



Reclaiming Kaho'olawe

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Geospatial Solutions



Crews uncover a UXO during environmental cleanup efforts on the Hawaiian Island of

Kaho'olawe

laid waiting for a day of rebirth.

Ancient chants and archaeological evidence indicate that the Hawaiian island of Kaho'olawe was inhabited for more than a thousand years. Hawaiians fished, farmed, and lived in coastal and interior settlements across the entire island. In ancient times, the island was called Kanaloa for the god of the ocean and the foundations of the Earth. It was a place where navigators were trained, and, thus, it played an important role in early Pacific migrations.

It seems fitting, then, that today's advanced art of navigation should play a part in the restoration of Kaho'olawe, which had come to be known for the past 50 years as "the most shot-at island in the Pacific." Six miles south of Maui, the island served as a naval gunfire and aerial bombardment target through World War II, Korea, Vietnam, and the Cold War. Today, the 28,000-acre island is gaining a new distinction. According to U.S. Navy sources, it is the site of the largest U.S. military cleanup project ever -- a massive \$400-million undertaking to clear unexploded ordnance (UXO), debris, bomb fragments, and scrap metal left over from decades of violence.

But there's even more to the Kaho'olawe story. Before the island became a military practice range in the wake of the 1941 attack on Pearl Harbor, it had been extensively overgrazed. Goat herds had stripped the vegetation and spurred massive erosion. And, even as the bombs rained down, evidence of 1,000 years of ancient Polynesian habitation and culture

Combined, these factors made the restoration of Kaho'olawe a nearly spiritual undertaking for some. Even as teams combed its arid red soil for more than six years -- locating and clearing UXO and shell fragments on the surface and in some places as much as 4 feet below -- archaeologists documented and mapped a treasure trove of ancient cultural sites dating back to around 800 A.D. Meanwhile, studies were underway to determine what the island's native vegetation had comprised, plans were being made to reintroduce that vegetation and restore the island to its natural state, and endangered species were being identified and mapped for protection.

With the Parsons-UXB-led project completed in August 2004, Kaho'olawe stands as the foundation for the revitalization of Hawaiian cultural practices. Possession of the island has been returned to the people of Hawaii, and its management has been assigned to the state's Kaho'olawe Island Reserve Commission (KIRC). The island will now be set aside for cultural and education activities and archaeological investigations, with no commercial development allowed.

And the entire task -- from safely clearing some 12.6 million pounds of ordnance and scrap metal while simultaneously mapping, documenting, and protecting more than 3,000 archaeological finds -- was managed using GPS, GIS, a spatial database, and Web-based technologies.

Logistics of a Massive Cleanup The Kaho'olawe mapping and cleanup effort was both massive and precise. Parsons-UXB began by dividing the 43-square-mile island into 11,500 grids of about 100 square meters each. Survey teams located the corner points of each grid map unit (GMU) in a Universal Transverse Mercator coordinate system using either centimeter-accurate GPS or traditional survey instruments. They then collected data within those grids to create 0.5-meter contours.

With the control surveys complete, workers began the cleanup. An average of 350 workers commuted daily by a 15-minute helicopter flight from Maui to Kaho'olawe. For transportation alone, the Navy contracted a helicopter fleet that included three Sikorsky 24-passenger heavy-lift helicopters and two Bell 12-passenger helicopters to shuttle workers to base camps at the island's south shore. That amounted to at more than 520,00 round trips.



Once on the island, workers searched for, geolocated, and cleared debris from 20,500 acres of the island during the six-year project.

Once on the island, workers were assigned to survey specific GMUs, document the location of ordnance and other debris, and remove or dispose of materials from approximately 20,500 acres of the island. Working within each GMU, surface-sweep teams walked shoulder to shoulder picking up scrap metal as small as 1/32 inches and using GPS to document the location at which each ordnance item was found. On any given day, team members could find unfired cartridges, rocket warheads, World War II aircraft wreckage, and practice bombs. Each significant find was barcoded, positioned with GPS, and photographed using a GPS-enabled digital camera before it was removed.



Some UXOs had to be destroyed on-site.

For subsurface clearance, the geophysical teams used a sophisticated metal detector, known as an EM-61, to examine the site and seek out anomalies below the surface. The EM-61 used GPS tied to a base station on the island, enabling the teams to automatically map the location of any subsurface items. If the EM-61 indicated a presence of metal, the team examined the surface for scrap metal and then disposed of it. If no scraps were detected and the machine still indicated metal below the surface, a red flag, indicating a possible UXO, was placed on the spot and the flag's position fixed using GPS.

Excavation teams then slowly dug around the spot to uncover UXO material and determine whether or not the object could be moved, or if the ordnance must be destroyed in place. On one afternoon midway through the cleanup, for example, the team detonated a 2,000-pound World War II-era bomb found on the island.

Technicians manually completed more than 1 million paper forms that recorded ordnance data and locations. Data were later entered manually into a GIS database.

Archaeologists in the Wake Because Kaho'olawe was listed on the National Register of Historic Places, the cleanup additionally required the preservation of thousands of archaeological or historically significant sites on the island, as well as the replanting of native vegetation to slow the erosion of the island's topsoil. The mapping of potentially dangerous ordnance paved the way for archaeologists, botanists, ordnance experts, and volunteers helping with a revegetation project on the island to stay clear of harm's way as they trekked each square daily and carefully recorded their findings of natural resources, historic properties, and ordnance.

"The plan was to integrate archaeological aspects of the island into the ordnance cleanup," said Dr. Hallet H. Hammatt, who founded Cultural Surveys Hawaii in Kailua on the island of Oahu. "So we learned how to recognize things that might pose a danger. Because of the certainty of the technology that went into this and the many, many rules we had to follow, we felt fairly comfortable in that rugged landscape."

As archaeological relics and ordnance were found, they were carefully marked, photographed, positioned with GPS, and documented on paper forms for inclusion in the Kaho'olawe Island GIS (KIGIS). Eventually, Cultural Surveys integrated a handheld GPS data-collection system into its process. They chose the system because its mobility and real-time features eliminated the need for postprocessing of data, further closing the gap between fieldwork and the GIS. Fieldworkers could easily hand off their logs and data cards at the end of each day for uploading to a GIS. With technicians going to the island

by helicopter each morning, mobility and light weight were further benefits of using the handheld GPS technology.

"The fieldwork in itself was sometimes in the upland areas and would have nice slopes where you could see the ground," said Tanya Lee-Greig, Cultural Surveys historic preservation supervisor. "But getting from site to site sometimes was difficult. In certain areas, where you could not walk because of slope, we had to rely on a helicopter, so mobility was important."



Among other finds, workers discovered a wing from a World War II-era airplane.

Clearing the Way with KIGIS To manage the massive amounts of data acquired throughout the Kaho'olawe project, Parsons-UXB and its subcontractors relied on KIGIS, an islandwide GIS implemented by San Francisco-based [Farallon](#)

[Geographics](#). Designed to track the location, disposition, and handling of every suspected UXO recovered from the island, it also became an integral resource to track the locations of historically significant sites, natural resources, endangered species, and environmental hazards. The GIS data resided in a spatial database running a commercially available GIS with an intranet GIS component. Though KIGIS resided at the Parsons-UXB operations office in a Maui heliport, Farallon developed a Web site that allowed workers on Oahu, Maui, or Kaho'olawe to access the system by way of an intranet. Both spatial and nonspatial data flowed into the KIGIS as workers from the island submitted their daily forms for data entry. The KIGIS aggregated georeferenced data about live and spent bombs, guided missiles, grenades, rockets, and artillery shells. The findings were then logged into the database, and the map of the area was redrawn and delivered daily to workers to guide their tasks and ensure their safety.

Eventually, this database held detailed information about each piece of ordnance that was found -- no matter how small -- every historical artifact and site, every natural resource and species, GPS coordinates, topography, photographs, and any other information collected. KIGIS ultimately comprised more than 100 GB of data, including such minute information as 0.5-meter topography across 43-square miles, 30,000 bar-coded ordnance items, 3,000 historic-properties sites, 100,000 photos, and countless natural resources data.



Using the GPS-enabled EM-61, a high-tech metal detector, workers conduct a subsurface search, mapping the location of anomalies beneath the surface.

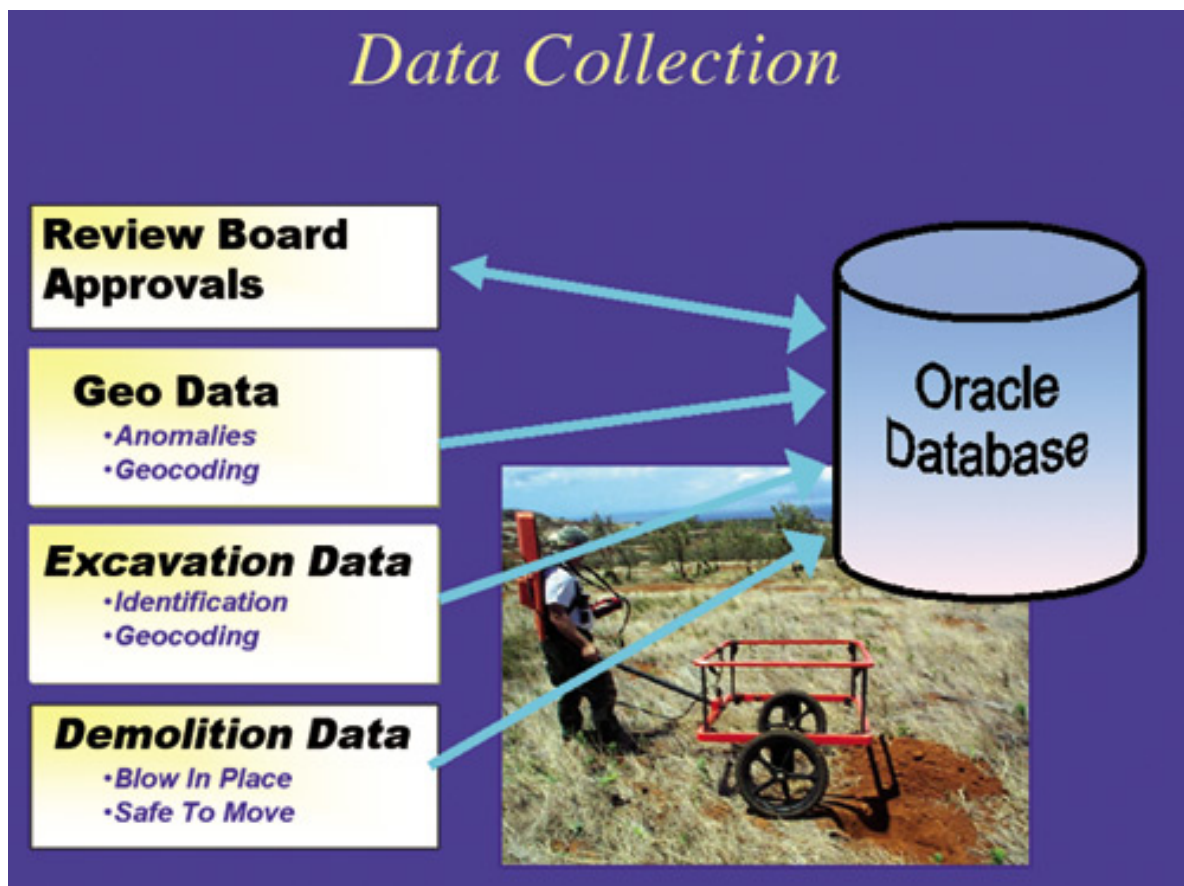


Figure 1 . Data from the field flowed into the KIGIS database. Project stakeholders -- including Parsons-UXB, the U.S. Navy, and the State of Hawaii -- accessed the data by way of an intranet to track progress and review proposed actions.

A color-coded system in KIGIS tracked the status and the assessment of the ordnance clearance, employing a 12-step process from the initial land survey to final acceptance that each of the 11,500 grids had been cleared. Stakeholders, including Parsons-UXB, the U.S. Navy and the State of Hawaii, could access the data by way of the intranet and track the progress of a specific site (see Figure 1). The color of the grid on the Web-based mapping page indicated the present status of that grid (see Figure 2). It also served as a management and decision-making tool when a specific course of action was needed.

A team consisting of contractors, Navy personnel, and KIRC staff constantly reviewed data packages to determine the specific course of action relative to given items. For instance, each time that an UXO was confirmed, a nine-member review board viewed the location of that ordnance through KIGIS. To determine the correct course of action, the board reviewed photos, locations, GMU assessment, surface-sweep data, subsurface detection information, construction activities, and UXO demolition practices. Their goal was to develop and view maps showing the most likely fragmentation distance of a UXO, whether it should be moved or detonated in place, and whether any archeological, environmental, or sensitive areas were located within that fragmentation pattern (see Figure 3). Using the spatial database to automatically create geometries based on input coordinates, Farallon automated the process of modeling these patterns and printing these maps and reports, allowing decision makers to create the required maps directly from the Web site. When the process first began, this project could take about a week. But once KIGIS was mature and online, this review took a matter of seconds.

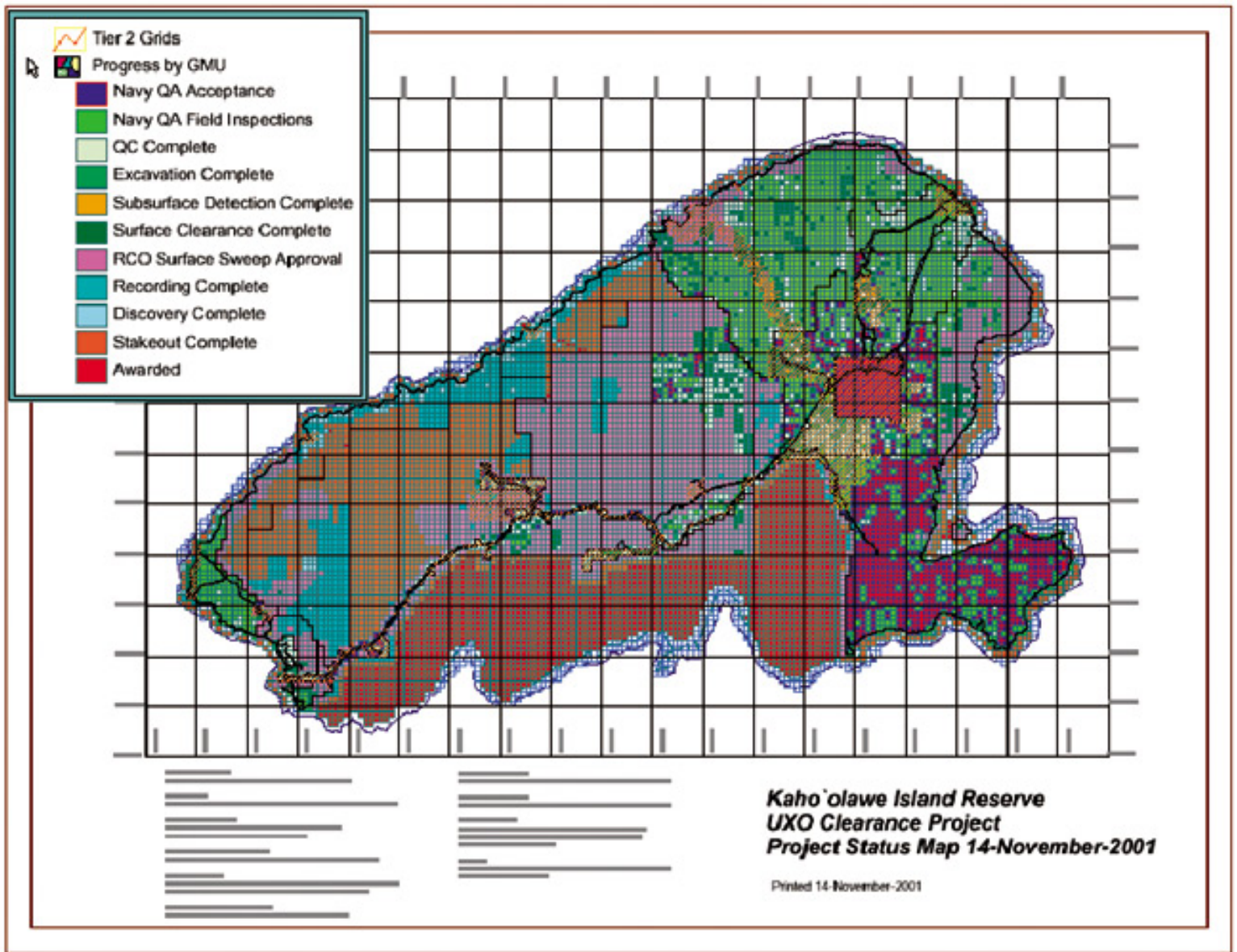


Figure 2 Color-coded weekly progress maps helped all interested parties to stay apprised of project status.

This was just one of many benefits KIGIS offered. Because the spatial database managed the geodata in a secure and validated manner, the project team now had a defensible and reliable record of exactly where cleanup had been completed, the type of work done, and the location of UXO objects when the State of Hawaii accepted responsibility for the island (see Figure 4).

An Island in Transition With the project complete, the documentation -- including KIGIS hardware, software, and data -- will be transferred to KIRC. KIRC will use KIGIS as a management tool as stakeholders work to reintroduce native vegetation to the island and track erosion where subsurface work was done. KIRC will continue to expand KIGIS as it works to plan the island's future.

"Precisely pinpointing the locations of the ordnance and knowing the boundaries were crucial during the cleanup because people were walking the island or using backhoes," said Hammatt. "But land planners also have to know where the archaeological sites are so they can integrate them in the overall plans for the island."

As the island begins to heal, Hawaiians are celebrating its rebirth and rediscovery, with several cultural sites already dedicated.

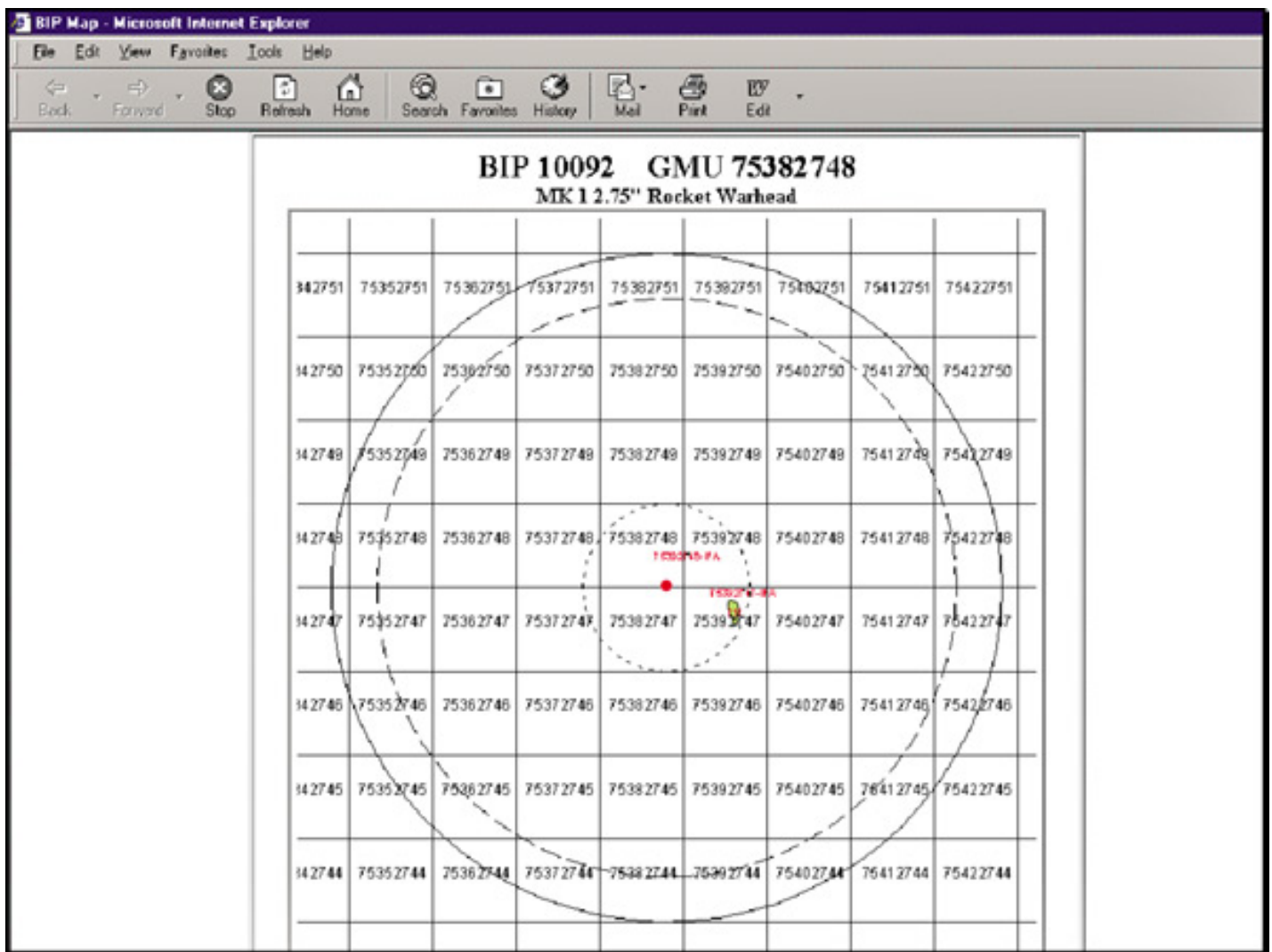


Figure 3 . Before any UXO was detonated in place, project managers created a 100-meter zone around the item (the fragmentation distance of the anticipated explosion) to determine if any archaeological sites or threatened or endangered species were at risk.

"Coming back home to Hawaii to do this job studying the archaeology of my native state has been very exciting," said Lee-Greig. "Being able to touch the tools that the people once used on this island and to realize the hardiness of the people was just amazing because the environment on the island is very harsh."

Among Hammatt's most prized finds was a lei niho palaoa, a hook-shaped pendant which is an ancient symbol of chiefly social rank given as a token of friendship and passed from one generation to another. The find was further evidence that Kaho'olawe was once tied to a moku, or independent chiefdom, which was then divided into a large number of sections called ahupua'a. These generally ran from the forested uplands, across the agricultural lands, and out to the coast and sea, encompassing the resources of both land and ocean.

Evidence of freshwater sources among lava formations was also discovered, along with a huge basalt quarry from which stone was crafted into tools, giving further clues to how ancient settlements survived amid the arid, rugged terrain.

"Everybody who worked on this project felt a real sense of purpose," said archaeologist Hammatt. He is particularly gratified by the project's attention to archaeological finds, including 3,000 sites that were identified and located using GPS during fieldwork that concluded in April 2004.

Kaho'olawe Island Reserve UXO Hazard

Multipliers:
 Bomb = 10 Projectile = 4
 Grenade = 30 Mine = 5
 Rocket = 5 Shell = 2
 Star = 5 Submarine = 10
 Projectile = 7 Total CDE = 1

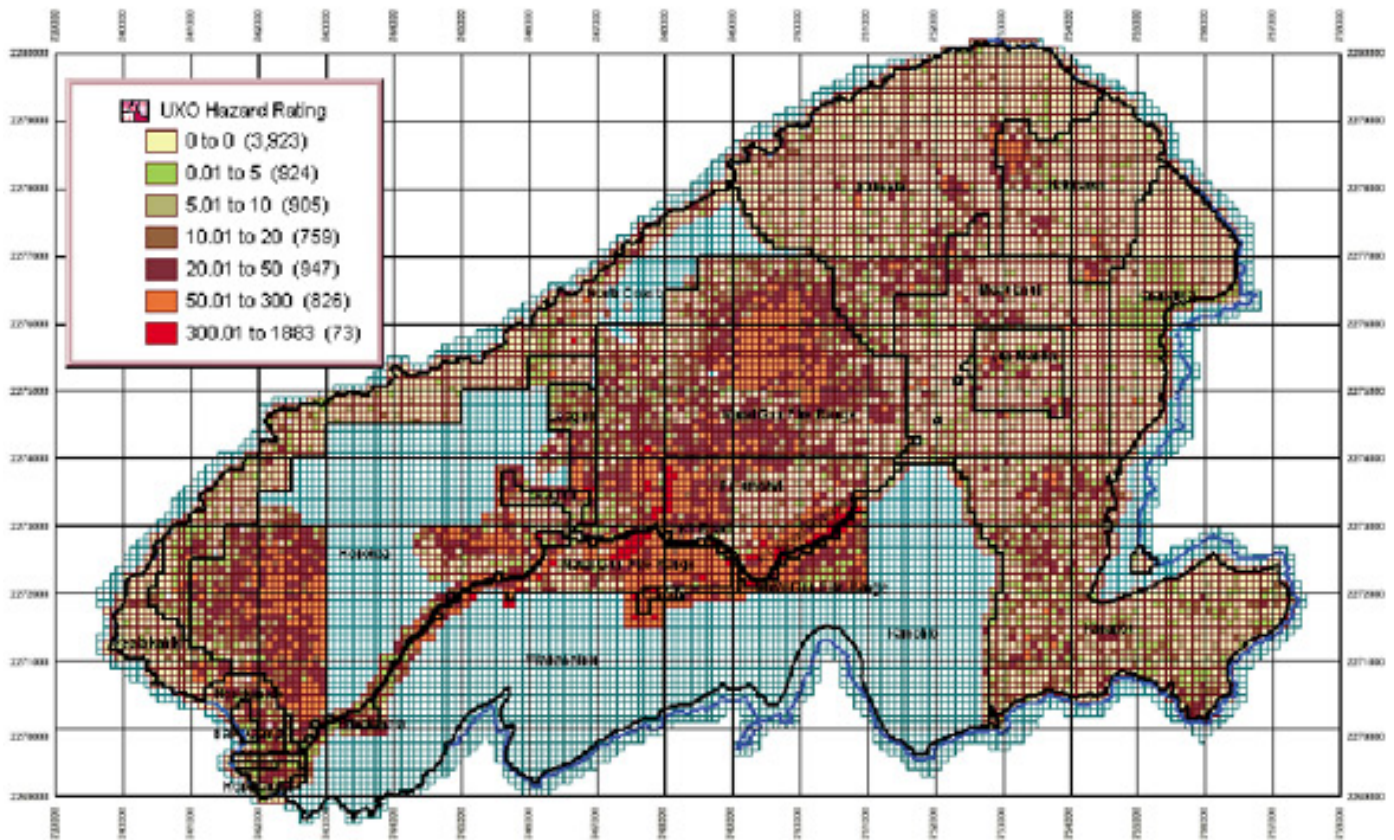


Figure 4. This UXO hazard map was produced from counts of items found on the island. A weighting factor was applied to each UXO type and a score produced for each grid -- with each grid then colored based on its score. Higher scores indicated by darker (hotter) colors contain the greatest hazard. This type of map helped to determine the most appropriate areas for subsurface detection.

"They were all located using GPS with 20 archaeologists taking the better part of six years to complete the project," said Hammatt. "The investigative and technological innovations generated by the Kaho'olawe Island project will provide a model for many years to come."

Manufacturers The prime contractor for the Kaho'olawe cleanup was Parsons-UXB, a joint venture formed in 1997 between Pasadena, California-based Parsons Inc., and UXB International of Ashburn, Virginia. San Francisco, California-based [Farallon Geographics](#) helped develop the Kaho'olawe GIS. Data reside in an Oracle 9i spatial database and are served up to users through the intranet using Intergraph Mapping and Geospatial Solutions GeoMedia Web Map. Field mapping and data collection relied on GeoXplorer and ProXR GPS receivers from Trimble and Husky data collectors from Tripod Data Systems. Field surveys used GPS Reliance and Z-Surveyor receivers from Ashtech (now Thales Navigation); Sokkia EDM Total Station theodolites; laser rangefinders and Mapstar Compass modules from Laser Technology, Inc.; radios from Pacific Crest Corporation; bipods, tripods, and prism poles from SECO Manufacturing Company Inc.; Omni whip antennas from Antennex; GPS marine antennas from Ashtech (Thales Navigation); and GPS data cards from SanDisk.