	121	20.59	113	33
5	167	103	23.54	80	15
6	133	81	14.94	22	7
7	123	87	14.21	32	8
8	128	79	13.68	22	6
9	113	83	13.96	23	6
10	118	79	12.81	22	6
11	117	71	13.02	18	3
12	92	59	11.53	17	6
13	73	40	11.33	10	2
14	76	46	10.7	17	7

15	62	23	12.17	4	1
16	63	23	12.29	7	1
17	66	27	11.47	11	1
18	67	19	13.05	9	0

CRSP Rocks Stopped Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G187.bmp

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	0
370 To 380 ft	0
380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0

430 To 440 ft	0
440 To 450 ft	0
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	0
530 To 540 ft	0
540 To 550 ft	0
550 To 560 ft	0
560 To 570 ft	0
570 To 580 ft	0
580 To 590 ft	0
590 To 600 ft	0
600 To 610 ft	0
610 To 620 ft	0
620 To 630 ft	0
630 To 640 ft	0
640 To 650 ft	0
650 To 660 ft	0
660 To 670 ft	0
670 To 680 ft	0
680 To 690 ft	0
690 To 700 ft	0
700 To 710 ft	0
710 To 720 ft	0
720 To 730 ft	0
730 To 740 ft	0
740 To 750 ft	0
750 To 760 ft	0
760 To 770 ft	0
770 To 780 ft	0
780 To 790 ft	0
790 To 800 ft	2
800 To 810 ft	22
810 To 820 ft	28
820 To 830 ft	5
830 To 840 ft	5
840 To 850 ft	2
850 To 860 ft	0
860 To 870 ft	0
870 To 874 ft	9

Rockfall simulation input and output data for profile P3

CRSP Input File -L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G190.dat

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 18
Analysis Point 1 X-Coordinate: 948
Analysis Point 2 X-Coordinate:
Analysis Point 3 X-Coordinate:
Initial Y-Top Starting Zone Coordinate: 1026
Initial Y-Base Starting Zone Coordinate: 1026

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	1026	107	933
2	.8	.8	.2	107	933	209	841
3	.8	.8	.2	209	841	249	752
4	.8	.8	.2	249	752	284	657
5	.8	.8	.2	284	657	313	554
6	.8	.8	.2	313	554	342	457
7	.8	.8	.2	342	457	382	379
8	.8	.8	.2	382	379	442	327
9	.8	.8	.2	442	327	497	279
10	.8	.8	.2	497	279	603	219
11	.8	.8	.2	603	219	678	161
12	.8	.8	.2	678	161	682	157
13	1.5	.8	.2	682	157	683	142
14	1.5	.8	.2	683	142	733	103
15	1.5	.8	.2	733	103	797	55
16	1.5	.8	.2	797	55	843	29
17	1.5	.8	.2	843	29	933	21
18	1.5	.8	.2	933	21	948	20

CRSP Simulation Specifications: Used with L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G190.dat

Total Number of Rocks Simulated: 200
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 18
Rock Density: 145 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G190.dat

Analysis Point 1: X = 948, Y = 20

Total Rocks Passing Analysis Point: 8

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	18.14	37200	0.31
75%	21.32	49063	7.55
90%	24.19	59732	14.06
95%	25.9	66137	17.97
98%	27.83	73326	22.36

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 25.35	Maximum: 1.63	Maximum: 66587
Average: 18.14	Average: .69	Average: 37200
Minimum: 10.45	G. Mean: .31	Std. Dev.: 17568
Std. Dev.: 4.71	Std. Dev.: 10.72	

Remarks:

CRSP Data Collected at End of Each Cell - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G190.dat

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	60	49	4.59	8	2
2	78	62	6.9	12	4
3	102	83	8.36	65	46
4	125	104	9.32	121	80
5	144	122	10.12	181	118
6	167	141	10.97	224	138
7	190	161	22.91	213	90
8	194	71	49.02	95	8
9	85	57	7.71	12	3
10	78	53	7	11	2
11	82	61	7.98	16	3
12	84	62	8	15	4
13	84	62	8.04	29	18
14	98	64	18.09	29	6
15	99	52	11.49	16	5

16	71	44	10.15	13	3
17	30	17	8.13	2	0
18	25	18	4.71	2	0

CRSP Rocks Stopped Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G190.dat

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	0
370 To 380 ft	0
380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0
430 To 440 ft	0

440 To 450 ft	0
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	0
530 To 540 ft	0
540 To 550 ft	0
550 To 560 ft	0
560 To 570 ft	0
570 To 580 ft	0
580 To 590 ft	0
590 To 600 ft	0
600 To 610 ft	0
610 To 620 ft	0
620 To 630 ft	0
630 To 640 ft	0
640 To 650 ft	0
650 To 660 ft	0
660 To 670 ft	0
670 To 680 ft	0
680 To 690 ft	0
690 To 700 ft	0
700 To 710 ft	0
710 To 720 ft	0
720 To 730 ft	0
730 To 740 ft	0
740 To 750 ft	0
750 To 760 ft	0
760 To 770 ft	0
770 To 780 ft	0
780 To 790 ft	0
790 To 800 ft	0
800 To 810 ft	0
810 To 820 ft	0
820 To 830 ft	0
830 To 840 ft	0
840 To 850 ft	0
850 To 860 ft	3
860 To 870 ft	14
870 To 880 ft	31
880 To 890 ft	28
890 To 900 ft	25
900 To 910 ft	31
910 To 920 ft	31
920 To 930 ft	17
930 To 940 ft	8
940 To 948 ft	4

Rockfall simulation input and output data for profile P4

CRSP Input File -L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G193.dat

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 11
Analysis Point 1 X-Coordinate: 403
Analysis Point 2 X-Coordinate:
Analysis Point 3 X-Coordinate:
Initial Y-Top Starting Zone Coordinate: 258
Initial Y-Base Starting Zone Coordinate: 258

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	228	49	206
2	.8	.8	.2	49	206	90	180
3	.8	.8	.2	90	180	126	159
4	.8	.8	.2	126	159	164	135
5	.8	.8	.2	164	135	198	112
6	.8	.8	.2	198	112	206	103
7	1.5	.8	.2	206	103	207	80
8	1.5	.8	.2	207	80	272	41
9	1.5	.8	.2	272	41	337	31
10	1.5	.8	.2	337	31	403	25
11	.8	.8	.2	403	25	404	25

CRSP Simulation Specifications: Used with L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G193.dat

Total Number of Rocks Simulated: 200
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 11
Rock Density: 145 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G193.dat

Analysis Point 1: X = 403, Y = 25

Total Rocks Passing Analysis Point: 1

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	6.63	4516	0.02
75%	6.63	4516	0.69
90%	6.63	4516	1.3
95%	6.63	4516	1.66
98%	6.63	4516	2.07

Velocity (ft/sec) Bounce Height (ft) Kinetic Energy (ft-lb)

Maximum: 6.63 Maximum: .02 Maximum: 4516
Average: 6.63 Average: .02 Average: 4516
Minimum: 6.63 G. Mean: .02 Std. Dev.: 0
Std. Dev.: 0 Std. Dev.: 1

Remarks:

CRSP Data Collected at End of Each Cell - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G193.dat

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	26	21	2.04	1	0
2	39	32	2.77	3	1
3	44	36	3.44	4	1
4	52	42	4.09	5	1
5	59	46	4.73	6	2
6	63	50	5.26	10	4
7	64	50	5.33	32	27
8	80	38	9.18	9	2
9	33	17	7.16	5	0
10	7	7	0	0	0
11	5	5	0	0	0

CRSP Rocks Stopped Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G193.dat

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0

30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	4
290 To 300 ft	16
300 To 310 ft	25
310 To 320 ft	26
320 To 330 ft	26
330 To 340 ft	25
340 To 350 ft	20
350 To 360 ft	26
360 To 370 ft	12
370 To 380 ft	12
380 To 390 ft	5
390 To 400 ft	2
400 To 404 ft	0

Rockfall simulation input and output data for profile P5

CRSP Input File -L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 26
Analysis Point 1 X-Coordinate: 1155
Analysis Point 2 X-Coordinate: 1196
Analysis Point 3 X-Coordinate:
Initial Y-Top Starting Zone Coordinate: 1010
Initial Y-Base Starting Zone Coordinate: 1010

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	1029	66	1012
2	.8	.8	.2	66	1012	106	976
3	.8	.8	.2	106	976	152	925
4	.8	.8	.2	152	925	203	876
5	.8	.8	.2	203	876	261	814
6	.8	.8	.2	261	814	333	715
7	.8	.8	.2	333	715	397	615
8	.8	.8	.2	397	615	466	509
9	.8	.8	.2	466	509	531	402
10	.8	.8	.2	531	402	605	305
11	1.5	.8	.2	605	305	698	244
12	1.5	.8	.2	698	244	772	212
13	1.5	.8	.2	772	212	873	164
14	1.5	.8	.2	873	164	933	117
15	1.5	.8	.2	933	117	963	110
16	1.5	.8	.2	963	110	994	94
17	1.5	.8	.2	994	94	1029	73
18	1.5	.8	.2	1029	73	1038	62
19	1.5	.8	.2	1038	62	1043	62
20	1.5	.8	.2	1043	62	1046	66
21	1.5	.8	.2	1046	66	1047	66
22	1.5	.8	.2	1047	66	1088	49
23	1.5	.8	.2	1088	49	1102	33
24	1.5	.8	.2	1102	33	1142	33
25	1.5	.8	.2	1142	33	1176	10
26	1.5	.8	.2	1176	10	1196	7

CRSP Simulation Specifications: Used with L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

Total Number of Rocks Simulated: 100
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 26
Rock Density: 165 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

Analysis Point 1: X = 1155, Y = 24

NO ROCKS PAST ANALSYSIS POINT 1

CRSP Analysis Point 2 Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

Analysis Point 2: X = 1196, Y = 7

NO ROCKS PAST ANALSYSIS POINT 2

CRSP Data Collected at End of Each Cell - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

Velocity Units: ft/sec   Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	No rocks	past end of cell			
2	38	32	2.75	4	1
3	62	51	4.97	9	2
4	71	58	6.84	11	3
5	86	68	9.36	14	5
6	105	84	10.88	34	10
7	124	92	15.2	39	11
8	140	100	15.31	37	14
9	151	106	19.99	50	14
10	146	91	17.19	32	9
11	89	54	14.32	17	5

12	70	39	11.47	10	2
13	55	31	10.05	8	1
14	75	42	10.43	19	3
15	43	21	8.6	4	1
16	46	25	8.13	8	1
17	47	28	6.7	6	2
18	54	35	6.43	12	5
19	51	24	13.96	9	1
20	37	34	0	2	1
21	38	35	0	1	0
22	34	25	0	2	0
23	44	35	0	7	4
24	No rocks	past end of cell			
25	No rocks	past end of cell			
26	No rocks	past end of cell			

CRSP Rocks Stopped Data - L:\work\Infra\Rockfall Projects\Haena State Park\CRSP\G194m.bmp

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0

320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	0
370 To 380 ft	0
380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0
430 To 440 ft	0
440 To 450 ft	0
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	0
530 To 540 ft	0
540 To 550 ft	0
550 To 560 ft	0
560 To 570 ft	0
570 To 580 ft	0
580 To 590 ft	0
590 To 600 ft	0
600 To 610 ft	0
610 To 620 ft	0
620 To 630 ft	0
630 To 640 ft	0
640 To 650 ft	0
650 To 660 ft	0
660 To 670 ft	0
670 To 680 ft	0
680 To 690 ft	0
690 To 700 ft	0
700 To 710 ft	0
710 To 720 ft	0
720 To 730 ft	0
730 To 740 ft	0
740 To 750 ft	0
750 To 760 ft	0
760 To 770 ft	0
770 To 780 ft	0
780 To 790 ft	0
790 To 800 ft	0
800 To 810 ft	0
810 To 820 ft	0
820 To 830 ft	0
830 To 840 ft	0
840 To 850 ft	0
850 To 860 ft	0
860 To 870 ft	0

870 To 880 ft	0
880 To 890 ft	0
890 To 900 ft	0
900 To 910 ft	0
910 To 920 ft	0
920 To 930 ft	0
930 To 940 ft	0
940 To 950 ft	0
950 To 960 ft	5
960 To 970 ft	2
970 To 980 ft	0
980 To 990 ft	0
990 To 1000 ft	0
1000 To 1010 ft	0
1010 To 1020 ft	0
1020 To 1030 ft	0
1030 To 1040 ft	5
1040 To 1050 ft	85
1050 To 1060 ft	0
1060 To 1070 ft	0
1070 To 1080 ft	0
1080 To 1090 ft	0
1090 To 1100 ft	0
1100 To 1110 ft	0
1110 To 1120 ft	2
1120 To 1130 ft	1
1130 To 1140 ft	0
1140 To 1150 ft	0
1150 To 1160 ft	0
1160 To 1170 ft	0
1170 To 1180 ft	0
1180 To 1190 ft	0
1190 To 1196 ft	0

Rockfall simulation input and output data for profile N0

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 10
Analysis Point 1 X-Coordinate: 376
Analysis Point 2 X-Coordinate: 400
Analysis Point 3 X-Coordinate: 460
Initial Y-Top Starting Zone Coordinate: 507
Initial Y-Base Starting Zone Coordinate: 507

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	507	66	432
2	.8	.8	.2	66	432	66.1	369
3	.8	.8	.2	66.1	369	218.4	173.8
4	.8	.8	.2	218.4	173.8	221.6	171.5
5	.8	.8	.2	221.6	171.5	221.7	24.4
6	.8	.8	.2	221.7	24.4	242	30
7	.8	.8	.2	242	30	272	21
8	.8	.8	.2	272	21	324	5
9	.8	.8	.2	324	5	376	0
10	.8	.8	.2	376	0	500	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 10
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

Analysis Point 1: X = 376, Y = 0

Total Rocks Passing Analysis Point: 808

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	18.09	45356	0.11
75%	24.5	104656	5.9
90%	30.27	157993	11.1
95%	33.73	190014	14.23
98%	37.62	225953	17.74

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 120.08	Maximum: 18.26	Maximum: 1277169
Average: 18.09	Average: .39	Average: 45356
Minimum: 3.09	G. Mean: .11	Std. Dev.: 87826
Std. Dev.: 9.5	Std. Dev.: 8.57	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

Analysis Point 2: X = 400, Y = 0

Total Rocks Passing Analysis Point: 379

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	12.44	20757	0.07
75%	15.86	31404	6.1
90%	18.94	40981	11.52
95%	20.79	46730	14.77
98%	22.87	53183	18.43

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 28.11	Maximum: 1.5	Maximum: 89967
Average: 12.44	Average: .22	Average: 20757
Minimum: 2.79	G. Mean: .07	Std. Dev.: 15769
Std. Dev.: 5.07	Std. Dev.: 8.93	

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

Analysis Point 3: X = 460, Y = 0

NO ROCKS PAST ANALSYSIS POINT 3

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	59	48	4.57	8	2
2	60	48	4.59	71	65
3	102	72	10.41	23	7
4	104	70	12.6	21	5
5	104	70	12.61	167	152
6	116	81	14	137	121
7	134	98	15.36	126	80
8	136	56	38.61	89	10
9	120	18	9.5	18	0
10	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\P1 New.dat

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0

110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	2
340 To 350 ft	14
350 To 360 ft	43
360 To 370 ft	76
370 To 380 ft	120
380 To 390 ft	182
390 To 400 ft	186
400 To 410 ft	169
410 To 420 ft	121
420 To 430 ft	53
430 To 440 ft	28
440 To 450 ft	6
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0

Rockfall simulation input and output data for profile N1 (with the small launching pad)

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 12
Analysis Point 1 X-Coordinate: 322
Analysis Point 2 X-Coordinate: 346
Analysis Point 3 X-Coordinate: 406
Initial Y-Top Starting Zone Coordinate: 509
Initial Y-Base Starting Zone Coordinate: 509

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	509	66	434
2	.8	.8	.2	66	434	66.1	392
3	.8	.8	.2	66.1	392	219.7	208.1
4	.8	.8	.2	219.7	208.1	222.6	207.3
5	.8	.8	.2	222.6	207.3	222.7	54.7
6	.8	.8	.2	222.7	54.7	241	44
7	.8	.8	.2	241	44	265	29
8	.8	.8	.2	265	29	300	7
9	.8	.8	.2	300	7	322	2
10	.8	.8	.2	322	2	337	4
11	.8	.8	.2	337	4	346	3
12	.8	.8	.2	346	3	500	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 12
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 1: X = 322, Y = 2

Total Rocks Passing Analysis Point: 1000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	91.79	904203	8.43
75%	121.52	1298257	20.95
90%	148.26	1652685	32.21
95%	164.32	1865470	38.97
98%	182.34	2104284	46.56

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 146.6	Maximum: 150.22	Maximum: 1842836
Average: 91.79	Average: 39.58	Average: 904203
Minimum: 7.71	G. Mean: 8.43	Std. Dev.: 583611
Std. Dev.: 44.03	Std. Dev.: 18.55	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 2: X = 346, Y = 3

Total Rocks Passing Analysis Point: 654

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	57.3	509273	0.66
75%	91.48	908600	21.85
90%	122.21	1267768	40.91
95%	140.67	1483400	52.35
98%	161.38	1725408	65.19

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 141.42	Maximum: 116.84	Maximum: 1750012
Average: 57.3	Average: 15.24	Average: 509273
Minimum: 2.97	G. Mean: .66	Std. Dev.: 591419
Std. Dev.: 50.61	Std. Dev.: 31.38	

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 3: X = 406, Y = 2

Total Rocks Passing Analysis Point: 56

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	15.62	66339	0.05
75%	30.46	236777	7.34
90%	43.81	390074	13.9
95%	51.82	482109	17.84
98%	60.81	585401	22.25

Velocity (ft/sec) Bounce Height (ft) Kinetic Energy (ft-lb)

Maximum: 127.01 Maximum: 4.69 Maximum: 1398117
Average: 15.62 Average: .29 Average: 66339
Minimum: 3.2 G. Mean: .05 Std. Dev.: 252424
Std. Dev.: 21.98 Std. Dev.: 10.8

Remarks:

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	59	48	4.44	8	3
2	59	48	4.46	50	44
3	101	72	10.03	20	6
4	100	64	17.72	18	4
5	101	64	17.74	170	156
6	111	72	20.14	163	148
7	126	86	20.66	170	128
8	148	109	20.02	168	82
9	147	92	44.03	150	39
10	143	77	51.83	129	24
11	141	57	50.61	117	15
12	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	121
330 To 340 ft	195
340 To 350 ft	88
350 To 360 ft	119
360 To 370 ft	138
370 To 380 ft	114
380 To 390 ft	84
390 To 400 ft	54
400 To 410 ft	47
410 To 420 ft	20

420 To 430 ft	10
430 To 440 ft	5
440 To 450 ft	1
450 To 460 ft	1
460 To 470 ft	2
470 To 480 ft	1
480 To 490 ft	0
490 To 500 ft	0

Rockfall simulation input and output data for profile N1 (without the small launching pad)

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 12
Analysis Point 1 X-Coordinate: 322
Analysis Point 2 X-Coordinate: 346
Analysis Point 3 X-Coordinate: 406
Initial Y-Top Starting Zone Coordinate: 509
Initial Y-Base Starting Zone Coordinate: 509

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	509	66	434
2	.8	.8	.2	66	434	66.1	392
3	.8	.8	.2	66.1	392	222.5	207.2
4	.8	.8	.2	222.5	207.2	222.6	207.3
5	.8	.8	.2	222.6	207.3	222.7	54.7
6	.8	.8	.2	222.7	54.7	241	44
7	.8	.8	.2	241	44	265	29
8	.8	.8	.2	265	29	300	7
9	.8	.8	.2	300	7	322	2
10	.8	.8	.2	322	2	337	4
11	.8	.8	.2	337	4	346	3
12	.8	.8	.2	346	3	500	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 12
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 1: X = 322, Y = 2

Total Rocks Passing Analysis Point: 978

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	94.11	986860	5.24
75%	126.91	1423906	17.65
90%	156.4	1817002	28.81
95%	174.11	2053002	35.51
98%	193.99	2317871	43.03

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 150.19	Maximum: 102.55	Maximum: 1933660
Average: 94.11	Average: 27.33	Average: 986860
Minimum: 10.44	G. Mean: 5.24	Std. Dev.: 647284
Std. Dev.: 48.57	Std. Dev.: 18.38	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 2: X = 346, Y = 3

Total Rocks Passing Analysis Point: 600

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	45.79	410200	0.28
75%	79.75	831584	14.79
90%	110.29	1210593	27.84
95%	128.63	1438135	35.68
98%	149.21	1693512	44.47

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 138.33	Maximum: 60.72	Maximum: 1692449
Average: 45.79	Average: 5.57	Average: 410200
Minimum: 2.61	G. Mean: .28	Std. Dev.: 624087
Std. Dev.: 50.29	Std. Dev.: 21.49	

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Analysis Point 3: X = 406, Y = 2

Total Rocks Passing Analysis Point: 48

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	11.12	16479	0.05
75%	14.21	25022	5.78
90%	16.99	32706	10.93
95%	18.66	37319	14.03
98%	20.54	42497	17.5

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 20.11	Maximum: 1.01	Maximum: 45903
Average: 11.12	Average: .16	Average: 16479
Minimum: 3.62	G. Mean: .05	Std. Dev.: 12652
Std. Dev.: 4.58	Std. Dev.: 8.49	

Remarks:

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	59	48	4.83	8	2
2	59	48	4.84	50	44
3	99	73	9.77	19	6
4	99	72	11.07	19	6
5	100	72	11.09	171	158
6	110	82	11.04	162	145
7	125	96	12.37	149	119
8	147	117	15.79	129	69
9	150	94	48.57	103	27

10	146	67	57.65	76	11
11	138	46	50.29	61	5
12	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N1Correct.doc

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	22
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	118
330 To 340 ft	213
340 To 350 ft	107
350 To 360 ft	139
360 To 370 ft	134
370 To 380 ft	94
380 To 390 ft	65
390 To 400 ft	40
400 To 410 ft	32
410 To 420 ft	20

420 To 430 ft	9
430 To 440 ft	6
440 To 450 ft	1
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0

Rockfall simulation input and output data for profile N2

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 15
Analysis Point 1 X-Coordinate: 405
Analysis Point 2 X-Coordinate: 655
Analysis Point 3 X-Coordinate: 735
Initial Y-Top Starting Zone Coordinate: 725
Initial Y-Base Starting Zone Coordinate: 725

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	725	66	650
2	.8	.8	.2	66	650	66.2	606
3	.8	.8	.2	66.2	606	340	278
4	.8	.8	.2	340	278	355	258
5	.8	.8	.2	355	258	405	63
6	.8	.8	.2	405	63	427	63
7	.8	.8	.2	427	63	492	60
8	.8	.8	.2	492	60	519	41
9	.8	.8	.2	519	41	545	31
10	.8	.8	.2	545	31	566	17
11	.8	.8	.2	566	17	621	9
12	.8	.8	.2	621	9	655	7
13	.8	.8	.2	655	7	675	7
14	.8	.8	.2	675	7	717	5
15	.8	.8	.2	717	5	817	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 15
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

Analysis Point 1: X = 405, Y = 63

Total Rocks Passing Analysis Point: 1000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	110.59	1137856	125.67
75%	119.57	1301697	126.45
90%	127.66	1449061	127.15
95%	132.51	1537533	127.57
98%	137.96	1636828	128.05

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 144.11	Maximum: 165.91	Maximum: 1804274
Average: 110.59	Average: 126.98	Average: 1137856
Minimum: 78.75	G. Mean: 125.67	Std. Dev.: 242654
Std. Dev.: 13.31	Std. Dev.: 1.16	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

Analysis Point 2: X = 655, Y = 7

Total Rocks Passing Analysis Point: 173

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	13.09	24987	0.05
75%	17.82	43491	7.34
90%	22.08	60135	13.91
95%	24.63	70127	17.85
98%	27.5	81341	22.27

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 40.76	Maximum: 2.34	Maximum: 186693
Average: 13.09	Average: .23	Average: 24987

Minimum: 2.88 G. Mean: .05 Std. Dev.: 27405
Std. Dev.: 7.01 Std. Dev.: 10.81

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

Analysis Point 3: X = 735, Y = 4

Total Rocks Passing Analysis Point: 3

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	11.91	17323	0.04
75%	11.91	17323	0.72
90%	11.91	17323	1.33
95%	11.91	17323	1.69
98%	11.91	17323	2.1

Velocity (ft/sec) Bounce Height (ft) Kinetic Energy (ft-lb)

Maximum: 16.49 Maximum: .3 Maximum: 30828
Average: 11.91 Average: .18 Average: 17323
Minimum: 8.9 G. Mean: .04 Std. Dev.: 0
Std. Dev.: 0 Std. Dev.: 1

Remarks:

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	60	48	4.67	8	3
2	60	49	4.7	52	46
3	117	82	12.48	25	7
4	118	85	12.4	27	9
5	144	111	13.31	166	126
6	156	123	13.62	142	83

7	146	28	37.71	52	1
8	140	32	11.72	22	1
9	63	29	6.95	5	0
10	65	35	6.99	11	1
11	44	17	6.54	4	0
12	41	13	7.01	2	0
13	30	13	7.27	2	0
14	21	15	6.02	1	0
15	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N2 new.doc

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0

360 To 370 ft	0
370 To 380 ft	0
380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0
430 To 440 ft	0
440 To 450 ft	9
450 To 460 ft	47
460 To 470 ft	86
470 To 480 ft	113
480 To 490 ft	148
490 To 500 ft	24
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	0
530 To 540 ft	0
540 To 550 ft	0
550 To 560 ft	0
560 To 570 ft	0
570 To 580 ft	0
580 To 590 ft	0
590 To 600 ft	0
600 To 610 ft	4
610 To 620 ft	10
620 To 630 ft	78
630 To 640 ft	118
640 To 650 ft	129
650 To 660 ft	113
660 To 670 ft	56
670 To 680 ft	31
680 To 690 ft	15
690 To 700 ft	5
700 To 710 ft	6
710 To 720 ft	3
720 To 730 ft	2
730 To 740 ft	0
740 To 750 ft	2
750 To 760 ft	1
760 To 770 ft	0
770 To 780 ft	0
780 To 790 ft	0
790 To 800 ft	0
800 To 810 ft	0
810 To 817 ft	0

Rockfall simulation input and output data for profile N3

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 14
Analysis Point 1 X-Coordinate: 722
Analysis Point 2 X-Coordinate: 741
Analysis Point 3 X-Coordinate: 801
Initial Y-Top Starting Zone Coordinate: 1043
Initial Y-Base Starting Zone Coordinate: 1043

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	1043	66	967
2	.8	.8	.2	66	967	181	727
3	.8	.8	.2	181	727	266	622
4	.8	.8	.2	266	622	286	542
5	.8	.8	.2	286	542	697	105
6	.8	.8	.2	697	105	697.2	99
7	.8	.8	.2	697.2	99	705.9	86.2
8	.8	.8	.2	705.9	86.2	707.6	85.2
9	.8	.8	.2	707.6	85.2	717.8	12.4
10	.8	.8	.2	717.8	12.4	721.7	11.6
11	.8	.8	.2	721.7	11.6	736.7	11.6
12	.8	.8	.2	736.7	11.6	740.7	11.3
13	.8	.65	.1	740.7	11.3	760.2	0
14	.8	.65	.1	760.2	0	900	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 14
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

Analysis Point 1: X = 722, Y = 12

Total Rocks Passing Analysis Point: 1000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	93.38	861966	69.99
75%	102.6	1013055	70.77
90%	110.9	1148951	71.46
95%	115.88	1230537	71.87
98%	121.47	1322103	72.34

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 135.11	Maximum: 96.04	Maximum: 1662134
Average: 93.38	Average: 70.59	Average: 861966
Minimum: 59.43	G. Mean: 69.99	Std. Dev.: 223769
Std. Dev.: 13.66	Std. Dev.: 1.14	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

Analysis Point 2: X = 741, Y = 11

Total Rocks Passing Analysis Point: 1000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	102.22	1001926	41.41
75%	111.58	1166344	42.4
90%	119.99	1314227	43.29
95%	125.04	1403011	43.83
98%	130.71	1502655	44.43

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 142.82	Maximum: 76.61	Maximum: 1834971
Average: 102.22	Average: 44.12	Average: 1001926
Minimum: 69.09	G. Mean: 41.41	Std. Dev.: 243509

Std. Dev.: 13.85 Std. Dev.: 1.47

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

Analysis Point 3: X = 801, Y = 0

Total Rocks Passing Analysis Point: 399

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	22.82	127244	0.06
75%	41.81	344474	9.41
90%	58.88	539858	17.81
95%	69.13	657160	22.86
98%	80.64	788810	28.52

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 127.68	Maximum: 19.59	Maximum: 1528599
Average: 22.82	Average: .69	Average: 127244
Minimum: 2.44	G. Mean: .06	Std. Dev.: 321726
Std. Dev.: 28.12	Std. Dev.: 13.84	

Remarks:

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	61	49	4.82	9	3
2	133	93	16.34	54	16
3	113	82	11.75	28	7
4	122	92	12.12	82	60
5	125	83	13.19	27	6
6	125	83	13.19	33	12
7	129	86	13.4	36	15

8	129	87	13.43	36	14
9	133	91	13.6	99	75
10	135	93	13.66	96	70
11	141	100	13.82	81	50
12	143	102	13.85	77	44
13	151	100	27.5	65	25
14	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N3.bmp

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0
300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	0
370 To 380 ft	0

380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0
430 To 440 ft	0
440 To 450 ft	0
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	0
530 To 540 ft	0
540 To 550 ft	0
550 To 560 ft	0
560 To 570 ft	0
570 To 580 ft	0
580 To 590 ft	0
590 To 600 ft	0
600 To 610 ft	0
610 To 620 ft	0
620 To 630 ft	0
630 To 640 ft	0
640 To 650 ft	0
650 To 660 ft	0
660 To 670 ft	0
670 To 680 ft	0
680 To 690 ft	0
690 To 700 ft	0
700 To 710 ft	0
710 To 720 ft	0
720 To 730 ft	0
730 To 740 ft	0
740 To 750 ft	0
750 To 760 ft	0
760 To 770 ft	19
770 To 780 ft	105
780 To 790 ft	213
790 To 800 ft	247
800 To 810 ft	166
810 To 820 ft	133
820 To 830 ft	60
830 To 840 ft	34
840 To 850 ft	12
850 To 860 ft	7
860 To 870 ft	4
870 To 880 ft	0
880 To 890 ft	0
890 To 900 ft	0

Rockfall simulation input and output data for profile N4

CRSP Input File -C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 12
Analysis Point 1 X-Coordinate: 272
Analysis Point 2 X-Coordinate: 314
Analysis Point 3 X-Coordinate: 396
Initial Y-Top Starting Zone Coordinate: 749
Initial Y-Base Starting Zone Coordinate: 749

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	749	66	673
2	.8	.8	.2	66	673	99	351
3	.8	.8	.2	99	351	183	266
4	.8	.8	.2	183	266	245	187
5	.8	.8	.2	245	187	255	160
6	.8	.8	.2	255	160	272	14
7	.8	.8	.2	272	14	296	14
8	.8	.8	.2	296	14	314	14
9	.8	.8	.2	314	14	336	12.2
10	.8	.8	.2	336	12.2	339.4	12
11	.8	.8	.2	339.4	12	360	0
12	.8	.6	.1	360	0	450	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 12
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Analysis Point 1: X = 272, Y = 14

Total Rocks Passing Analysis Point: 1000

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	81.57	642902	135.64
75%	92.48	860812	136.39
90%	102.29	1056808	137.07
95%	108.18	1174476	137.47
98%	114.79	1306538	137.93

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 200.75	Maximum: 159.42	Maximum: 3305991
Average: 81.57	Average: 136.37	Average: 642902
Minimum: 55.08	G. Mean: 135.64	Std. Dev.: 322733
Std. Dev.: 16.15	Std. Dev.: 1.11	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Analysis Point 2: X = 314, Y = 14

Total Rocks Passing Analysis Point: 944

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	102.79	988459	25.87
75%	120.47	1200648	30.37
90%	136.38	1391500	34.41
95%	145.93	1506080	36.84
98%	156.65	1634676	39.57

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 139.97	Maximum: 105.81	Maximum: 1882099
Average: 102.79	Average: 46.77	Average: 988459
Minimum: 5.21	G. Mean: 25.87	Std. Dev.: 314262

Std. Dev.: 26.19 Std. Dev.: 6.66

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Analysis Point 3: X = 396, Y = 0

Total Rocks Passing Analysis Point: 144

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	11.37	17433	0.04
75%	14.6	26902	6.19
90%	17.51	35419	11.72
95%	19.25	40532	15.05
98%	21.21	46271	18.77

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 24.97	Maximum: .74	Maximum: 71123
Average: 11.37	Average: .13	Average: 17433
Minimum: 2.69	G. Mean: .04	Std. Dev.: 14024
Std. Dev.: 4.78	Std. Dev.: 9.11	

Remarks:

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	60	49	4.61	8	3
2	94	76	8.09	295	271
3	172	132	43.32	201	72
4	183	65	23.11	51	5
5	186	70	15.85	35	18
6	201	82	16.15	159	136
7	151	98	12.37	131	87

8	140	103	26.19	106	46
9	135	60	51.1	72	12
10	137	55	50.74	66	9
11	134	37	27.17	38	1
12	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N4.dat

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	1
290 To 300 ft	6
300 To 310 ft	26
310 To 320 ft	35
320 To 330 ft	68
330 To 340 ft	111
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	68
370 To 380 ft	320
380 To 390 ft	147
390 To 400 ft	122

400 To 410 ft	69
410 To 420 ft	22
420 To 430 ft	5
430 To 440 ft	0
440 To 450 ft	0

Rockfall simulation input and output data for profile N5

Input File Specifications

Units of Measure: U.S.
Total Number of Cells: 27
Analysis Point 1 X-Coordinate: 664
Analysis Point 2 X-Coordinate: 694
Analysis Point 3 X-Coordinate: 754
Initial Y-Top Starting Zone Coordinate: 773
Initial Y-Base Starting Zone Coordinate: 773

Remarks:

Cell Data

Cell No.	S.R.	Tang. C.	Norm. C.	Begin X	Begin Y	End X	End Y
1	.8	.8	.2	0	773	66	697
2	.8	.8	.2	66	697	102	345
3	1	.8	.2	102	345	168	292
4	1	.8	.2	168	292	190	275
5	1	.8	.2	190	275	220	253
6	1	.8	.2	220	253	240	240
7	1	.8	.2	240	240	254	223
8	1	.8	.2	254	223	275	212
9	1	.8	.2	275	212	332	182
10	1	.8	.2	332	182	360	164
11	1	.8	.2	360	164	365	145
12	1	.8	.2	365	145	374	139
13	1	.8	.2	374	139	383	121
14	1	.8	.2	383	121	410	105
15	1	.8	.2	410	105	432	94
16	1.5	.8	.2	432	94	448	90
17	1	.8	.2	448	90	466	79
18	1	.8	.2	466	79	540	58
19	1.5	.8	.2	540	58	571	46
20	1	.8	.2	571	46	589	35
21	1	.8	.2	589	35	601	35
22	1	.8	.2	601	35	623	26
23	1	.8	.2	623	26	654	16
24	.8	.8	.2	654	16	664	9
25	.8	.8	.2	664	9	694	9
26	.8	.8	.2	694	9	710	0
27	.8	.8	.2	710	0	790	0

CRSP Simulation Specifications: Used with C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

Total Number of Rocks Simulated: 1000
Starting Velocity in X-Direction: 1 ft/sec
Starting Velocity in Y-Direction: -1 ft/sec
Starting Cell Number: 1
Ending Cell Number: 27
Rock Density: 155 lb/ft^3
Rock Shape: Spherical
Diameter: 4 ft

CRSP Analysis Point 1 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

Analysis Point 1: X = 664, Y = 9

Total Rocks Passing Analysis Point: 837

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	22.33	52945	0.26
75%	25.21	66467	6.25
90%	27.81	78629	11.64
95%	29.36	85930	14.88
98%	31.11	94125	18.51

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 39.69	Maximum: 5.73	Maximum: 156622
Average: 22.33	Average: .75	Average: 52945
Minimum: 13.49	G. Mean: .26	Std. Dev.: 20026
Std. Dev.: 4.27	Std. Dev.: 8.87	

Remarks:

CRSP Analysis Point 2 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

Analysis Point 2: X = 694, Y = 9

Total Rocks Passing Analysis Point: 89

Cumulative Probability	Velocity (ft/sec)	Energy (ft-lb)	Bounce Ht. (ft)
50%	8.47	9942	0.02
75%	11.12	16197	5.89
90%	13.5	21824	11.18
95%	14.93	25202	14.35
98%	16.54	28994	17.91

Velocity (ft/sec)	Bounce Height (ft)	Kinetic Energy (ft-lb)
Maximum: 19.5	Maximum: .65	Maximum: 42960
Average: 8.47	Average: .08	Average: 9942
Minimum: 2.73	G. Mean: .02	Std. Dev.: 9265
Std. Dev.: 3.92	Std. Dev.: 8.7	

Remarks:

CRSP Analysis Point 3 Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

Analysis Point 3: X = 754, Y = 0

NO ROCKS PAST ANALSYSIS POINT 3

CRSP Data Collected at End of Each Cell - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

Velocity Units: ft/sec Bounce Height Units: ft

Cell #	Max. Vel.	Avg. Vel.	S.D. Vel.	Max. Bounce Ht.	Avg. Bounce Ht.
1	59	49	4.62	8	3
2	98	79	8.45	322	293
3	171	141	15.96	253	128
4	175	120	57.03	210	57
5	177	59	50.86	134	8
6	178	41	24	72	2
7	180	46	11.2	32	6
8	63	37	7.61	12	1
9	62	38	5.95	8	1
10	62	42	6.39	9	2
11	64	45	6.65	25	17
12	69	50	6.96	24	15

13	75	56	7.19	37	23
14	82	50	17.6	34	4
15	83	37	7.51	20	1
16	51	28	6.97	6	1
17	58	35	7.06	12	2
18	42	22	6.81	4	0
19	46	19	7.68	5	0
20	49	25	6.25	9	0
21	39	14	5.62	3	0
22	43	17	4.99	4	0
23	34	16	4.83	3	0
24	40	22	4.27	6	0
25	19	8	3.92	1	0
26	31	17	2.91	2	0
27	No rocks	past end of cell			

CRSP Rocks Stopped Data - C:\Users\Yucheng\Documents\Pan\Haena State Park\CRSP\N5.dat

X Interval	Rocks Stopped
0 To 10 ft	0
10 To 20 ft	0
20 To 30 ft	0
30 To 40 ft	0
40 To 50 ft	0
50 To 60 ft	0
60 To 70 ft	0
70 To 80 ft	0
80 To 90 ft	0
90 To 100 ft	0
100 To 110 ft	0
110 To 120 ft	0
120 To 130 ft	0
130 To 140 ft	0
140 To 150 ft	0
150 To 160 ft	0
160 To 170 ft	0
170 To 180 ft	0
180 To 190 ft	0
190 To 200 ft	0
200 To 210 ft	0
210 To 220 ft	0
220 To 230 ft	0
230 To 240 ft	0
240 To 250 ft	0
250 To 260 ft	0
260 To 270 ft	0
270 To 280 ft	0
280 To 290 ft	0
290 To 300 ft	0

300 To 310 ft	0
310 To 320 ft	0
320 To 330 ft	0
330 To 340 ft	0
340 To 350 ft	0
350 To 360 ft	0
360 To 370 ft	0
370 To 380 ft	0
380 To 390 ft	0
390 To 400 ft	0
400 To 410 ft	0
410 To 420 ft	0
420 To 430 ft	0
430 To 440 ft	0
440 To 450 ft	0
450 To 460 ft	0
460 To 470 ft	0
470 To 480 ft	0
480 To 490 ft	0
490 To 500 ft	0
500 To 510 ft	0
510 To 520 ft	0
520 To 530 ft	1
530 To 540 ft	1
540 To 550 ft	3
550 To 560 ft	8
560 To 570 ft	15
570 To 580 ft	1
580 To 590 ft	0
590 To 600 ft	99
600 To 610 ft	35
610 To 620 ft	0
620 To 630 ft	0
630 To 640 ft	0
640 To 650 ft	0
650 To 660 ft	0
660 To 670 ft	4
670 To 680 ft	314
680 To 690 ft	350
690 To 700 ft	82
700 To 710 ft	0
710 To 720 ft	18
720 To 730 ft	55
730 To 740 ft	13
740 To 750 ft	1
750 To 760 ft	0
760 To 770 ft	0
770 To 780 ft	0
780 To 790 ft	0

Appendix B
Cost Estimates

Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 1
Wire Mesh Drape System

Length: 3050 FT Covered Area: 4843760 SF

Item	Quantity		Engineer's Estimate	
	Unit	Qty	$/U	Total
Mobilization/ De-mobilization	LS	1	100000	100,000
General clear and grub	SF	4843760	2.0	9,687,520
Rock Scaling (2 Crews of 3)	HRS	40	1,100	44,000
Rock Demolition	DAYS	5	6,000	30,000
Draped Mesh System	SF	4843760	28	135,625,285
Traffic Control	HRS	830	105	87,150
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	CY	1020	5	5,100
Erosion Control/Hydromulching	SF	4843760	0.8	3,875,008
Subtotal				149,464,063
Contingencies (@ 10%)				14,946,406
O & P (@ 20%)				29,892,813
Hawaii Tax (@ 4.712%)				9,155,571
Bonding (@ 1.5%)				3,051,883
Total Construction Cost				$ 206,510,736
			Rounded	$ 206,510,000

Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 2
Anchored Wire Mesh System

Length: 3050 FT Covered Area: 4843760 SF

Item	Quantity Unit	Quantity Qty	Engineer's Estimate $/U	Engineer's Estimate Total
Mobilization/ De-mobilization	LS	1	100000	100,000
General clear and grub	SF	4843760	2.0	9,687,520
Rock Scaling (2 Crews of 3)	HRS	40	1,100	44,000
Rock Demolition	DAYS	5	6,000	30,000
Draped Mesh System	SF	4843760	48	232,500,488
Traffic Control	HRS	830	105	87,150
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	CY	1020	5	5,100
Erosion Control/Hydromulching	SF	4843760	0.8	3,875,008
Subtotal				246,339,267
Contingencies (@ 10%)				24,633,927
O & P (@ 20%)				49,267,853
Hawaii Tax (@ 4.712%)				15,089,758
Bonding (@ 1.5%)				5,029,962
Total Construction Cost				$ 340,360,767
			Rounded	$ 340,360,000

Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 3
Impact Fence System

Length: 3050 FT Covered Area: 4843760 SF

Item	Quantity Unit	Quantity Qty	Engineer's Estimate $/U	Engineer's Estimate Total
Mobilization/ De-mobilization	LS	1	100000	100,000
General clear and grub	SF	61000	2.0	122,000
Rock Scaling (2 Crews of 3)	HRS	200	1,100	220,000
Rock Demolition	DAYS	20	6,000	120,000
Rockfall Impact Fence	LF	3050	1,800	5,490,000
Traffic Control	HRS	830	105	87,150
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	CY	1020	5	5,100
Erosion Control/Hydromulching	SF	61000	0.8	48,800
Subtotal				6,203,050
Contingencies (@ 10%)				620,305
O & P (@ 20%)				1,240,610
Hawaii Tax (@ 4.712%)				379,974
Bonding (@ 1.5%)				126,659
Total Construction Cost				$ 8,570,598
			Rounded	$ 8,570,000

Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 4
Impact Fence and anchored Wire Mesh System

Length: 3050 FT Covered Area: 4843760 SF

Item	Quantity Unit	Quantity Qty	Engineer's Estimate $/U	Engineer's Estimate Total
Mobilization/ De-mobilization	LS	1	100000	100,000
General clear and grub	SF	61000	2.0	122,000
Rock Scaling (2 Crews of 3)	HRS	200	1,100	220,000
Rock Demolition	DAYS	20	6,000	120,000
Rockfall Impact Fence	LF	3050	1,800	5,490,000
Anchored Mesh System	SF	18300	48	878,400
Traffic Control	HRS	830	105	87,150
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	CY	1020	5	5,100
Erosion Control/Hydromulching	SF	61000	0.8	48,800
Subtotal				7,081,450
Contingencies (@ 10%)				708,145
O & P (@ 20%)				1,416,290
Hawaii Tax (@ 4.712%)				433,781
Bonding (@ 1.5%)				144,595
Total Construction Cost				$ 9,784,261
			Rounded	$ 9,780,000

Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 5
Catchment Ditch

Length: 3050 FT Covered Area: 4843760 SF

Item	Quantity Unit	Quantity Qty	Engineer's Estimate $/U	Engineer's Estimate Total
Mobilization/ De-mobilization	LS	1	100000	100,000
General clear and grub	SF	61000	2.0	122,000
Rock Scaling (2 Crews of 3)	HRS	40	1,100	44,000
Rock Demolition	DAYS	5	6,000	30,000
Excavation	CY	11861	200	2,372,222
Concrete Retaining Wall	CY	791	1,500	1,186,111
Anchored Mesh System	SF	18300	48	878,400
Traffic Control	HRS	830	105	87,150
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	CY	1020	5	5,100
Erosion Control/Hydromulching	SF	61000	0.8	48,800
Subtotal				4,883,783
Contingencies (@ 10%)				488,378
O & P (@ 20%)				976,757
Hawaii Tax (@ 4.712%)				299,161
Bonding (@ 1.5%)				99,721
Total Construction Cost				$ 6,747,801
			Rounded	$ 6,750,000

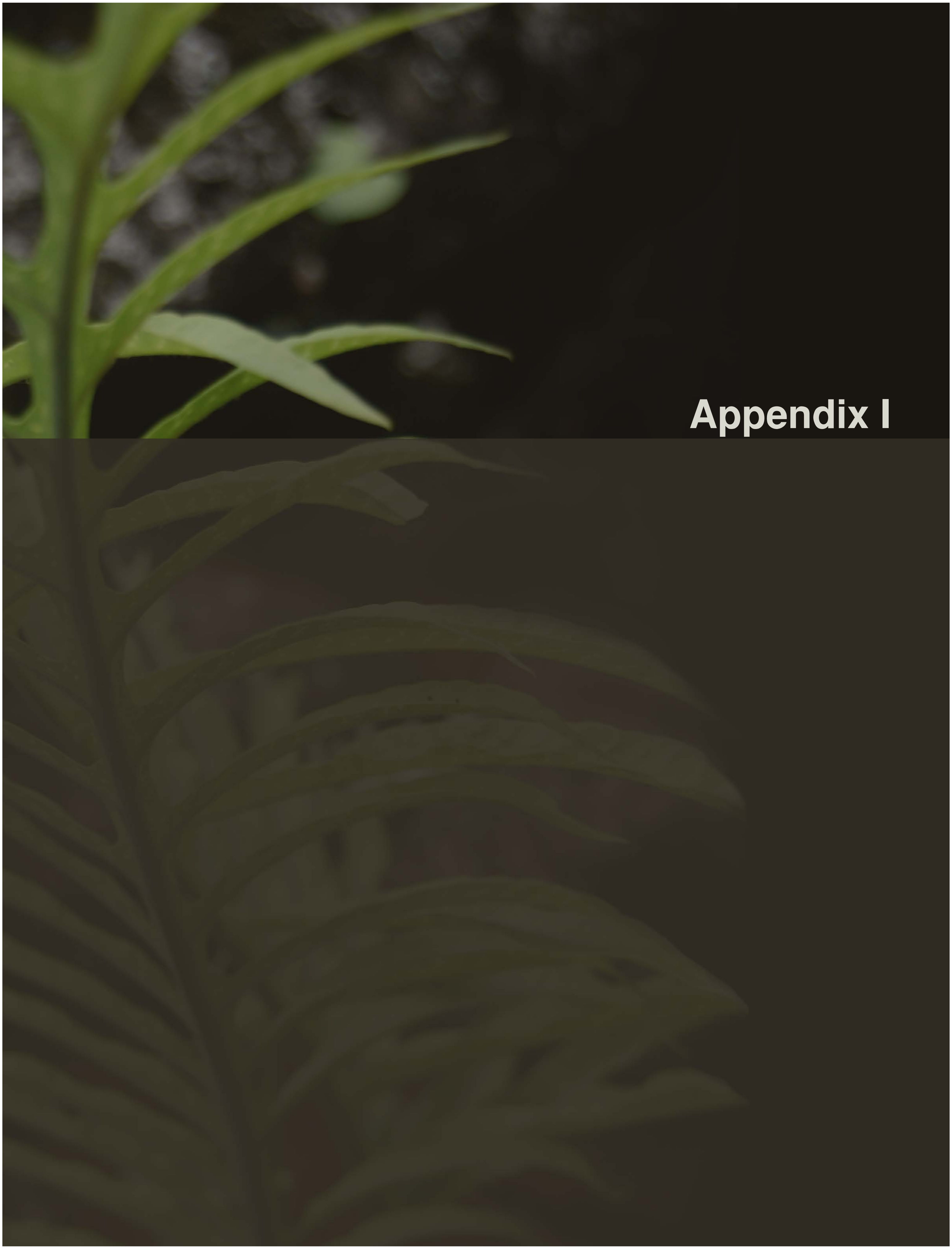
Preliminary Cost Estimate

Project:
Haena Park Rockfall Hazard Assessment

Alternative Design: No. 6
Realign Roadway

Length: 3050 FT Covered Are 4843760 SF

Item	Quantity		Engineer's Estimate	
	Unit	Qty	$/U	Total
Mobilization/ De-mobilization	LS	1	250000	250,000
General clear and grub	SF	100000	2.0	200,000
Rock Scaling (2 Crews of 3)	HRS	500	1,100	550,000
Roadway Realignment	LF	1200	6,000	7,200,000
Rockfall Impact Fence	LF	1500	1,800	2,700,000
Traffic Control	HRS	2050	105	215,250
Signage	LS	1	10,000	10,000
On Site Disposal of Debris	LS	1	40,000	40,000
Erosion Control/Hydromulching	SF	61000	0.8	48,800
Subtotal				11,214,050
Contingencies (@ 10%)				1,121,405
O & P (@ 20%)				2,242,810
Hawaii Tax (@ 4.712%)				686,928
Bonding (@ 1.5%)				228,978
Total Construction Cost				$ 15,494,171
			Rounded	$ 15,490,000



Appendix I

Appendix 1 – Hā'ena State Park Background Research Report

Please see the Hā'ena State Park website to download the Background Research Report: http://dlnr.hawaii.gov/dsp/parks/kauai/haena-state-park/

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Appendix J

Appendix J – Draft Recommendations for the Establishment and Responsibilities of the Cultural Advisory Group

Because the entire park is culturally significant, it is critical to have a Cultural Advisory Group available to provide guidance to State Parks and the management entity on park improvements, interpretive programs and management actions as these actions affect cultural sites. The management entity and park staff will be responsible for facilitating and implementing the decisions set forth by the Division of State Parks and may also seek input from other experts such as archaeologists, cultural practitioners, biologists and kūpuna, among others. The Cultural Advisory Group serves to advise State Parks on various issues that arise at the park including but not limited to interim improvement and construction projects, staff training, ongoing maintenance, and changes to park access.

Because those who serve on the Cultural Advisory Group must have a sound foundation in cultural practices and knowledge, the following criteria and process are suggested as an appropriate way to select individuals who can serve effectively as cultural advisors to Hāʻena State Park but are subject to change.

Number of Seats and Length of Term for the Cultural Advisory Group

- The Cultural Advisory Group shall be made up of five members.
- Each member shall serve a four-year term.
- Members shall serve staggered terms.

Representation within the Cultural Advisory Group

- One seat will be reserved for a representative of the original Hāʻena families, lineal descendants of Hāʻena who received kuleana lands or Land Commission Awards (LCA) within the Hāʻena ahupuaʻa.
- One seat will be reserved for a kumu hula, preferably one with knowledge specific to Ke Ahu a Laka and Ka Ulu a Paoa Heiau.
- Two seats will be filled by at-large candidates nominated and appointed by the Selection Committee for the Cultural Advisory Group (see below). The Selection Committee shall strive to appoint a Cultural Advisory Group with diverse backgrounds and expertise in Hawaiian culture relevant to Hāʻena. Ideally, the group will also be diverse in age with a mix of kūpuna and moʻopuna (multigenerational representatives).
- One seat will be reserved for a State Parks archaeologist or staff.

Criteria to Serve as an At-Large Member of the Cultural Advisory Group

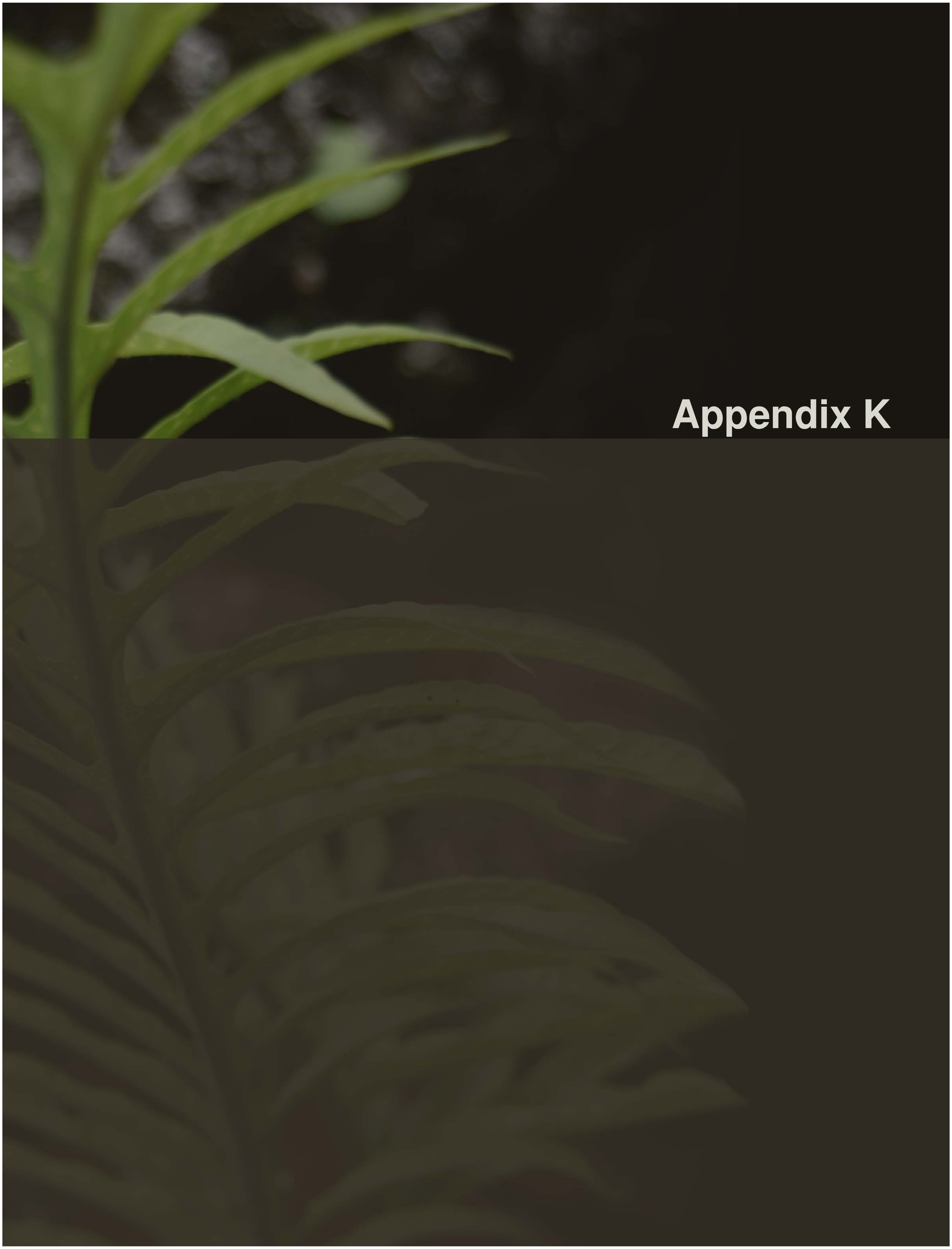
- Shall be a resident of Hawaiʻi (with preference for Kauaʻi residents).
- Shall have direct ties to Hāʻena or have expertise in Hawaiian culture and spirituality specific to Hāʻena, its sites and practices such as hula, fishing, hala weaving.
- Shall be willing to participate and uphold cultural protocols.

- Shall demonstrate a depth of cultural knowledge and protocol.
- Shall have been active for at least five years in cultural activities.
- Shall submit a biography or background information with a letter of interest that exhibits connection to the site.
- Shall be able to commit a reasonable level of service and time to the group including regular attendance at CAG meetings.

SELECTION COMMITTEE FOR THE CULTURAL ADVISORY GROUP

A three-person selection committee will screen all candidates and appoint the top candidates to serve on the Cultural Advisory Group. The Selection Committee will be made up of the following persons/representatives:

- State Parks Administrator.
- Hāʻena community representative selected by a local Hāʻena group such as the Hāʻena ʻOhana Council.
- Faculty member of the Hawaiian Studies Program of the University of Hawaiʻi system.



Appendix K

Appendix K – Case Studies for Visitor Limits

HANAUMA BAY NATURE PRESERVE

Currently, the City and County of Honolulu Department of Parks and Recreation limits the number of people in the lower level of the preserve to 2,000 persons at any one time. They also allow this number to be adjusted based on futures studies or reports. There is no other visitor limit at this time.

HUECO TANKS STATE PARK AND HISTORIC SITE

At Hueco Tanks State Park and Historic Site in Western Texas, a daily limit of 70 people within the self-guided area of the park and 160 in the guided area has been instituted. The park is 860 acres in size and includes extensive rock paintings, or pictographs, left by a mix of Native American groups and those from the prehistoric Jornada Mogollon culture. There is also a historic ranch house that serves as the park's interpretive center, and ruins of a stagecoach station. Activities permitted in the park include picnicking, camping, hiking, rock climbing, birding, nature study, viewing of prehistoric and historic pictographs, stargazing, slide shows, and guided tours. Tours are free with paid entry to the park.

Park officials still encourage people to visit the park but instituted the visitor limits to protect the resources as they have had problems with damage to the land by tourists and particularly vandalism at the pictograph sites. Visitors are encouraged to call ahead to book reservations and to check the online calendar for events and access restrictions. There is an entrance fee of $7 per day, per person 13 years and up. Children 12 and under are free. Other user fees are charged for camping and holding weddings or ceremonies at the park. There are also special rates for Texas State Parks Annual Pass holders.

NEW MEXICO

In New Mexico, their Administrative Code permits visitor limits. Section 19.5.2.9 (B) of their code reads:

> *The [park] superintendent may set a visitor capacity limit for a park or areas within a park. State park officials shall enforce each park's visitor capacity to protect visitors and to prevent damage to the park's natural or cultural resources. Once capacity is reached, state park officials shall not admit additional visitors until some of the visitors already there have left.*

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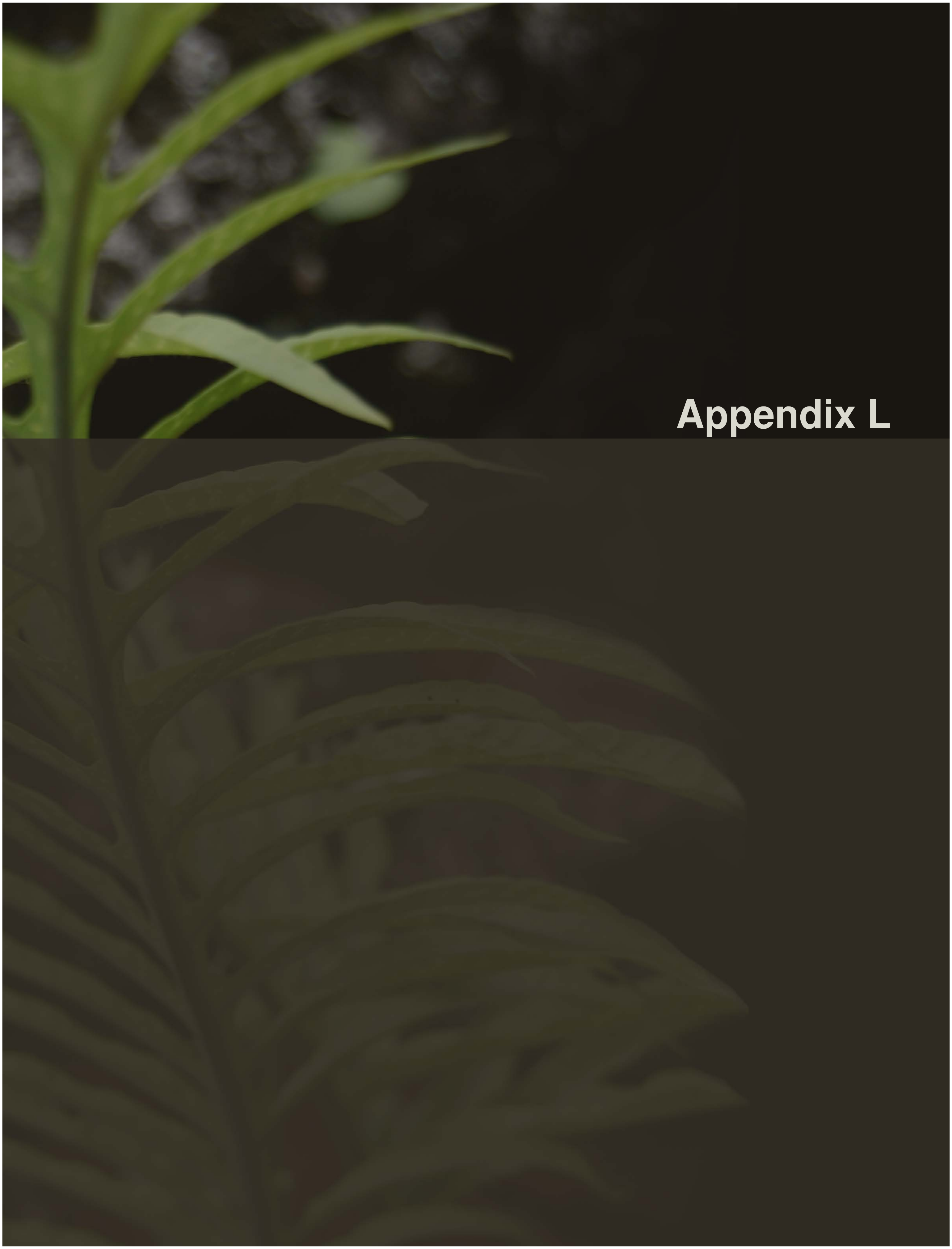


Appendix L

Appendix L – Additional Park Access, Transportation, and Parking Concepts

Throughout the master plan process, several different scenarios and alternative concepts for the following main management concepts were discussed:

- Park access and transportation modes
- Parking management
- Fees for park entry and/or parking
- Point of purchase or ticket pickup

For each component there are several management options that State Parks may consider as it adaptively manages the park. To help organize these concepts, a range of options under each component is provided in table format, including the pros and cons of each option and some discussion points or decisions that have to be made if the option is implemented. These lists provide State Parks with a menu of alternatives to consider as different management strategies are implemented and evaluated over time, allowing for flexibility for future management decisions and adjustments. The lists are not meant to be comprehensive but provide a description of the potential options. Case studies are also provided below for some of the concepts.

PARK ACCESS AND TRANSPORTATION MODES

The primary means of park access by visitors is by personal vehicle. According to traffic counts taken by ATA, over 750 vehicles enter and exit the park daily. However, this should decrease with the implementation of the daily visitor limit. During community meetings, it was also noted that people also walk, jog, and bicycle to the park; some of whom enjoy early morning or late afternoon treks to the beach when the park is not as crowded. The overwhelming sentiment from the public and project team is that the traffic congestion is a significant problem that needs to be addressed. It causes safety concerns for pedestrians, backs up traffic into the neighboring areas, discourages local residents from going to the park, and negatively impacts the overall experience at the park. While many of these issues will improve with the institution of the daily visitor limit, the following describes the pros and cons of each mode of transportation to the park.

Table 12 – Transportation Options for Park Access

Mode	Pros	Cons	Implementation Considerations
Pedestrian	• Minimal impact to environment and traffic. • Encourages healthy, active lifestyle.	• Safety concerns along highway due to narrowness of roadway.	• May require road shoulder improvements on highway leading up to park to improve safety. • Design park gates and institute policy to allow for early morning and late afternoon access to the park even when main gate is locked. Consider excluding early morning or late afternoon arrivals from daily visitor limits if counts are minimal.
Bicycle	• Minimal impact to environment and traffic. • Encourages healthy, active lifestyle.	• Safety concerns along highway due to narrowness of roadway.	• May require improvements to highway leading up to park to improve safety. • Design park gates and institute policy to allow for early morning and late afternoon access to the park even when main gate is locked. Consider excluding early morning or late afternoon arrivals from daily visitor limits if counts are minimal.
Shuttle (as independent modes of access or in combination with other modes)	• Provides an alternate means of traveling to/from the park. • May reduce traffic. • Supports those who may not be physically able to walk, bike or drive to the park as well as those who prefer not to walk, bike or drive. • Provides an opportunity to educate visitors by having informational/ orientation programing during the ride to the park. Presentation could be recorded or live. • Depending who operates the service, could provide economic opportunity for third party operators and potential jobs.	• Limited to 15- and 20-passenger vehicles due to weight limits of Kūhiō Highway bridges. • May be economically infeasible depending on rates charged, ridership, and people's willingness to pay for the service. • Will require evacuation plan for emergencies.	• Determine who will provide service. • Determine service area, routes, stops, and scheduling. Convenience is critical to increasing ridership. • Determine whether it will serve an offsite parking area. Community members suggested that if there is an offsite parking area, it should be located outside of the special flood hazard and tsunami evacuation zones. The closest place would be in Princeville. • If State Parks providing service, determine economic feasibility especially with visitor limits. • If illegal parking persists, determine whether shuttle should become mandatory. • A variety of scenarios were developed with the MPAC as part of a preliminary shuttle study. See • Appendix C.
Personal Vehicle	• Provides flexibility and convenience for park visitors. • Provides a potential source of revenue if fees are collected separately from park entry.	• Not as efficient as shuttles in bringing people to the park since there are fewer occupants per vehicle. • Adds to highway traffic, congestion within park, and parking demand. • Environmental concerns such as noise and air emissions, polluted runoff.	• Requires parking either onsite or offsite unless only drop-off is permitted. Due to the density of cultural sites, parking must be limited to previously disturbed areas of the park. • Based on community input, the majority support limiting the number of parking stalls to ~100 as a maximum, as originally recommended in the 2001 Draft Park Plan. Some of the MPAC suggested reducing it further to discourage people from driving to the park. See additional discussion under "Parking Management Options".

During the meetings with the MPAC and community, various suggestions were made including encouraging and even requiring that visitors arrive at the park by different modes of transportation to help reduce traffic. The primary modes discussed included shuttles, bicycles and pedestrian as well as different ideas on how to manage personal vehicle access. A preliminary shuttle study was completed and is attached as Appendix C. Other modes of transportation by air or water were eliminated from the discussion as most felt they were inappropriate for the park and that it would be difficult to manage multiple entry points particularly for ocean-based access. The following sections describe the three main concepts explored with the MPAC.

Scenario 1: Princeville-based Park Entry

One of the concepts introduced by members of the MPAC involved having all visitors except those with special access passes or lifetime passes to access the park via a Princeville-based park entry facility and parking lot with shuttle service to the park. The site for this facility is described as the "Alternative Princeville Site" in Appendix C. The shuttle bus would operate from the Princeville entry facility to Hāʻena, making several stops along the way. Park visitors with entry wristbands could exit and re-board the shuttle along the way; and other people (both residents and tourists) could board and exit the bus along the way, using the shuttle as a local bus service. The bus service could either be operated by, or in formal coordination with, the Kauaʻi Bus, thereby allowing it to be subsidized to the same extent that the remainder of the Kauaʻi Bus system is subsidized. The shuttle should be implemented in Phase I so a smaller parking lot (as shaded in light green or smaller) or no parking lot would be needed. No walk-in or bike-in access would be allowed as people may be encouraged to park in nearby neighborhoods and walk or bike to the park. This would also mean that no one could access the park unless they are arrive on the shuttle, including those who live between Princeville and Hāʻena. If they wanted to enter the park, they would either have to jump on the shuttle at one of the interim stops, or drive back to the Princeville-based entry point, park, and then take the shuttle in to Hāʻena. This would greatly reduce traffic to the park except for those wishing to drive till the end of the highway and turn around.

Scenario 2: Combination On-site Parking and Princeville Entry Facility

The potential Princeville site described above currently has widespread support. With an estimated potential of 200+ stalls, it would be large enough to serve the park with a 900 daily visitor limit at the current ratio of 2.5 riders per vehicle if the stalls turn over at least once per day. However, the site may also be used to serve the parking needs for other nearby uses, in which case the Princeville-based parking lot may not be sufficient for the park. The master plan shows a smaller parking lot labeled as Phase I to supplement the parking in Princeville as needed and the size of the parking lot should be adjusted appropriately so as not to discourage use of the shuttle. The stalls at the park should be made available via a reservation system similar to the entry tickets to encourage visitors to plan ahead and could be offered at a premium prices to encourage use of the shuttle and carpooling. Controls should also be instituted to limit the number of parking reservations individuals are able to make. An example of similar parking controls at Katahdin Trailheads at Baxter State Park in Maine is discussed below.

Scenario 3: On-site Parking Only

If no shuttle or transit service is available to the park, the full 100-stall parking lot will need to be built in order to minimize impacts to surrounding neighborhoods. Visitors will need to carpool more than they currently do, having more than the current 2.5 riders per vehicle, or find other means to the park such as taxis or bicycling and walking. A daily visitor limit set at 900, and a

100-stall parking lot that is estimated to turn over at least once a day would require the average vehicle to carry 4.5 people to the park. Or, if the stalls turn over two times a day, that would require roughly 3 people to ride per vehicle.

In all three scenarios, strict parking enforcement along the highway is required to discourage illegal parking, traffic hazards, and safety issues. Also, a widespread public information campaign should be held months in advance to inform the public and the visitor industry of any changes to park access.

TRAFFIC AND SHUTTLE ANALYSIS

A preliminary analysis of a potential shuttle system and various alternatives was also prepared by ATA and is included in their report as Section IV in Appendix D. It includes engineering considerations, potential traffic impacts, and five example shuttle service scenarios based on the amount of parking with potential costs and break even estimates. Scenario 1 describes baseline projection of traffic with the 900-daily visitor limit but without a shuttle. Traffic is reduced and remains well below the estimated roadway capacities for two-lane highways and one-lane bridge. However, ATA noted that there may be backups at the parking lot unless parking passes or some other parking management system is instituted. See “Parking Management Options”.

Scenarios 2 and 3 are the shuttle scenarios, comparing the proposed 900 daily visitor limit with a smaller 50-stall parking lot and with no parking lot. The reduced parking lots were requested by members of the MPAC since it was discussed that the demand for a shuttle may not be high enough if there is ample parking at the park. For comparison’s sake, ATA also studied what the shuttle requirements would be if there were no visitor limit with both a 50-stall parking lot and no parking lot in Scenarios 4 and 5.

In Scenarios 2 and 3, ATA estimated that six or seven 15-person capacity vans making nine trips per day would be needed to serve the 50-stall parking lot and no parking lot scenarios, respectively. They estimated it would cost $10.28 and $10.18, respectively, per person for the system to be self-sustaining. It also included a 30% contingency for low or sporadic ridership.

Scenarios 4 and 5 estimated the requirements of the current unconstrained situation with 2,000 visitors per day and found that 15 vans operating constantly from a remote parking lot would be needed to shuttle all visitors to the park or 14 vans with a 50-stall parking lot. Roundtrip shuttle tickets would need to be about $10.80 to break even with a 50% contingency for low or sporadic ridership.

In a previous analysis, ATA provided a reverse calculation and estimated that it would take 245 riders per day at $10 per roundtrip ticket to make a two van (15-passenger capacity) system sustainable. This is comparable to what the owners of the Experience Kauaʻi shuttle service shared with the County of Kauaʻi’s North Shore Shuttle Committee in March 2014. In all the shuttle scenarios, there was not much difference in estimated costs per rider or difference in traffic impacts based on the Waipā Bridge’s volume-to-capacity (VTC) ratio. The VTC ranged from 27% to 31%, compared with the existing traffic’s 39%, a difference of about 55 cars per hour. The reduction in daily visitors alone is estimated to reduce the hourly flow by 100 vehicles per hour.

SHUTTLE SERVICE PROVIDERS

Regardless of the shuttle routes implemented, a variety of service providers could be involved including:

- The State of Hawaiʻi
- The County of Kauaʻi
- A third party operator
- Combination of the above

Recent discussions with the County Transportation Agency and Office of Economic Development have indicated interest by the County to provide some sort of local bus service for the North Shore. They are contracting a planning study to determine feasibility and the findings from this preliminary shuttle study have been shared with them to support their efforts.

Green vehicles such as electric vehicles that can be charged with renewable energy sources such as solar PV or vehicles that use alternative fuels and have low or no emissions are recommended.

CASE STUDY: ACADIA NATIONAL PARK (MAINE)

Acadia National Park in Maine is 47,000 acres in size. Personal vehicles are permitted within the park. From June 23 to early October, Island Explorer buses provide service between park destinations, local communities, and the Bar Harbor-Hancock County Regional Airport. Regularly scheduled buses stop at specific destinations in the park including campgrounds, carriage road entrances, and many trailheads. Visitors are also allowed to flag down buses along their route; drivers will pick up passengers anywhere it is safe to stop.

The Island Explorer was established in the late 1990s as a unique partnership between:

- National Park Service
- U.S. Department of Transportation
- Maine Department of Transportation
- Friends of Acadia
- Six municipalities
- Private businesses

Downeast Transportation, Inc., a nonprofit organization, operates the fleet of propane-powered buses. Entrance fees help support the Island Explorer bus service which is a free service. Park officials also state that use of the buses help reduce traffic congestion, parking, and air pollution problems on the island.

A recent transit plan was developed for the near planning horizon for the Island Explorer, the document provides some insights to the practical issues associated with running a shuttle and includes a capital and financial plan.

CASE STUDY: ZION CANYON AT ZION NATIONAL PARK (UTAH)

In 1997, visitation at Zion National Park was 2.4 million and increasing. The park is 146,597 acres in size and a shuttle system was established to eliminate traffic and parking problems, protect vegetation, and restore tranquility to Zion Canyon.

Figure 32 – Shuttle and Parking Map, Zion National Park

According to National Parks materials, the parking lot at the Zion Canyon Visitor Center fills up by mid-morning. Thus, a shuttle from neighboring Springdale is strongly encouraged. The shuttle operates between April and November.

The Springdale Shuttle stops at six locations in Springdale (yellow line in Figure 32). Shuttle parking signs are posted at the stops. Riders can then transfer to The Zion Canyon Shuttle loop (green line below) which stops at eight locations within the park. The transfer between loops is made at the Zion Canyon Visitor Center. Passengers may board and disembark without limit. The shuttle is free.

Only limited personal vehicles are permitted along the Zion Canyon Shuttle Loop such as visitors who lodge at the National Park's Zion Lodge. They receive a pass for their motor vehicle. All others must take a shuttle.

PARKING MANAGEMENT OPTIONS

Parking demand can be influenced by a number of factors including the availability, attractiveness, and perceived convenience of alternate means of access to the park, socio-economic characteristics of visitors, the accessibility, efficiency, and perceived safety of the parking facility, the cost of parking, and time frame factors (i.e. week day vs. weekend; seasonal fluctuations; and, other unexpected events such as a downturn in the economy). If the main parking lot remains, parking management can be achieved by manipulating one or more of the above factors, either alone or in concert. Table 13 summarizes the various options discussed at the MPAC and community meetings for managing the main parking lot, ranging from the simple to the more complex. Some of the management options could be applied together while others would not.

Table 14 provides management options for automating access to the special access parking lot at Kēʻē. The discussion on fees is also presented below as a separate management issue. Fees could be charged or not charged under any of the following options.

PARKING MANAGEMENT PROVIDERS

State Parks has determined that parking management would likely be contracted out to a third party operator rather than be managed in-house. If overall park management is contracted with a third party entity, the parking management provider could either be part of this group or subcontracted by the park management entity.

CASE STUDY: HANAUMA BAY NATURE PRESERVE

Parking at Hanauma Bay is open but limited to the 311 parking stalls marked within the paved area of the parking lot. Vehicles are allowed to park on a first come, first served basis and denied entry into the parking lot when the lot is full. When the lot fills, a sign is posted at the entrance along the highway. The parking lot opens at 6:00 a.m. and is often full by 7:30-8:30 a.m. during the busy season.

CASE STUDY: KATAHDIN TRAILHEADS AT BAXTER STATE PARK, MAINE

At the Katahdin Trailheads, Day Use Parking Reservations (DUPR) are required for the 76-stall parking lot prior to arrival. DUPRs must be made by 3:00 p.m. on the day prior to arrival. Maine residents can make a DUPR for the summer season as early as April 1. A Maine driver's license and registration is required to make the reservation. Non-residents can make a DUPR two weeks or less prior to the date of their intended visit. A maximum of three DUPRs per month can be made by residents and non-residents. After 7:00 a.m., unreserved spots open to the public on first-come, first-served basis. Technically, visitors who do not wish to pay a fee can take their chances and arrive after 7:00 a.m. that day to see if any parking stalls are available.

FEES FOR PARK ENTRY AND/OR PARKING

When State Parks decides to initiate fees at the park, a portion of the fees collected will go towards the ongoing maintenance and improvements for the park. There are two potential entry points at which a fee could be administered — at the parking lot for parking and for park entrance for individuals (both remote, if established, and onsite).

Initially, State Parks plans to assess an entry fee per person with Hawaiʻi residents exempt, to enter the park regardless of how they arrive at the park. Although the park can be accessed from the beach and the Nāpali Coast State Wilderness Park, enforcement from these public accesses is not anticipated with this plan and therefore is not included in the discussion. Because the proposed master plan describes a single entry from Kūhiō Highway, the plan focuses on this single point of entry and the management of this access.

Parking fees charged separately from entry fees may help manage parking demand. In general, ample free parking encourages vehicular trips and long stays. Parking priced at a premium or hourly could encourage alternative modes of access and higher turn-over rates within the parking lot. Furthermore, if parking is reduced onsite, premiums could be charged to park onsite. Torrey Pines State Natural Reserve charges hourly parking rates as well as all-day rates that are based on demand, meaning busier weekend days have higher rates. On Mondays through Thursdays, the rate for less than an hour is $4. For 0-2 hours, it is $6. All day parking is $10. On Fridays through Sundays, it is $6 for less than an hour. For 0-2 hours, it is $8. All day fees are $10 to $15 based on demand.

Many parks across the nation also charge different rates for overnight camping and additional overnight parking fees for more than one vehicle such as Washington State which charges $10 for the additional vehicle. Some parks require parking reservations be made ahead of arrival because of high demand, such as at the Baxter State Park Katahdin Trailheads in Maine. There is no parking fee but it costs $5 to reserve a parking stall in advance.

When fees are introduced, there are other options to help encourage repeat visitation or support local attendance such as offering annual or lifetime passes and open houses/fee free days. It is important to note, however, that because federal LWCF monies were used to acquire the park lands, any fees charged to non-residents cannot exceed twice that charged to residents. Where there is no charge for residents but a fee is charged to nonresidents, nonresident fees cannot exceed fees charged for residents at comparable State or local public facilities. In addition, the fees administered at Hāʻena State Park must be consistent with statewide standards.

Two state parks have entry fees, Diamond Head State Monument and ʻAkaka Falls State Park, and there are a few state parks with fees for parking and higher fees for commercial vehicles. At the City and County of Honolulu's Hanauma Bay, entry fees and parking fees are charged. However, the entry fee is waived for persons 12 years and younger and for each Hawaiʻi Resident and Hawaiʻi school student 13 years and older with proper ID. Entry and parking fees vary at the national parks in Hawaiʻi. Table 15 summarizes the fees currently charged at some of Hawaiʻi's most popular parks. Table 16 shows different options of how fees could be charged for both entry and parking.

Table 13 – Main Parking Lot Management Options

Management Option	Pros	Cons	Implementation Considerations
Open parking (first-come, first-served)	• Minimal management requirements.	• Could contribute to unnecessary traffic to the park and circulating traffic if people drive around waiting for stalls to open.	• Informational signs should be posted when the lot is full to inform drivers. Signs should similarly be updated when stalls become available.
Eliminate overnight parking	• Increases parking availability to other park visitors. • Requires overnight hikers to find other means of getting to/from the park. • Could spur economic development of specialty services serving campers such as a shuttle service. • Eliminates the need for the Caretaker to unlock the gates after hours.	• May be inconvenient for overnight hikers although eliminates risk of car break-ins and vandalism.	• Requires hiker education and advanced planning. • Encourages shuttle use.
Eliminate overnight parking except for a few stalls designated for overnight campers	• Helps to limit the overall number of stalls taken that could have been occupied by overnight vehicles. • Helps to distinguish between an abandoned car and overnight stay.	• Stalls could be underutilized if no reservations are made or hikers do not show.	• Require parking reservation in advance with purchase of camping permit. • Consider charging a higher fee for overnight parking.
Limit parking availability to general public (e.g. allow only 50 vehicles to park at the park by phasing parking lot construction)	• Requires visitors to plan ahead and find alternative means to get to the park. • Can help save on construction costs depending on the phasing of parking lot improvements.	• Reduces the amount of parking available. • Could exacerbate circulating traffic without adequate public notice of parking availability. • Could encourage illegal parking in surrounding area without enforcement or offsite parking area(s).	• Consider this option in conjunction with alternate means of transportation to the park, such as the North Shore shuttle/transit service. • May complicate or increase costs of parking lot improvements/phasing plan. See Section 5.4. • Informational signs should be posted when the lot is full to minimize circulating traffic and any backups that may be caused by it. Will require more frequent updates with fewer stalls and increased enforcement. • Good tool to encourage shuttle/transit use once operational. Adjust number of stalls appropriately.
Require reservation of a parking permit prior to arrival	• Requires visitors arriving by car to plan ahead and carpool. • Once permits sell out, visitors must find alternate means of getting to the park which can help minimize vehicular traffic to the park, including circulating	• Could require alternate means of getting to the park such as a shuttle or bus and/or offsite parking. • Could limit revenues from	• Determine appropriate length of permits (hourly, half-day, or full day). If only full-day parking passes are available, alternate parking areas or shuttle/bus service will be required and the amount of revenue generated from parking fees will be limited. If, however, partial day parking permits

Management Option	Pros	Cons	Implementation Considerations
	traffic waiting for a parking stall to open. If the parking stalls are made available to the public after the permit holder does not arrive by a certain time, this eliminates this benefit but allows for additional fee collection.	parking fees depending on length of permit. • Requires additional management and enforcement.	are available, enforcement will need to be increased and/or rules/fees for unplanned extended stays would need to be developed, which will complicate management. • Requires public information campaign prior to implementation.
Limit parking availability to special uses only with all other arrivals by shuttle only	• Requires visitors to plan ahead and find alternative means to get to the park. • Can help save on construction costs depending on the phasing of parking lot improvements. • Improves feasibility of shuttle/remote entry only gate concept. • Eliminates neighborhood overflow parking if all arrivals are limited to shuttle.	• Reduces that amount of parking available. • Eliminates all public parking with exception of special uses and accessible parking from the site. • Eliminates pedestrian and bicycle access.	• May require land acquisition by State Parks or reliance upon agreements for use of non-State Parks land for off-site parking and shuttle service.

Table 14 – Special Access Parking Lot Automated Entry Options

Options	Pros	Cons	Implementation Considerations
Keypad access	• Access code can be changed frequently. • Easy to distribute access code to users. • Can program multiple access codes for different users.	• Equipment vulnerable to vandalism and damage. • Requires maintenance and may require power if electronic.	• Cost will depend on sophistication of system. • Consider installing a mechanical lock to avoid power requirement.
Lock and key access	• Minimal cost and maintenance. • Can be set up with multiple locks (daisy chain configuration) for different users. • Allows for access before and after park hours. • Does not require power.	• Vulnerable to lock cutting. • Keys can be lost. • Keys can be easily duplicated.	• Will require management of key distribution.
Electronic access card	• Easy to use. • Could use both permanent and paper access cards. • If lost, permanent cards can be deactivated. • One-time use paper access cards are low-cost option and can be distributed to day users without requiring them to be returned.	• Equipment vulnerable to vandalism and damage. • Permanent cards require manage-ment and tracking of cardholders. • Permanent cards can be lost. • Requires power and maintenance.	• Cost will depend on sophistication of system. • One-time use paper cards can be issued for day users.

PARK PASS SYSTEMS

If entry fees are charged at the park, park pass systems such as annual passes or lifetime passes could be implemented to make it more affordable for frequent visitors. The passes could include benefits such as free or discounted parking if parking fees are charged, priority parking spaces, priority park entry and/or parking reservations or potential exclusion from daily visitor limits. If pass holders are excluded from daily visitor limits, the MPAC suggested requiring passes be obtained prior to park arrival so visitors who did not plan their visit could not bypass the daily limit and purchase an annual pass upon arrival.

The LWCF rules require that reservations, memberships, or annual permit systems available to residents must also be available to nonresidents and the period of availability must be the same for both residents and nonresidents. However, as noted earlier, they do allow for "reasonable differences in admission and other fees." Also, "fees charged to nonresidents cannot exceed twice that charged to residents. Where there is no charge for residents but a fee is charged to nonresidents, nonresident fees cannot exceed fees charged for residents at comparable State or local public facilities" (LWCF 2008).

There are several types of pass systems that could be implemented at the park. Even with the restrictions required by State and LWCF rules, there is flexibility in the way the pass systems may be offered and a wide range of benefits they could offer. They could be implemented alone or in combination depending upon the desired impact on visitorship. Table 17 provides a list of different types of passes and is not meant to be comprehensive.

FEE FREE DAYS

Many parks and museums that have entry fees offer open house or fee free days to encourage visitation and serve those who may not be able to pay. Depending how entry fees are established for Hāʻena State Park, similar programs could be implemented. With the daily visitor limits in place, advance reservations would be highly recommended for both parking and entry.

Table 15 – Example Entry and Parking Fees for Hawai'i Parks, 2012

Park	Entry Fee (Adult/Child)	HI Resident Entry Fee	Parking Fee*	HI Resident Parking Fee*	Passes† Available	Notes
HAWAI'I STATE PARKS						
Nu'uanu Pali State Wayside	None	None	$3	Free		Commercial PUC vehicles: $6 for 1-7 passenger vehicles, $12 for 8-25 passenger vehicles, $24 for 26 + passenger vehicles.
'Īao Valley State Monument	None	None	$5	Free		Commercial PUC vehicles: $10 for 1-7 passenger vehicles, $20 for 8-25 passenger vehicles, $40 for 26 + passenger vehicles.
'Akaka Falls State Park	$1 per walk-in	Free	$5 per vehicle entry	Free		Commercial PUC vehicles: $10 for 1-7 passenger vehicles, $20 for 8-25 passenger vehicles, and $40 for 26 + passenger vehicles.
Diamond Head State Monument	$1 per walk-in	$1 per walk-in	$5 per vehicle entry	$5		Commercial vehicles: $10 for cars/vans, $20 for mini-buses, and $40 for buses.
'Iolani Palace State Monument	None	None	metered	Metered	N/A	Fees charged for tours and basement gallery exhibits administered by The Friends of 'Iolani Palace. Self-led audio tour is $7 for adults, $5 for children aged 5-12. Guided tour is $20 for adults, $6 for children aged 5-12, $15 for Hawai'i residents and military with proper ID. Entry for the Basement Gallery Exhibits is $7 for adults, $3 for children aged 5-12.
NATIONAL PARKS						
World War II Valor in the Pacific National Monument	None	None	None	None	N/A	No fees for entry to USS Arizona Memorial. However, entry tickets must be obtained prior to entry either online or in person on a first come, first served basis. Audio tours available for $7.50. The Battleship Missouri Memorial, USS Bowfin Submarine Museum & Park, and Pacific Aviation Museum are operated by non-profit entities that charge fees for admission. Online purchases regardless of fees are assessed a $1.50 processing fee per ticket.
Haleakalā National Park	$5 per person with no vehicle	$5 per person with no vehicle	$10	$10	Yes	Vehicle entry fees (except for commercial groups) good for 3 days. Motorcycles are $5 plus $5 for each additional passenger. Youth 15 and under are free. Non-commercial groups charged: • $10 for vehicle capacity of <14. • $5 per person for vehicles with a capacity of 15 or greater. Commercial groups charged: • $5 per person for non-road based organized groups that offer activities such as Astronomy and Hiking. • $30 plus $5 per person for road based vehicles with a 1-7 passenger capacity. • $45 for road based vehicles with an 8-25 passenger capacity. • $100 for coach buses with a passenger capacity of 26 people or more.
Pu'uhonua 'O Hōnaunau Nat'l Historical Park	$3 per person	$3 per person	$5	$5	Yes	Entry and parking fees are valid for 7 days. Up to 8 people per vehicle entrance fee.

Park	Entry Fee (Adult/Child)	HI Resident Entry Fee	Parking Fee*	HI Resident Parking Fee*	Passes† Available	Notes
Hawaiʻi Volcanoes National Park	$5 per pedestrian or bicyclist	$5 per pedestrian or bicyclist	$10	$10	Yes	With a valid receipt, general admission entrance fees allow entrance for 7 days. Non-commercial groups in vehicles with a capacity of 15 or more are charged $5 per person. Persons 15 years or younger are free. Commercial operations charged on vehicle capacity and type of tour given (road-based or not).
Kilauea Point National Wildlife Refuge	$5/Free under 16 yrs.	$5/Free under 16 yrs.	None	None	Yes	Passenger vehicles are limited to vans with a capacity of 15 or fewer people.
CITY & COUNTY OF HONOLULU						
Hanauma Bay Nature Preserve	$7.50/Free 12 yrs. and under	Free	$1	$1		Parking fee is refundable if vehicle exits the parking lot within 15 minutes.
NOTES: *For private non-commercial vehicles. †Refers to any type of pass such as an annual pass, lifetime pass, volunteer pass, multi-park pass, etc.						

Table 16 – Options for Fees

Option	Pros	Cons	Implementation Considerations
Flat Rate (for Entire Day)	• Simple to administer. • No enforcement required.	• Does not take into account different impacts of different users.	• Payment can be made in advance. • Consider different rates for residents/non-residents as long as it meets State and LWCF rules.
Half-Day Rate	• Offers lower fee options for those spending less time at the park.	• Difficult to enforce.	• Payment can be made in advance. • Requires enforcement.
Hourly Rate	• Offers lower fee options for those spending less time at the park. • Could be graduated to encourage turnover, especially for parking.	• Difficult to enforce.	• Requires fee collection upon exit or enforcement. • Implement real-time parking space availability notification system to help mitigate unnecessary traffic to the park.
Rates Based on User (e.g. hiker vs. park user)	• Charge fees appropriately based on use and user impacts.	• Could be difficult to enforce within the park.	• Payment can be made in advance. • Requires more check-in points and enforcement.

Table 17 – Types of Passes

Type	Description
Annual Pass	Annual passes could be issued at discounted rates for either park entry or parking, or for both. Annual passes would need to be renewed each year and could be valid from the month of purchase (or of distribution, if free), a person's birthday, or by calendar year. Fees would be pro-rated appropriately. Parking passes could either be issued to an individual or to a specific vehicle. Annual park passes could be issued to individuals or to families at different rates (if there is no charge for residents, there would also be no charge for resident families).
Volunteer Pass	Park passes could be issued to those who put in a certain minimum number of volunteer hours at the park.
Kūpuna Pass	Park passes could be issued at discounted rates to kūpuna or seniors of a certain age.
Lifetime Pass	Park passes could be issued to certain individuals who meet specific criteria as long as it does not violate State or LWCF rules. An example might be to recognize those who have dedicated or volunteered a high amount of time to the park or original Hāʻena family members who once resided on the land within the park. These passes would be valid for the duration of a person's lifetime and would not require renewals.

Table 18 – Point of Ticket Purchase/Pickup

Options	Pros	Cons	Implementation Considerations
Hāʻena State Park	• Convenient for visitors. • Simple to manage.	• Encourages drop-in traffic. • Does not encourage visitors to plan ahead.	• Requires staff at the park to manage ticket administration. • Requires minimal public education/ information.
Phone	• Convenient for visitors. • Services people without access to the internet who want to plan ahead.	• Requires staff to answer phones.	• Requires a location or means for ticket pickup (and possibly staff to manage) and/or coordination at park entry.
Internet	• Convenient for visitors with Internet access. • Allows visitors to reserve tickets in advance. • Real-time ticket availability can be posted online.	• Serves only a portion of the general population (those with Internet access). • Requires other means for those without Internet access to obtain tickets.	• Tickets can be printed at home so no physical pickup location or will-call service required. • Requires management of Internet site but may reduce overall staff requirements on a daily basis. • Could support offsite ticket locations such as hotels and other visitor centers.
Automated Pay Stations (For Parking)	• Minimal staff requirements. • Option for visitors to add time by making a phone call if cell phone coverage exists.	• May be vulnerable to vandalism and especially theft if cash is accepted.	• Requires power and telecom/data connection if cashless (credit card only). • Possible to allow visitors to add time to parking remotely, if desired and cell phone coverage exists.
Offsite Location	• Encourages visitors to plan ahead. • Might help reduce the number of drop-in visitors.	• Require additional cost and/or agreement for remote location if not State owned. • May be inconvenient for visitors and residents depending on shuttle schedule and location if it requires backtracking. • May add to traffic if visitors arrive at the park not knowing and need to double back to obtain tickets, then return back to the park.	• Requires public information campaign prior to kick-off. • Would not eliminate those driving to the end of the highway. • Requires ongoing public education and coordination with visitor industry. • Could become complicated if parking fees are charged separately from entry fees.
Shuttle-Based (i.e. entry tickets are distributed by shuttle operator to encourage or require visitors to travel to the park by shuttle)	• Encourages visitors to plan ahead. • Helps reduce the number of private vehicles traveling to the park.	• Inconvenient for residents, especially those located closer to the park than the shuttle pick-up location. • May be inconvenient for visitors with limited time to visit the park. • If this is the only means of obtaining entry tickets, this may create an over reliance on a shuttle system that may or may not be available/feasible.	• Park entry tickets could be sold or distributed with purchase of shuttle ticket. • Considerations need to be made if annual pass systems are implemented.
Fees Based on When or Where Purchased (cheaper for advanced purchase)	• Encourages visitors to plan ahead. • May encourage visitors to use shuttle depending on price.	• Could be complicated to administer.	• This could also be applied to parking if advance parking reservations are available.

Case Study: National Park System

The National Park System (NPS) offers a wide range of park passes for various parks, including those in Hawai‘i.

- NPS Hawai‘i Tri-Park Annual Pass: $25. Admits the pass holder and passengers in a non-commercial vehicle (14-person capacity or less) to Haleakalā National Park, Hawai‘i Volcanoes National Park and Pu‘uhonua ‘O Hōnaunau National Historical Park. Annual passes are available to the general public including international visitors and are valid for twelve months.

- NPS Interagency Pass Program (IPP): A nationwide pass program that includes four participating parks in Hawai‘i, Haleakalā National Park, Hawai‘i Volcanoes National Park, Kīlauea Point National Wildlife Refuge, and Pu‘uhonua ‘O Hōnaunau National Historical Park. The five federal agencies who participate in the IPP are:
    - National Park Service
    - U.S. Forest Service
    - U.S. Fish and Wildlife Service
    - Bureau of Land Management
    - Bureau of Reclamation

  The IPP offers both annual passes and lifetime passes. The annual passes are:
    - Interagency Annual Pass: $80. This pass provides access to or permits the use of federal recreation sites that charge an entrance or standard amenity fee. The pass also admits the pass holder and passengers in a non-commercial vehicle at areas that have per vehicle fees and admits the pass holder plus three adults to areas that have per-person entrance fees. The pass is available to the general public and is valid for twelve months from the purchase date.

    - Volunteer Pass: 250 Volunteer Hours. This pass is free for volunteers acquiring 250 service hours with federal agencies that participate in the Interagency Pass Program. This pass provides access to, and use of, federal recreation sites that charge an entrance or standard amenity fee. This pass admits the holder and passengers in a non-commercial vehicle at per vehicle fee areas and the pass holder plus 3 adults at per person fee areas. The pass is valid for 12 months.

    - Free Annual Pass for Military: Free pass for active duty military personnel and dependents with proper identification.

  The lifetime passes offered by the IPP are available to all U.S. citizens or permanent residents with some restrictions. The passes are non-transferable and must be obtained in person.

    - Interagency Senior Pass: $10. This is a lifetime pass for U.S. citizens or permanent residents age 62 or over. This pass provides access to, and the use of federal recreation sites that charge an entrance or standard amenity fee. The pass admits the pass holder and passengers in a non-commercial vehicle at locations where a per-vehicle fee is charged. It also permits access for the pass holder and 3 adult guests at per person fee areas. The cost of obtaining the pass through the mail is $20. A $10 processing fee is added to the cost of the permit.

- Interagency Access Pass: This pass is free and valid for life for U.S. citizens or permanent residents with permanent disabilities. Documentation is required to obtain the pass. This pass provides access to, and use of, federal recreation sites that charge an entrance or standard amenity fee. The pass admits the pass holder and passengers in a non-commercial vehicle at areas where per vehicle fees are charged. It also grants access to a pass holder and 3 adult guests at areas with per person fees. The cost of obtaining an Access Pass through the mail is $10 for processing since the pass itself is free.

CASE STUDY: USFWS KĪLAUEA POINT NATIONAL WILDLIFE REFUGE
Annual kamaʻāina passes can be purchased for $20.00. The pass allows entry for the pass holder and up to 3 guests. All other federal recreational lands passes are also honored at the refuge.

CASE STUDY: TEXAS STATE PARKS
Texas offers a State Parks Annual Pass for $70 for the first, and $15 for a second pass purchased at same time. If a second pass is purchased later, it is $25. Pass holders enjoy unlimited access to over 90 Texas State Parks and discounts on camping fees, equipment rentals, and park store merchandise.

The Texas Parklands Passport is a special pass that was created by an act of the Texas Legislature. For Texas residents over the age of 65 or who are permanently disabled, a 50% discount is given for entry fees. For residents and non-residents born before 1930 or who are disabled veterans, the pass provides a 100% discount on entry fees.

CASE STUDY: PARKING PASSES
Several parks across the nation offer a variety of parking passes for those which charge parking fees. The following list includes brief descriptions of the diverse parking pass programs and their current fees. Most are annual parking passes which tend to target residents and frequent visitors. However, the Oregon Sno-Parks pass offers a 3-day pass for those who may be visiting but wish to access the park for more than one day.

- Oregon Sno-Parks Winter Recreational Areas: The annual parking pass is $20. A 3-day parking pass is $7. Daily parking passes are $3.

- Minneapolis Park and Recreation Board Annual Patron Parking Permit: This parking pass is valid for their most popular regional parks and municipal parking lots. The annual permit is $34 with a second permit costing $17. There are lower fees for seniors.

- Massachusetts State Parks ParksPasses: This annual parking pass is $35 for residents and $45 for non-residents. The ParksPass is a hangtag issued for one vehicle with a sticker that is valid for one calendar year. ParksPass holders may purchase a second car sticker for $15. The second car sticker is affixed to the hangtag and the hangtag can be interchanged between the two family vehicles. The second sticker does not allow two separate vehicles to park at the same time.

- Orange County Parks: Combined annual regional parks and beach parking decals can be purchased for $80. For seniors and ADA vehicles, they are $50. For distinguished veterans, the combined parking decals are free. Annual parking decals can also be purchased separately for regional parks only, or for beach only parking, for $55 each. The senior/ADA decal for regional parks only or for beach parking only is $35.

- Alaska State Parks: Annual parking passes are $40 for the first pass and a second pass may be purchased for $20. The second pass discount is only valid for the same family at the same address. Daily parking rates are typically $5.

- Minnesota State Parks: Annual parking passes are $25 with additional vehicle passes available for $18. Special Permits are also offered for ADA vehicles at $12 and for motorcycle at $20 per year.

- Torrey Pines State Natural Reserve: Annual parking passes are $85. For $125, annual parking passes that are valid for the reserve and throughout the State Park system may be purchased. For comparison, the California State Park Annual Day Use Passes are $195.

POINT OF PURCHASE OR TICKET PICKUP

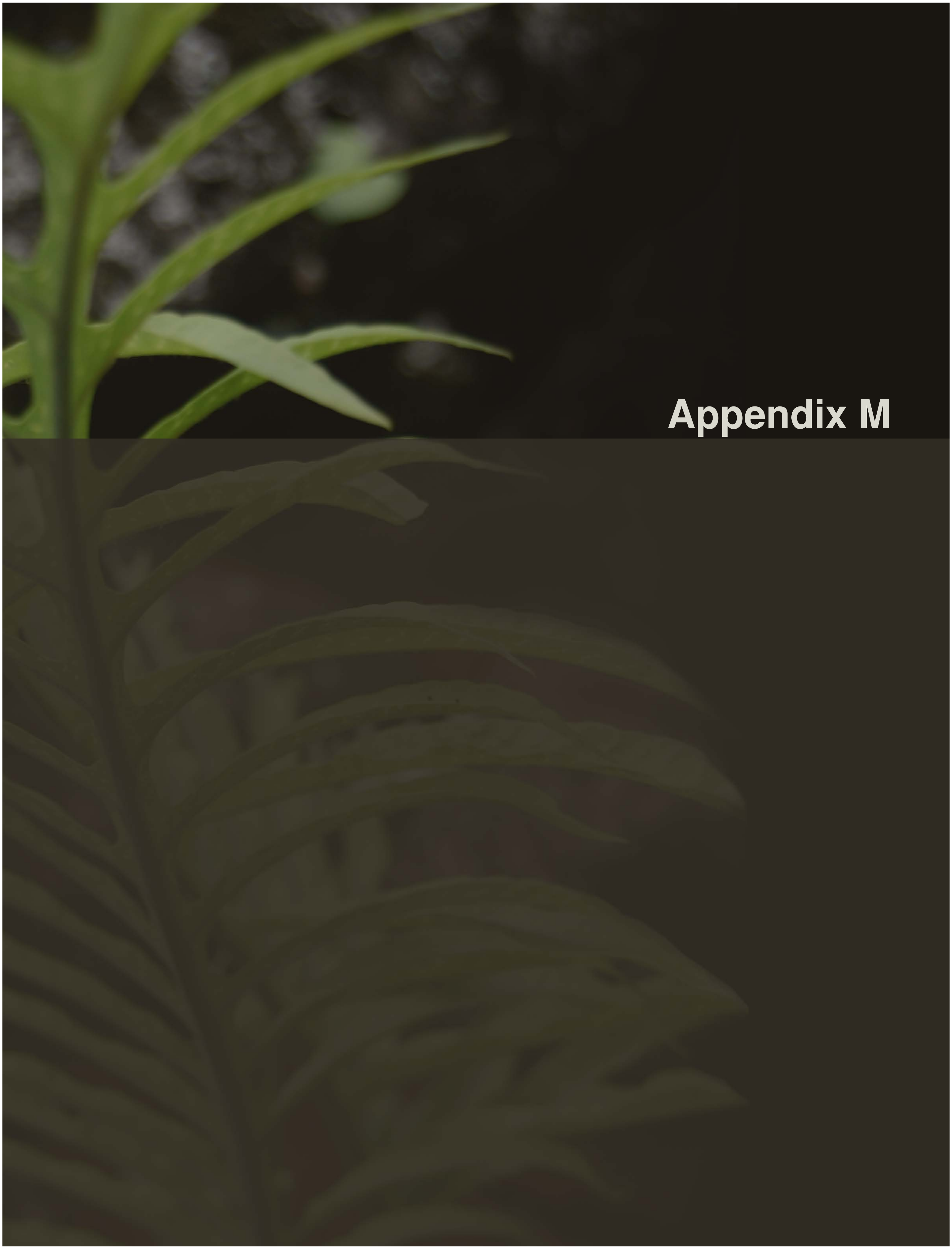
During the meetings with the MPAC, creative ideas about how to manage the flow of visitors to and from the park were discussed. One involved the point of purchase for tickets, or where tickets to the park could be obtained or picked up. One suggestion was to locate it offsite to minimize unnecessary drop-in vehicle traffic to the park (see 0). If visitors were required to obtain their tickets prior to arrival, this would encourage them to plan their trips to the park ahead of time and would also give park managers an idea of how many people to expect at the park on any given day. Tickets could be obtained online or through an authorized ticket vendor/distributor and ticket availability could be posted on the website in real time. Another option the MPAC suggested was to have visitors obtain entry tickets through a shuttle service which would also help reduce traffic to the park. Also, if annual passes were available and pass holders were excluded from daily visitor limits, the MPAC felt it important to make them only available online or remotely, or to have the passes mailed to the recipient, so that visitors could not bypass the daily limit by purchasing one at the park. All of these options require extensive public outreach and education. This situation may actually create more unnecessary traffic for those who may go to the park thinking they can purchase tickets there only to have them turn back to purchase them at a remote location and then return to enjoy the park. Table 18 provides a list of options from the traditional to those requiring more complicated management and their respective pros and cons.

Case Study: Denali National Park (Alaska)

Similar to the Zion National Park, access to the park beyond a certain point, the Savage River Check Station, is only permitted by shuttle bus, bicycle or on foot. This check station is located at mile 15 of the park road and private vehicles are required to turn back. Because Denali Park Road is the only road in the six million-acre park, park officials implemented a transit system and eliminated private vehicle access except for a few exceptions in order to reduce traffic congestion and to protect the natural resources of the park.

Because of this, the $10 entrance fee is added to the shuttle fees. If individuals have annual passes or other park passes, refunds for the $10 entrance fee must be requested. If reservations or shuttle bookings are made through a third party vendor, such as cruise line operators, refunds must be sought from those vendors. Shuttle bus tickets can be purchased online or at the Wilderness Access Center which is located at mile 0.75 near the entrance of the park. A concessioner operates the center, the shuttle bus system and tours, and collects all fees (including campground reservations).

As an aside, the NPS does operate a courtesy shuttle bus system that takes visitors between the NPS-run Denali Visitor Center and specific sites along the 15-mile public portion of the park road including campgrounds. Visitors who do not purchase shuttle/tour bus tickets or campground reservations pay their entrance fee, or show their federal lands pass, at the Denali Visitor Center upon arrival at the park.



Appendix M

Appendix M – Interpretive and Educational Opportunities

EXISTING INTERPRETIVE PROGRAM

Interpretive materials were first provided at Hāʻena State Park in 1988 when an interpretive kiosk was installed at the Kalalau trailhead to inform visitors about trail conditions, the cultural history, and park rules relative to the Kalalau Trail. It was expanded in 2008 when additional signs were placed to meet ADA requirements. State Parks has also developed brochures for the Kalalau Trail and Nāpali cultural sites, which are currently distributed with camping permits for Nāpali Coast State Wilderness Park (SWP) and available online but not at the park. These interpretive materials have focused on the resources of Nāpali rather than Hāʻena State Park.

In 1992, State Parks drafted a conceptual interpretive plan for Hāʻena State Park as part of the previous master planning effort. The plan inventoried the natural, cultural, and scenic resources, identified some potential interpretive themes, assessed the audience based on the visitation in 1992, and recommended various interpretive devices. Many aspects of the 1992 plan including several interpretive themes are still relevant and have been incorporated into this report.

In 2000, State Parks and Hui Makaʻāinana o Makana entered into a curator agreement for the Hui to assist with restoration of the loʻi kalo in areas that had been cleared of vegetation for an archaeological mapping project. The project area has expanded to about 4.4 acres and is considered a first phase in the restoration of the cultural landscape of the park. The Hui has extended its public outreach to incorporate education programs and workdays for the community, including schools and cultural organizations.

A State Parks Interpretive Technician, also referred to as a Park Ranger, was hired in 2007 to provide interpretive services for park visitors and implement resource management measures. Funding for this position lasted for 4 years. A new Interpretive Technician was hired in 2013.

VISION AND INTERPRETIVE/EDUCATIONAL OBJECTIVES

The wealth of cultural, archaeological and natural resources within the park provides excellent opportunities to develop rich, multilayered interpretive and educational experiences for all visitors. Interpretation provides an opportunity to share the natural and cultural history of Hāʻena and the Nāpali Coast, highlight ocean and hiking safety messages, and encourage visitor behavior that will promote respect and preservation of the resources for future generations. The park should be envisioned as an outdoor classroom, providing learning opportunities for all visitors, including out-of-state and international visitors, Kauaʻi and Hawaiʻi residents, school groups from preschool to college, field schools, families and interest groups/organizations, cultural practitioners and scientific researchers.

An interpretive program must address the sensitivity of the cultural sites and the potential for damage from visitors. Interpretive displays, wayside exhibits, and other devices should be located to minimize the impacts to viewplanes and sensitive resources. Cultural interpretive messages and devices should be developed and located in consultation with appropriate cultural practitioners.

Interpretive programs should serve multiple objectives:

- Increase visitors' knowledge, awareness, and understanding about the cultural and ecological history and significance of the park area, as well as the relationship between these resources;
- Instruct visitors how to interact appropriately and sensitively with the natural and cultural resources;
- Promote respect and stewardship of the resources;
- Educate visitors about potential safety hazards and current weather conditions; and
- Enhance and enrich the experience for a variety of visitors who come to the park by providing a variety of educational and interpretive programs for various ages and levels of knowledge.

VISITATION AND AUDIENCE

Understanding park visitors and users is critical to developing an interpretive program that effectively meets the vision and objectives. Hāʻena attracts a large number of visitors with diverse interests and backgrounds due to its rich resources, its location at the end of the state highway, and the ocean and outdoor recreational opportunities available. Casual visitors range from those using the Kalalau Trail for day hikes, overnight hikes and camping to sightseers and beachgoers at Kēʻē Beach and the shoreline who snorkel, swim, sunbathe, fish, and windsurf. A special audience are the cultural practitioners who are mostly closely associated with the hula sites and loʻi kalo.

Recent visitor surveys conducted between 1998 and 2010 by State Parks and OmniTrak for the Hawaiʻi Tourism Authority (HTA) provide insights on current visitation at Hāʻena State Park. The survey conducted by OmniTrak for HTA in 2007 indicated an annual visitation average of 708,000 for Hāʻena and 423,000 for Nāpali Coast. It should be noted that the visitation count for Nāpali is part of the Hāʻena count because visitors must access Nāpali through Hāʻena State Park. On average there are about 2,000 visitors per day during the peak season (OmniTrak 2007) and about 1,000 during the off-season (State Parks 2010). The surveys also indicate 88-90% of the visitors are from out-of-state.

Visitors participate in a variety of activities while at the park (see Table 4 and Vaughan survey). A majority of visitors participate in ocean recreation and about a third participates in hiking or walking. One-day sample counts on the trail found 285 hikers in 1998, increasing to 574 hikers on the trail in 2009 with only 2% hiking beyond Hanakāpīʻai. These numbers suggest about 25% of the visitors are hiking at least a portion of the Kalalau Trail. Also, despite not having any formal picnic areas, the 2007 survey found that 46% of Hawaiʻi residents and 39% of non-residents picnic at the park. High percentages of both Hawaiʻi residents and non-residents also enjoyed the scenic views. Very few (7-8%) visited the historical or cultural sites which is due in large part to the lack of signs and paths that makes these resources known to visitors.

When asked what their primary motivation was for visiting the park, the responses differed greatly between Hawaiʻi residents and non-residents. Most Hawaiʻi residents (63%) came for an outing with family and friends while almost half (46%) of the out-of-state visitors came for ocean/water activities.

The surveys also indicated a high visitor interest in having more interpretive materials in the park. Some respondents specifically mentioned signs and tours. Given the diversity of park visitors, interpretive programs and displays should be developed for a wide range of ages and varying familiarity with local history and customs. They should also be implemented in consultation with the Cultural Advisory Group.

INTERPRETIVE THEMES

Interpretive themes are central ideas and messages conveyed in an interpretive program. The presentation should spark interest and learning among visitors, as well as encourage understanding and respect for the natural, cultural, and scenic resources. The themes identified for Hāʻena range from the cultural and natural history of the area to the geological and scenic qualities. The themes serve as a preliminary framework for an interpretive program and allow for further development and expansion with input from the Cultural Advisory Group, including those knowledgeable of the place, history and cultural practices of Hāʻena, as well as natural scientists and other experts in related fields.

<u>Theme</u>: Kēʻē (Hāʻena) continues to be a significant cultural place for the perpetuation of Hawaiian hula traditions.

At the foundation of any interpretive program planned for Hāʻena State Park should be recognition of the cultural significance of this place. Hāʻena is a major wahi pana (legendary place) in Hawaiʻi and is significant for its cultural sites and traditions related to hula (Ka Ulu a Paoa Heiau and Ke Ahu a Laka) and the stories of Pele, Hiʻiaka, and Lohiʻau. Many present-day hula hālau perpetuate these hula traditions at Hāʻena, including the use of the sites to conduct their ʻūniki (graduation) ceremonies.

<u>Theme</u>: The history of Hāʻena reflects a continuity of cultural traditions and a strong association with the Nāpali Coast.

The abundance of marine resources and the fertile agricultural lands of the valleys and coastal flats of Hāʻena made it a very rich ahupuaʻa that supported early Hawaiian occupation, ca. AD 989. Hāʻena serves as an important region to understand the early settlement subsistence history and socio-economic patterns of Kauaʻi.

The cultivation of kalo continued in the Hāʻena area until the 1960s indicating a long cultural tradition of fishing and farming. Recent efforts to restore and replant the loʻi kalo for cultural learning and perpetuation of cultural traditions can be supplemented with interactive learning opportunities such as work days in the loʻi and poi tastings.

<u>Theme</u>: The natural resources reflect a dynamic geological history and are linked to the cultural history and legends of Pele, Hiʻiaka, and Lohiʻau.

The two wet caves (Wai a Kanaloa and Waiakapalaʻe) and one dry cave (Maniniholo) found in Hāʻena were formed in early times of higher standing sea level. Additionally, the various legends associated with these caves such as Pele and Kanaloa suggest the value of these sites to early

Hawaiians. Makana is associated with the famed ʻōahi festivals, the legend of Nou and the menehune, and Queen Emma's 1860 visit. Kilioe, a kumu hula and one of the moʻo sisters who guarded Lohiʻau's body, is embodied in the pōhaku piko below the Ka Ulu a Paoa. She is also featured in the story of the naupaka.

<u>Theme</u>: The natural resources of Hāʻena are fragile and subject to impacts from both natural and human forces.

The coastal sand dune is a key element of the Hāʻena landscape but subject to erosion from natural forces (high surf, rising sea level due to climate change, tsunami) and human action (trails, vehicles). There are also numerous burials in the dune that must be respected. Interpretation can encourage visitors to assist in protecting the dune by staying on designated paths and leaving the dune undisturbed.

Hāʻena is located at the western edge of the Hawaiian Humpback Whale Marine Sanctuary (as designated by the National Oceanic and Atmospheric Association, NOAA). Its entire shoreline and marine environment to the 200-meter depth contour is designated as critical habitat for the endangered Hawaiian monk seal (*Monachus schauinslandi*) or ʻīlio-holo-i-ka-uaua and is also frequented by the honu or green sea turtle (*Chelonia mydas*). Guidelines exist to protect these native, endangered marine species but interpretive materials are needed to inform visitors of these rules and guidelines.

<u>Theme</u>: Natural hazards exist in the park requiring extra precautions.

The ocean and geological formations in the park present several natural hazards. These hazards extend into the Nāpali Coast making it important to post safety messages for visitor safety. Interpretive materials that encourage visitors to stay in designated areas and avoid certain activities that put them at risk are critical messages.

<u>Theme:</u> The sites and resources of Hāʻena are fragile and valuable parts of the heritage of Kauaʻi and must be protected and preserved.

Awareness about the importance of cultural sites and the natural resources (flora and fauna, rock formations, the ocean and water resources) will help visitors gain a meaningful understanding and connection with Hāʻena and teach them to appreciate the connection between the natural environment and its human caretakers who continue to tend to the site. Respect for these resources and heritage values through preferred behavior patterns will promote preservation.

INTERPRETIVE PROGRAMS, FACILITIES, AND DEVICES

<u>Interpretive Program Options</u>

A wide variety of interpretive programs could be implemented and designed to serve a spectrum of park visitors including an audience of international visitors, out-of-state visitors, residents, school groups and others. Hāʻena State Park could also serve as an outdoor classroom to actively learn about significant Hawaiian culture and history, natural resource restoration and ecological studies through hands-on research and participation and field schools. Interpretive programs could incorporate, where possible, ongoing cultural activities such as the cultivation of kalo. Figure 33 shows the conceptual location for various interpretive elements and Table 19 provides a summary of the types of programs that could be implemented at the park. They are separated in two categories: passive programs (self-guided and audio tours) and active programs (guided tours and work programs). Passive programs require interpretive materials such as brochures, signs or audio devices. The audience is primarily the international and out-of-state visitor. Active programs such as guided tours require staffing in order to be implemented. Staffed tours and active programs can serve a broader spectrum of the park's visitors, depending on the content of the tour/program. Tours and programs typically require greater resources and ongoing coordination, but can provide greater depth of content and experience.

Table 19 – Interpretive Programs

Program Type	Description
Passive	***Requires Interpretive Materials***
Self-Study	• Provide information in printed materials such as brochures and booklets) as well as online on a website and via smartphone applications. • Allows person to learn about the park at their convenience. • Can be distributed widely and accessed remotely.
Self-Guided Tours	• Visitors tour the park reading interpretive signage and interacting with interpretive displays/wayside exhibits located throughout the park. • Printed maps and supporting educational materials could be distributed. To reduce the amount of paper waste that may be generated, reusable maps/materials should be considered as well as smartphone applications. • Quick Response (QR) Codes and GPS-based information could be included in materials and displays in areas of the park where phone and satellite reception permits.
Audio Tours	• Visitors tour the park having audio devices with prerecorded information. • Fees are often charged for this enhanced service.
Active Programs	***Requires Staff Support***
Guided Tours	• Visitors tour the park with a trained guide. • Different tours could be provided, highlighting the rich and diverse cultural and natural resources.
Work Program	• Visitors participate in hands-on activities to support the park. • Could include habitat or archaeological site restoration projects, loko restoration, shoreline and marine environment restoration, wildlife monitoring, invasive species clearing, or culturally-based agricultural work in the lo‘i.

Program Type	Description
Junior Ranger/ Junior Lifeguard	• School-aged children participate in educational programs and hands-on experiences that emphasize environmental and cultural stewardship. • Teens learn about water safety and the protection of shoreline and marine resources. • Helps develop from an early age the skills, knowledge and interest in caring for Hāʻena.
School-Based Programs	• Educational programs catering to school groups. • A wide range of topics could be taught and hands-on experiences provided. • Teach children from an early age about the significance and the richness of resources in Hāʻena.
Immersive Study	• Immersive study programs would involve more in-depth research and/or work projects onsite over a certain period of time. • Study topics could include cultural, historic, and archaeological resources, environmental, ecological, and natural resources, marine and coastal environments, navigation, social/human impacts, baseline measurements, mapping park resources, etc. • As an example, the Hawaiian Studies program at the University of Hawaiʻi has suggested starting a program that would involve a group of students working at the park over a period of several days and potentially up to a semester depending on the work.

INTERPRETIVE FACILITIES

Chapter 3.0 describes the facilities proposed in the master plan, several of which could support interpretive programs.

- Entry Complex including the Welcome Hale – main entry point for visitors and interpretive displays.
- Pedestrian Path to Kēʻē – main pedestrian path between the park entry and Kēʻē where visitors can explore and learn about the varied scenic, natural and cultural resources found in the park including the loʻi, Makana, Wai a Kanaloa, the wetlands, hau tunnel and dune system.
- Reconstructed Hale Interpretive Site – located off the main parking lot, the site provides an opportunity for visitors to see and explore a reconstructed hale pili and loʻi.
- Agricultural Complex – in addition to viewing a working agricultural complex, there are opportunities for community work groups and educational groups, volunteer programs, and immersive study.
- Hula Complex – depending on the cultural protocols developed for the Hula Complex, there may be opportunities for restoration and maintenance work programs, and cultural immersive study for hula practitioners.

- Cultural Gathering Place – the Cultural Gathering Place is envisioned to support community/educational groups and where overnight stays would be permitted. This area could support a wide range of interpretive programs such as school groups, work groups, junior rangers, and immersive study groups.
- Hālau Wa‘a – this facility would mainly support culturally-based programs involving canoe building, paddling, and navigation as well as some marine-based programs.
- Poi Mill – while it is to be determined whether it would be possible or desirable to rebuild a working poi mill in this area, the site of the historic poi mill could, at a minimum, be interpreted with signage and/or displays.
- Constructed Wetlands, Stream Restoration, Bioswales, Renewable Energy, and Green Infrastructure – the constructed wetlands, bioswales, renewable energy, and other green infrastructure and technologies implemented throughout the park can help educate visitors on a variety of sustainable design concepts including the water cycle, solar/wind power, and natural processes used to treat wastewater and reuse rainwater.
- Trails – trails throughout the park support self-guided as well as guided tours and audio tours.
- Interpretive Displays/Wayside Exhibits – interpretive displays and wayside exhibits could be located throughout the park within facilities, along paths, trails and at interpretive sites and kiosks, some of which are shown on the master plan. Displays that will be located outdoors should be designed to be easy to maintain, are durable (particularly resistant to salt air, mold and sun) and vandal-proof.

INTERPRETIVE PROGRAM OPPORTUNITIES

Visual access to Hā‘ena’s beaches from the Kalalau Trail offers unique opportunities for wildlife viewing and education. Wildlife viewing is a low-impact recreational activity that could be accommodated within the park without dramatic infrastructure improvements and could include guided as well as self-guided tours.

The relatively pristine character of Limahuli Stream offers a rare opportunity for visitors and locals alike to observe a functional stream ecosystem complete with native fishes such as ‘o‘opu. Any educational experiences relating to the stream should be undertaken with great care to preserve it as is and to minimize pollutants and further infiltration by alien or invasive species. With the exception of restoration activities, trails and clearing along banks for general or unguided observation are not recommended.

Special guided interpretive programs could also include educational and work groups tending to the lo‘i just mauka of the pedestrian path but makai of the highway. As the loko are restored, they could also be included in special interpretive programs. For safety reasons and due to the sensitivity of these areas, these special programs should be managed and operated by knowledgeable staff.

As an outdoor classroom, the park has the potential to support service learning and field schools. University of Hawai‘i (UH) has also expressed interest in a conceptual program to use Hā‘ena State Park as a learning laboratory for their Hawaiian Studies program. Students would perform their practicum work in the State Park along the shoreline, near shore systems, and Limahuli Garden and Preserve to study mauka systems, allowing the opportunity to immerse students within a real-world context to study traditional and customary practices. The Cultural Gathering Place is one location which could support such a program as well as other special educational programs with other school groups. In 2012, UH Hawaiian Studies students had an opportunity to interface with members of Hui Makaʻāinana o Makana onsite and interest in the collaboration remains strong. There is the potential for Hawaiian Studies to partner with State Parks in the interim to help with baseline studies of the park's ecological and cultural resources as well as performing ongoing monitoring, maintenance, and restoration efforts should State Parks be willing. Such partnership efforts to monitor and care for existing park resources would not need to wait until the master plan and EIS are completed. There is great potential for UH Mānoa's Center for Hawaiian Studies to support State Parks and its current loʻi curator, Hui Makaʻāinana o Makana and further discussions should be held with State Parks and the Hui.

IMPLEMENTATION OF AN INTERPRETIVE PROGRAM

GUIDELINES FOR IMPLEMENTATION

The following list describes general techniques and implementation considerations for the interpretive plan.

- Establish a consistent design, complimentary content and a system of distribution.
- Develop detailed site signage and an interpretive display plan including specific sign locations, materials, text and graphics.
- Seek ways to reduce paper and related waste in distributing interpretive information and materials.
- Locate interpretive displays and wayside exhibits at locations to ensure the public's safety from rockfall and shoreline hazards and so as not to interfere with culturally and/or ecologically sensitive areas.
- Use native and Polynesian-introduced plants to create a natural buffer and to guide visitors toward safer, less sensitive viewing locations.

PHASED IMPLEMENTATION

Interpretive and educational programs can be phased to correspond to phases of park improvement and development. Elements of a passive interpretive program can be implemented as an interim measure until facilities and staffing are in place. A passive approach will address the immediate need to heighten awareness about the park's resources, cultural significance, and safety concerns.

With the ongoing restoration of the loʻi kalo, it is possible to implement an active interpretive program focused on traditional subsistence in the near-term. Interpretive programs that offer richer curriculum for families, school groups, cultural practitioners, scientists and scholars and require minimal facilities could also be implemented in earlier stages as the park itself could operate as an outdoor classroom or field school.

POTENTIAL INTERPRETIVE PARTNERSHIPS

The interpretive program can be developed and implemented by State Parks. However, a program that builds upon park partnerships will provide a greater diversity of offerings for park visitors and the community. Consultation with the Cultural Advisory Group and relevant resource specialists can provide ideas and information to design the program elements. For State Parks, these partnerships may range from management leases to concession agreements.

Opportunities abound for State Parks to develop interpretive programs with third-party agencies and nonprofits. Initial discussions with Mrs. Jean Souza of the NOAA Hawaiian Humpback Whale Marine Sanctuary identified potential educational partnering opportunities, including installation of interpretive signs at the park provided by NOAA, as well as educational brochures and materials. The interpretive signage would include information about the sanctuary activities such as rescue, resource protection, science education and outreach.

The interpretive program for the park could also include the Nāpali Coast and Kalalau Trail and should be coordinated with the ongoing efforts for the Nāpali Coast State Wilderness Park. Coordination with the Nā Pali Coast ʻOhana and/or other established groups that provide interpretations and management within the Nāpali Coast State Wilderness Park would also benefit the interpretive efforts at Hāʻena State Park.

Ongoing efforts such as the clearing and cultivation of the agricultural complex under a State Parks' curatorship by Hui Makaʻāinana o Makana could itself be expanded to include organized active programs. Similarly, the Makai Watch program which has operated at times to monitor the park's nearshore ocean resources could also expand to serve interpretive functions.

Other potential agencies and organizations who State Parks could partner with on developing interpretive themes and programs include:

- USFWS and the Kīlauea Point National Wildlife Refuge
- Hawaiʻi Tourism Authority and Kauaʻi Visitors Bureau
- County of Kauaʻi Office of Economic Development and Department of Parks and Recreation
- Hanalei Hawaiian Civic Club, Limahuli Garden and Preserve, Waipā Foundation, Hanalei to Hāʻena Community Association
- Kauaʻi North Shore Business Council

Many of these organizations are represented by members of the MPAC or were contacted as part of the master plan process and initially indicated an interest in furthering potential partnerships related to the park.

MEASURES OF EFFECTIVENESS

Once the interpretive programs are in place and operational for a period of time, the different programs should be evaluated on various levels of effectiveness.

- Develop measurable criteria to determine effectiveness of interpretive programs. Measure visitor learning and understanding of Hāʻena's cultural and natural resources as well as effectiveness in protecting and managing the park's sensitive resources.
- Determine which quantitative and qualitative measurements will be used to evaluate effectiveness and perform baseline measurements before interpretive program implementation.
- Consider the resources that are affected by human interaction and monitor human use before and after implementation of the associated interpretive device(s).

- Establish performance standards and identify the principal feedback mechanisms to be applied in service delivery monitoring.
- Perform regular data collection once programs are implemented.
- Include an amendment clause to revise the interpretive plan as necessary to improve effectiveness.

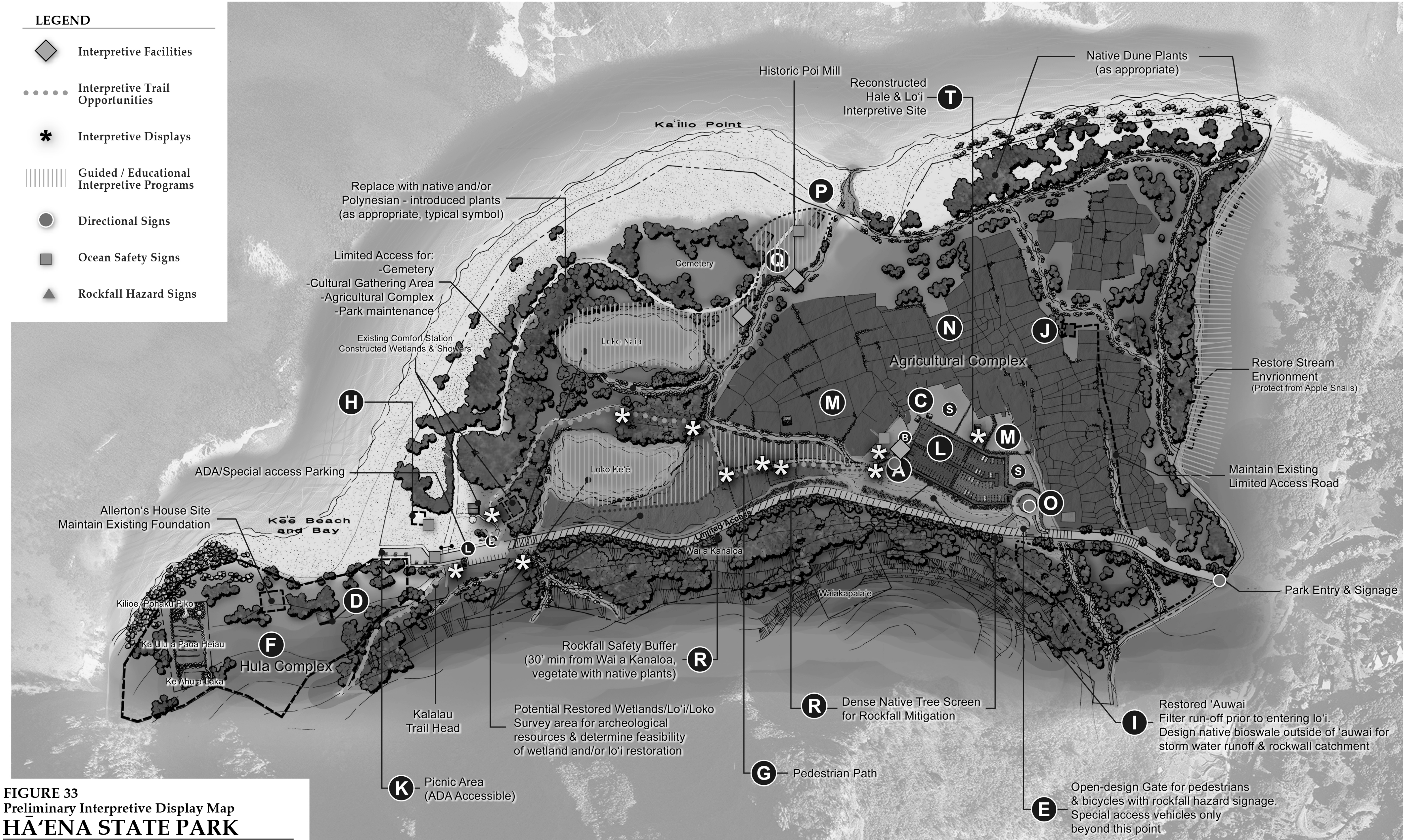


FIGURE 33
Preliminary Interpretive Display Map
HĀ'ENA STATE PARK

Department of Land and Natural Resources — Island of Kaua'i

North — Linear Scale (Feet) 0 250 500

PBR HAWAII & ASSOCIATES, INC.

Source: Based on 2001 Community Preferred Master Plan prepared by The Keith Companies

Disclaimer: This graphic has been prepared for general Planning purposes only and should not be used for boundary interpretations or other spatial analysis beyond the limitations of the data.

Kaulana Kēʻē

Mehana Blaich Vaughan

Kaulana Kēʻē i ka nape o ka niu
Haʻa i ka ʻehu kai aʻo Hāʻena

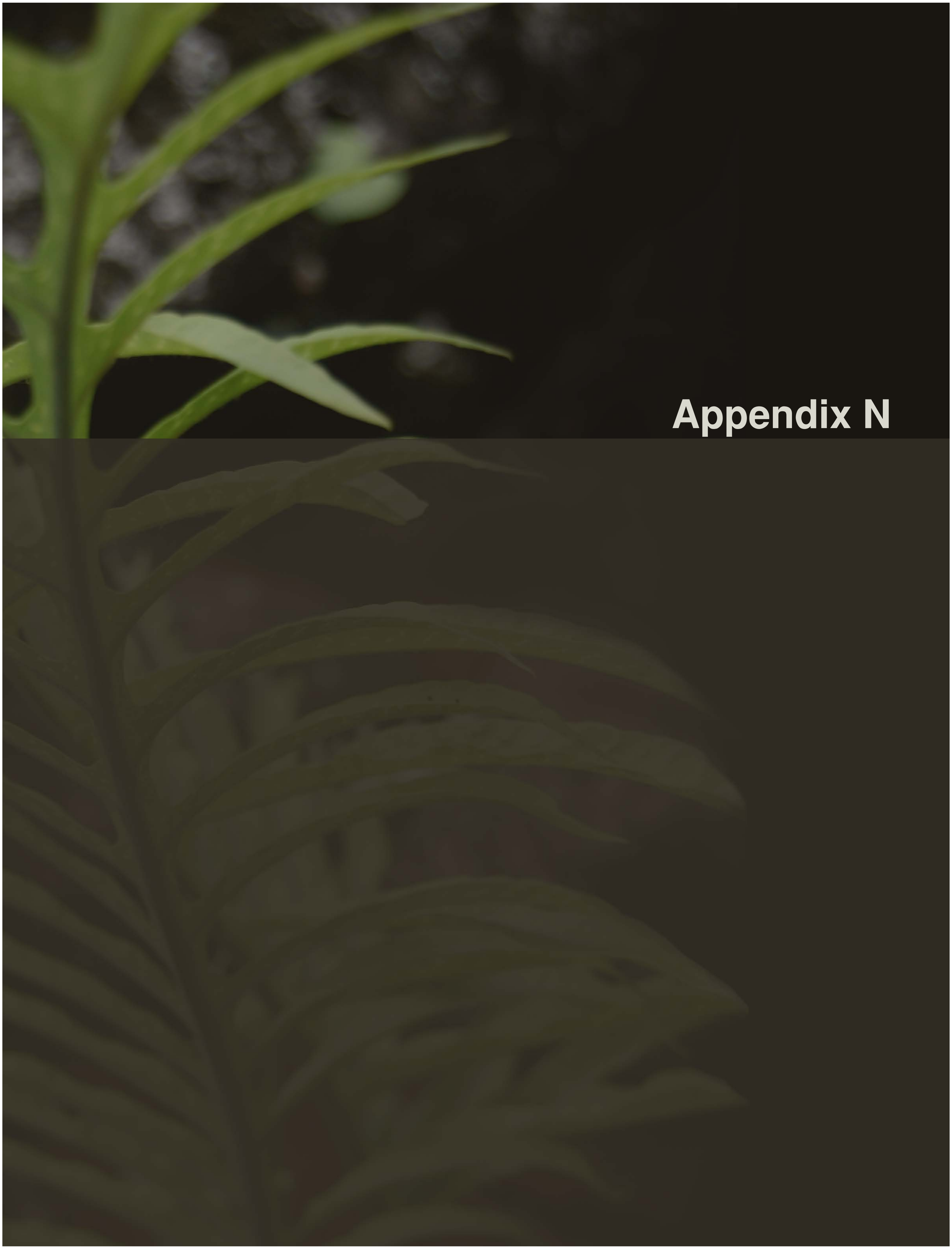
ʻEnaʻena ʻoāhi o Makana
Kanu ʻia Hāloa e nā lima huli
Huli aku mākou i wai a kane
Māpu ka lauaʻe i ka poli Waialoha

Puana ʻia ke aloha pau ʻole
No Hāʻena pili i ke kai

Kēʻē is known for its swaying palms
Rising and falling in the seaspray of Hāʻena

The soaring fires of Makana glow fiery hot,
Mountain before which hands turn down to set roots

We seek the waters of Kāne,
fragrance of lauaʻe fern at the spring Waialoha
Unceasing aloha is shared
For Hāʻena, nestled close to the sea



Appendix N

Appendix N – Park Organization and Operation

ROLES AND RESPONSIBILITIES

RESPONSIBILITIES OF THE STATE

DLNR, Division of State Parks
As the owner of the park, the Division of State Parks (State Parks) is charged with the care, upkeep and management of the park. In managing Hāʻena State Park, State Parks has an obligation to provide outdoor recreation activities in accordance with the Land and Water Conservation Fund (LWCF) Act while protecting the public's health, safety and welfare and preserving the park's resources.

State Parks will implement management strategies consistent with these priorities, thus they are echoed in the master plan objectives discussed earlier in this report. The Division of State Parks is responsible for the management of the park. However, as discussed above, there may be a variety of ways State Parks can meet these responsibilities through mutually beneficial relationships with third parties such as curatorships, leases, and concessions. Concessions would be limited to park management and parking/shuttle management.

Department of Transportation
As the current owners of Kūhiō Highway, the State DOT is responsible for the maintenance of the roadway and assumes all liability associated with the roadway. Should State Parks wish to have ownership of the roadway transferred from the State DOT to State Parks, an executive order should be sought from the Governor for the transfer of title. However, if ownership remains with State DOT, then close coordination between State Parks and State DOT will be required to implement the improvements as discussed in Section 4.4.1.

RESPONSIBILITIES OF THE PARK MANAGEMENT ENTITY

Whether management of the park falls to the Division of State Parks or to a third party, certain responsibilities for the day-to-day operations, maintenance, interpretation, provision of outdoor recreation, resource protection and public safety along with implementation of the Master Plan should be carried out in a coordinated manner. The managing entity will report either directly to or through State Parks staff to the Board of Land and Natural Resources (BLNR).

The management entity will be responsible to:

- Ensure the objectives of the master plan are accomplished in all park management and development decisions.
- Seek guidance from the Cultural and Community Advisory Groups and State Parks regarding cultural impacts, maintenance and interpretive programs and improvements for the park.
- Manage the park in a financially responsible manner.

RESPONSIBILITIES OF THE COUNTY OF KAUAʻI

The County of Kauaʻi is the landowner of TMK: 5-9-01:25 upon which Ka Ulu a Paoa Heiau and Ke Ahu a Laka are located and are technically responsible for the care and management of the site. The County currently has a Stewardship Agreement with the Hui Makaʻāinana o Makana to maintain the heiau. An access agreement or easement will also need to be worked out between State Parks and the County since the only access to the parcel is through Hāʻena State Park.

PERSONNEL NEEDS

At a minimum, Hāʻena State Park will include an onsite Park Ranger to oversee natural and cultural resource protection and daily park operations.

Implementation of basic services, maintenance and the development, management and interpretation envisioned in the master plan will require park staff. Following is a list of recommended personnel developed by the MPAC, envisioned to implement the objectives of the master plan. However, the actual list of required positions and job descriptions will be determined by State Parks.

Park Coordinator

- Oversees overall park management, budgets and staffing.
- Serves as the primary contact for State Parks.

Hula Complex Coordinator

- Oversees the protection, preservation, interpretation, operation and maintenance of the Hula Complex, including coordinating the scheduling of the use of the site by hālau hula.
- Maintains the site and its cultural integrity and acts as the prime source of public contact and information about the site including instruction on appropriate protocols and decorum.
- Maintains cooperative relationships with federal, state, county and community/hula organizations.
- Provides security and enforces protocol at the site.

Park Interpretive Technician(s)

- These individuals provide cultural education and outreach as well as general park education about safety and appropriate behavior within the park.
    - Hula practitioner
    - Mahi ʻai (farmer) practitioner in loʻi and loko iʻa
    - Waʻa (masters of the canoe and ocean)
    - Lawaiʻa (fisherperson)
    - Lauhala weaver (plaiting of hala leaves)

Mauka-Makai Watch

- DLNR formalized the Mauka-Makai Watch Program under DOCARE and its Coastal Policy.
- Coordinate with DOCARE to possibly station someone at the park to coordinate and supervise the Mauka-Makai Watch program including:

- supervision of staff and volunteers
- coordination of data recovery and reporting
- coordination with other Mauka-Makai programs and partners
- communication with enforcement agencies

Resource Staff

- Provide resource monitoring, management data, information and instruction about the natural and cultural resources of Hāʻena ahupuaʻa.
- Could either be hired as general park staff, or under Mauka-Makai Watch program, or possibly staffed in partnership with another public agency, non-governmental organization (NGO), or university program.

Lifeguards

- Employed by County of Kauaʻi, but salaries paid by State Parks.
- Provide ocean safety services and first aid at Kēʻē.
- There are currently three lifeguards stationed at Kēʻē.

OPERATIONAL ISSUES

The following section focuses on specific operational issues that are universal regardless of the specific management structure implemented at the park. They include park hours of operation, emergency preparedness, communications, and enforcement.

DAILY HOURS OF OPERATION

The official hours of the park are during daylight hours. However, access has technically been available to the public 24 hours a day, 365 days a year since there is no gate or barrier at the park entrance. Throughout the meetings with the project team, community and MPAC, several issues were identified with regards to park access, including:

- The inappropriate access and use of the park during late night hours, including rave parties. The traffic counts taken by ATA over the Admissions Day weekend in 2008 showed that there were between four and eleven cars entering the park each night between 8:00 p.m. and 6:00 a.m. and between five and seventeen cars exiting the park during those same hours.
- The desire by local residents to be able to access the park during early morning hours and at sunset.
- The need for overnight hikers to be able to exit the park at any time of the day or night.
- The constant flow of vehicles to the park and circling within parking lots, creating hazards for pedestrians and diminishing the experience within the park, as well as the traffic on the highway leading up to the park.

In order to facilitate implementation of the management strategies, including the objectives to restore Hāʻena as a living place and to uphold State Parks' responsibility for the public's safety and welfare, the park should be closed to motorized vehicles (with exception of emergency vehicles and park staff) daily from 10:00 p.m. till 4:00 a.m. However, the park should be monitored to see if continued vandalism and misuse occurs and consider revising access policies if they do.

HOʻOMAHA

Periods of rest are recommended where the park would be closed to the general public to allow the place and the natural resources to recover and replenish themselves. These are considered kapu periods or hoʻomaha. The community recommended this be done at least one day a week on a regular basis as is currently done every Tuesday at the Hanauma Bay Nature Preserve on Oʻahu. Also, the park could be closed over several days possibly at certain times of the year to allow for intensive park maintenance or when weather conditions are typically harsh and not safe for recreational activity. These public closure days could also be used for special educational groups, groups associated with cultural practices, and community work groups participating in restoration activities. Hikers with overnight permits for the Kalalau Trail and hunters with valid hunting permits will also be allowed access on closed days.

Additionally, prior to implementing any new park entry rules, the community recommends closing the park to the public for both a cultural and physical cleansing. They suggest making this a community event and recommend consultations with resource managers and the Cultural Advisory Group on appropriate procedures.

PUBLIC OUTREACH AND COMMUNICATIONS

With the proposed changes, public outreach and communications will be critical in implementation of the plan. Therefore, a communications plan and ongoing communications policies should be developed to help keep the public informed.

- Develop a list of contacts to whom park information and announcements will be distributed on a regular basis. Include appropriate public agencies, news outlets, community and visitor industry representatives and contacts such as the Hawaiʻi Tourism Authority, Kauaʻi Visitors Bureau, Hawaiʻi Hotel and Lodging Association, and Kauaʻi hotels.
- Provide daily reports on information not limited to current weather and surf conditions, special events, park closures, parking and shuttle availability, and entry ticket availability, as appropriate.
- Use electronic technology including the Internet, social media, and smartphone applications to distribute real-time information. Such information would allow hotels and other visitor information specialists to inform their guests of up to the minute conditions at Hāʻena prior to their leaving for the North Shore.

Emergency Preparedness

Due to the remote location of the park and the potential for hazardous conditions, an emergency evacuation plan and rescue plans should be developed. Coordination and regular drills with State Civil Defense, Kauaʻi fire and police departments should be performed annually at a minimum to ensure readiness. All park staff and others involved with the ongoing maintenance of the park such as volunteers, concessionaires/lessees and their staff, and specialists tending the Agricultural Complex and Hula Complex should be trained in the proper procedures for handling different emergency situations and participate in the annual drills.

For tsunami events, two different scenarios should be planned since locally-generated tsunami give very little time to evacuate coastal areas and distantly generated tsunami can take hours to make landfall. Evacuation plans and readiness plans should be developed by State Parks and all visitors should be informed on what to do for both scenarios in park orientation and informational materials. Tsunami evacuation signs should be posted appropriately on paths and evacuation routes.

Enforcement

Enforcement was a major concern raised by the community and MPAC members. DOCARE is the primary entity within the State charged with enforcement of park rules and conservation district rules. They have full police powers and as noted earlier, their responsibilities cannot be transferred to another entity.

If, however, State Parks chooses to charge for parking in the main parking lot or put other restrictions on the parking lot, parking tickets can be issued by third-party parking lot operators. Also, the parking lot operator can manage the collection of ticket fees and towing services for vehicles, in accordance with §290-11, HRS.

OPPORTUNITIES FOR LEASES AND/OR CONCESSION AGREEMENTS

Lease and Concession Agreements with third parties are allowed within LWCF sites. However, the State must retain control and tenure of the property and remains responsible for maintaining compliance with all federal regulations and there are specific rules for the agreements and operations including compliance with civil rights and accessibility laws, periodic compliance reviews, competitive fees, and clear indication that the area is a public facility. Building on the range of options discussed in Section 4.2, potential lease agreements for the park include:

- Overall park management
- Cultural site and/or natural resource/habitat management

Potential concession opportunities at the park include:

- Park management
- Shuttle service
- Parking management

Nā Hala o Naue

J. Kahinu

Nani wale nā hala ʻeā ʻeā
O Naue i ke kai

Ke ʻoni aʻe la
Pili mai Hāʻena

ʻEna aku nā maka
ʻO nā manu i ka pua

Haʻina ka inoa
ʻO Kaleleonālani

Beautiful are the pandanus
Of Naue by the sea

They are swaying
Close to Hāʻena

The eyes of the birds look eagerly
At the flowers

The end of the name song
For The-Flight-of-the-Royal-Ones

This mele honors Kaleleonalani (Flight of the Royal Ones), the name taken by Queen Emma after the deaths of her son Prince Albert in 1862, and her husband, King Kamehameha IV in 1863 and her visit to Kauaʻi in 1871. Praise of trees, flowers, birds and places was a way of honoring a beloved person. Source: King's Hawaiian Melodies Copyright 1930, 43 Charles E. King, www.huapala.org