# Appendix B
## Expert Reports

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Meteorological Report

By Kevin Hamilton, Ph.D.

December 23, 2006
By: Kevin Hamilton, Ph.D.

An Unusually Wet Late Winter/Early Spring in Hawai‘i

The Kaloko dam breach on March 14, 2006 occurred 24 days into one of the most unusual periods of extended wet and stormy weather ever observed in Hawai‘i. Starting February 18, National Weather Service (NWS) flash flood watches (i.e. flooding is determined to be possible within the next 36 hours) were in effect over at least parts of the state for 31 of the next 42 days (the last of this series of warnings was issued for April 2). During the 42 day period 111 flash flood warnings (potentially dangerous flooding already occurring or expected within the next hour) were issued for various locations. In most years typically only 2 or 3 such flash flood warnings would be issued during the same calendar period.

In addition to causing a number of costly local flooding episodes, including extensive flooding in urban Honolulu on April 1, the rainy weather very likely contributed to two tragic events. On March 14 the Kaloko Dam was breached with a loss of several lives. On March 24 a sewer line in Waikiki ruptured, forcing raw sewage to be dumped in the Ala Wai Canal for several days, likely contributing to the death of a man who fell into the Ala Wai boat harbor.

Kaua‘i shared fully in the anomalous rainfall during the period commencing February 18. The rain gauge at Lihu‘e Airport recorded 45.33 inches of rain over the 42 day February 18-April 2 period. Just in March the Lihu‘e rainfall was 36.13", which was almost 60% more than ever recorded in any single calendar month (the previous record was 22.91" in December 1968). The rain gauge on Mt. Wai‘ale‘ale, regarded by some as the rainiest spot on earth, recorded an impressive 138.79" of rain during this 42 day period.

Rainfall Near Kaloko Reservoir Before the March 14 Dam Breach

Rainfall is currently measured at 23 stations throughout Kaua‘i. These are mainly cooperative observing stations with daily rainfall measurements. It is fortunate for present purposes that the NWS cooperative observing network includes a Kaloko Reservoir Station (NWS coop ID #514758) close to the reservoir itself, and that it has a rather long record. The Kaloko Reservoir Station coordinates are given by the NWS as 22°11’N and 159°23’W and its elevation is given as 490 feet above sea level. The station opened on October 1, 1949 and has provided daily data since then, although with numerous large and small gaps. Notably data are non-existent or very intermittent between October 1972 and February 1979. However outside of this period, the data should be adequate to determine the rainfall at the station for the January-March periods in each year of operation, i.e. 1950-1972 and 1980-2006, for a total of 50 years. This is a long data set which should provide some context for understanding how exceptional the winter 2006 rainfall in the vicinity of the reservoir really was.

The data considered are 24-hour accumulated rainfall amounts determined each day at 1800 hours Greenwich Mean Time (8 am HST) using a rain gauge. A simple analysis of the daily data has been undertaken as follows. For each year values of the mean rainfall rate during the 7 days prior to 8 am March 14 were calculated. Then values averaged over the 14 days previous to 8 am March 14 were computed, then for 21, 28...70 day periods. Fig. 1 shows the results plotted for the 50 individual winters. The 2006 results are denoted by circles, and three other exceptionally wet
winters (1956, 1960 and 1962) are also marked with special symbols. Missing days in the record are not counted in the averaging. The 2006 results certainly stand out, with this year determined to have either the second wettest or third wettest pre-March 14 period, depending on the averaging length used. By this measure at least, the 2006 rainfall near Kaloko Reservoir in the pre-March 14 period can be called very unusual, but not unprecedented in a roughly 50 year record.

The Kaloko Reservoir rainfall data can also be analyzed to find all wet spells of a particular length that exceed a given threshold, regardless of time of the year. So, for example the 14-day March 1-14, 2006 daily average rainfall (1.206") has been exceeded 11 times in the earlier record, with the largest such daily mean rainfall being 1.70" in November 13-28, 1990. The 28-day Feb-

![Kaloko Reservoir Average Rainfall Rate](image-url)

Fig. 1. Average rainfall rates at the Kaloko Reservoir Cooperative Weather Station during the 7 day, 14 day, 21 day, 28 day, 35 day, 42 day, 49 day, 56 day, 63 day, 70 day periods before 8 am HST on March 14 each year from 1950-1972 and 1980-2006. For each averaging period there are 50 symbols plotted for the 50 years. The results for the unusually wet years 1956, 1960, 1962 and 2006 are each marked with special symbols.
uary 15-March 14, 2006 mean daily rainfall (1.130") was exceeded 4 times in the earlier record, with the largest 28-day mean daily rainfall rate being 1.394" during March 26-April 21, 1963. Once again the data suggest that the heavy pre-March 14, 2006 period rainfall is rare, but far from unprecedented.

A Broader Meteorological Context

The rainfall falling on all the major Hawaiian Islands occurs through several distinct mechanisms. Under common trade wind conditions the prevailing low-level flow has a strong easterly component and is accompanied by a stable vertical atmospheric structure which acts to inhibit deep convection. Rainfall is mainly concentrated on the windward and upland areas, and extended spells of exceptionally wet weather are rare. In the late-fall/winter period (November-March), however, the prevailing trade wind pattern is perturbed more often and more strongly. Typically 2-4 times per winter an isolated low pressure system, a so-called Kona low, will form and may move slowly in the vicinity of the Hawaiian Islands. As the storm moves it can produce strong Kona winds, and when these winds have southerly components they transport large amounts of moisture from lower latitudes. Kona lows are often accompanied by perturbations in the upper troposphere that generate unstable vertical atmospheric structure. Such conditions are conducive to heavy rainfall over the entire extent of the islands, and even fairly strong thunderstorms occur in Hawai‘i in association with Kona low circulations. The long-lasting nature of the Kona lows leads them to be the main cause of extended wet periods in Hawai‘i, particularly on the normally drier leeward side of the islands. The formation and behavior of the Kona lows is affected by larger scale flow in the atmosphere and with the El Nino and La Nina cycle in the equatorial Pacific. Notably the extensive Kona low winters are less common when the tropical Pacific is in the El Nino state and more common during the La Nina state. In 2006 the extensive February-April rainy spell corresponded to the development of La Nina conditions in the equatorial Pacific. The development of significant persistent equatorial ocean temperature anomalies provides a kind of anchoring of weather patterns that are conducive to extended spells of unusual weather.

Just as the El Nino/La Nina cycle in the ocean can affect the occurrence of persistent anomalies in Hawai‘i weather in a given winter, longer period variations in ocean conditions may drive even lower frequency modulation of weather conditions. This means that statistics based even on a 50-year record may not sample the full range of relevant climatological conditions. This problem of representativeness of the existing weather record could be even more acute when the possibility of a long term trend in climate is considered. This will be discussed below.

Tropical cyclones, including hurricanes, are another source of extreme rainfall events in Hawai‘i, and one that can occur in the summer and early fall. However, such tropical cyclones generally move rapidly, and the heaviest rainfall episodes may be confined to a few hours. Thus very large accumulations over extended periods are not expected to accompany hurricanes. The most dramatic example in the observed record is Hurricane Iniki which passed over Kaua‘i on September 11, 1992, with landfall for the center of the storm observed at about 3:30 pm HST. The Kaloko Reservoir Station rainfall in the 24 hour periods ending 8 am HST on September 11, 12 and 13 were 0.45", 2.40" and zero. Another strong hurricane, Hurricane Iwa, brushed by
Kaua‘i on November 23, 1982. The Kaloko Reservoir Station rainfall in the 24 hour periods ending 8 am HST on November 23, 24, and 25 were 0.95", 3.38" and 0.06".

**Future Climate Change**

An interesting issue for assessing future extreme weather impacts in Hawai‘i is the possible effect of global climate change. It is now generally accepted that mankind’s activities are significantly affecting the concentration of radiatively-active constituents of the atmosphere, such as greenhouse gases and aerosols. Notably, combustion of fossil fuels and large-scale deforestation are acting to increase the atmospheric concentration of carbon dioxide, and continuing significant increases can be confidently anticipated over at least the next century. Similarly, atmospheric methane, nitrous oxide and sulfate aerosol concentrations are all changing due to human activities. Much effort has gone into understanding the changes in Earth’s climate that can be expected to result from these alterations in atmospheric composition. This work must rely to a large extent on predictions made from comprehensive global climate models. While much current research is aimed at improving such models, there has already been considerable activity in producing forecasts of climate for the next century or so based on plausible assumed future scenarios for continuing changes in atmospheric composition. Such scenarios generally assume that carbon dioxide concentrations will continue to rise substantially over the next century. The basic science of climate change and the forecast of future effects using state-of-the-art models was reviewed comprehensively in the Third Assessment Report of the Intergovernmental Panel on Climate Change. Under reasonable scenarios models suggest that global mean surface temperature will rise over the next century by between about 2 and 5 degrees C (4-9 degrees F), with tropical surface air and ocean temperatures rising by roughly 1-3 degrees C.

Predicting the effects of climate change in Hawai‘i is complicated by the pervasive influence of the steep topography on the weather on the major Hawaiian Islands. This is particularly the case for rainfall, which is strongly modulated by topographic influences. Unfortunately, the global computer models used in forecasts provide little direct guidance for Hawai‘i rainfall, since the horizontal numerical resolution of the models is typically about 300 km. Thus the models may represent the entire Hawaiian Island region by a single grid-box without any realistic topographic contrasts.

Despite these limitations, the current models do provide some overall guidance for expected rainfall changes in Hawai‘i. The increase in global temperature predicted by the models is associated with increased global evaporation and with increased precipitation. Thus an overall more intense hydrological cycle in the future is extremely likely. There is also a tendency reported for at least some current models to predict that a warmer global climate will be associated with more intense extremes of the hydrological cycle in individual regions, with longer and more extreme periods of both drought and flood anticipated. It should be emphasized again that no reliable detailed predictions specifically for Hawai‘i are now available. However, the global climate perturbations expected over coming decades will almost certainly have a significant effect on the rainfall in Hawai‘i, and any statistical analysis based mainly on the 20th century experience may become increasingly inaccurate as a guide for future planning.
C.V. for Kevin Hamilton

Education
1976: B.Sc. (Physics) Queen’s University (Kingston, Ontario, Canada)
1977: M.Sc. (Physics) McMaster University (Hamilton, Ontario, Canada)
1981: Ph.D. (Geophysical Fluid Dynamics) Princeton University

Employment
July 2004-present: Chair, Department of Meteorology, University of Hawaii at Manoa
October 2000-present: Professor, Department of Meteorology, and Team Leader for “Regional Impacts of Global Environmental Change” Research at the International Pacific Research Center, University of Hawaii at Manoa
1988-2000: Research Meteorologist at the NOAA Geophysical Fluid Dynamics Laboratory
1987-88: Visiting Scientist, Atmospheric and Oceanic Sciences Program, Princeton University
1985-87: Assistant Professor, Department of Meteorology, McGill University
1982-85: Research Fellow, Department of Oceanography, University of British Columbia
1981-82: Postdoctoral Fellow, National Center for Atmospheric Research

Concurrent Position
1988-2000: Visiting Lecturer with Rank of Associate Professor (1988-1996) and Full Professor (1997-2000), Program in Atmospheric and Oceanic Sciences, Princeton University

Awards and Honors
1992: Canadian Meteorological and Oceanographic Society President’s Prize for “outstanding contributions to the atmospheric and oceanic sciences”
1994: American Meteorological Society Meisinger Award for “wide-ranging and prolific research on the dynamics and climate of the atmosphere and ocean”
1997: NOAA Environmental Research Laboratories Outstanding Scientific Paper Award
2000: American Geophysical Union Jule Charney Lecturer
2001: Elected Fellow of the American Meteorological Society
2005: International Association for Meteorology and Atmospheric Science President’s Lecturer
Editorships and Editorial Board Memberships

1997-2000: Associate Editor, *Reviews of Geophysics*


2001-present: Editor, *Atmospheric Chemistry and Physics* (EGU)

2004-present: Co-Chief Editor for Springer Publishing *Atmospheric and Oceanic Sciences Library* monograph series

Commission Presidency

1999-present: President of the International Commission on the Middle Atmosphere

Scientific Committee Chairpersonships

1993-present: Co-Chair of Committee on Gravity Wave Processes and Parameterization of the SPARC (Stratospheric Processes and their Role in Climate) Initiative of the World Climate Research Program

1995-present: Chair of International Commission on the Middle Atmosphere Working Group on Numerical Modelling

1999-2002: Co-Chair of SCOSTEP EPIC (“Equatorial Processes Including Coupling”) Program Working Group 1 (Dynamics)

Scientific Committee Memberships

1986-94: American Meteorological Society Scientific and Technical Activities Committee for the Middle Atmosphere

1987-95: International Commission on the Middle Atmosphere (formerly the International Commission on the Meteorology of the Upper Atmosphere)

1994-present: Committee on Middle Atmosphere Climatology of the SPARC (Stratospheric Processes and their Role in Climate) Initiative of the World Climate Research Program

1995-2005: Scientific Steering Group for SPARC (Stratospheric Processes and their Role in Climate) Initiative of the World Climate Research Program

1997-present: Advisory Committee for the SPARC Data Center, Stony Brook University


1999-present: International Association for Meteorology and Atmospheric Science Executive Committee

2000-2002: American Geophysical Union Selection Committee for the Walter Sullivan and David Perlman Awards (for excellence in earth science journalism)

2005-present: External Advisory Committee for the NCAR Institute for Integrative and Multi-disciplinary Earth Studies (TIIMES)
Other Scientific Community Service (1996-present)

Director of NATO Advanced Research Workshop on “Gravity Wave Processes and Their Parameterization in Global Climate Models,” Santa Fe, April 1996

Member of American Geophysical Union Search Committee for *Journal of Geophysical Research* Editors in 1999-2000

Member of NSF Review Panel for Information Technology Research Initiative, January 2001

Co-Director of School on “Physics of the Equatorial Atmosphere” International Centre for Theoretical Physics (Trieste, Italy) September-October 2001

Co-convenor of the SCOSTEP “Equatorial Processes Including Coupling” Symposium (Kyoto, Japan) March 2002

Member of Scientific Program Committee for AGU Western Pacific Geophysics Meeting (Wellington, New Zealand) July 2002

Convenor of Workshop on “Analysis of DAWEX Results” (Honolulu) December 2002

Convenor of ICMA “Workshop on Modelling Atmospheric Tides” (Honolulu) March 2003

Lead Convenor of “Middle Atmosphere Science” Symposium at the 2003 IUGG Assembly (Sapporo, Japan) July 2003

Co-convenor of “Equatorial Middle Atmosphere-Thermosphere-Ionosphere Dynamics and Energetics” Symposium at the 2003 IUGG Assembly (Sapporo, Japan) July 2003

Reviewer for the *Strategic Plan for the US Climate Change Science Program*, 2003

Convenor of AGU Chapman Conference on “Gravity Wave Processes and Parameterization” (Kona, Hawaii) January 2004

Member of Program Committee for IAGA “Workshop on Vertical Coupling in the Atmosphere/Ionosphere” (Bath, UK) July 2004

Member of Scientific Program Committee for AGU Western Pacific Geophysics Meeting (Honolulu) August 2004

Convenor for Union Session “Earth Science on the Earth Simulator” at the AGU Western Pacific Geophysics Meeting (Honolulu) August 2004


Member of Scientific Program Committee for the Tenth IAGA General Assembly (Toulouse, France) July 2005

Lead Convenor for the “Middle Atmosphere Science” Symposium at the Tenth IAGA General Assembly (Toulouse, France) July 2005.

Teaching Experience (full one semester course unless noted otherwise)

University of British Columbia
1984: Physics 421 “Introduction to Atmospheric Physics”

McGill University
1985: Meteorology 410 “Dynamical Meteorology I”
1986-87: Meteorology 653 “Climatology” (1/3 of a two-semester course)

Princeton University
1988, 1996, 2000: Atmospheric and Oceanic Sciences 572 “Atmospheric and Oceanic Waves”
1997: Environmental Studies 202: “Environmental Science, Policy and Management: Quantitative Assessments and Interventions” (1/3 of a one-semester course)
1998: Geosciences 502/Civil Engineering 577 “Data Analysis and Modelling in the Environmental Sciences” (1/6 of a one-semester course)
1998: Atmospheric and Oceanic Sciences 537 “Atmospheric Chemistry” (1/2 of a one-semester course)

University of Hawaii
Fall 2001: MET 752: “Special Topics: Climate, Climate Modelling and Climate Change”
Fall 2002: MET 402: “Applied Atmospheric Dynamics”
Fall 2003: MET 704: “Climate, Climate Modelling and Climate Change”
Spring 2004: MET 765: “Seminar in Meteorology”
Spring 2005: MET 620: “Physical Meteorology” (1/2 of course), and MET 402: “Applied Atmospheric Dynamics”, and MET499 “Independent Study” (3 students enrolled)
Fall 2005: MET200: “Descriptive Meteorology” (1/2 of course)
Spring 2006: MET 620: “Physical Meteorology” (1/2 of course), and MET 765: “Seminar in Meteorology” and MET 495 “Undergraduate Thesis” (coordinator)
Publications

1979

*Paper in Refereed Journal*


1980

*Papers in Refereed Journals*


1981

*Papers in Refereed Journals*


*Unrefereed Publication*


1982

*Papers in Refereed Journals*


*Unreferred Publication*


1983

*Papers in Refereed Journals*


1984

*Papers in Refereed Journals*


1985

*Papers in Refereed Journals*


**Refereed Book Chapter**


**Unrefereed Publication**


1986

**Papers in Refereed Journals**


**Unrefereed Publication**

1987

Papers in Refereed Journals


Unrefered Publications


1988

Papers in Refereed Journals


Unrefered Publication


1989

Paper in Refereed Journal


Unrefered Publication

1990

*Paper in Refereed Journal*


1991

*Paper in Refereed Journal*


1992

*Paper in Refereed Journal*


1993

*Papers in Refereed Journals*


*Unrefered Publications*


1994

*Paper in Refereed Journal*

**Referred Book Chapter**


**Referred Encyclopedia Article**


**Unreferred Publications**


1995

**Papers in Referred Journals**


**Referred Book Chapter**

Un refereed Publications


1996

Papers in Refereed Journals


Refereed Encyclopedia Article


Un refereed Publication


1997

Book Edited


Papers in Refereed Journals


**Unrefereed Publications**


**1998**

**Papers in Refereed Journals**


**Unrefereed Publication**

**K. Hamilton.** Dynamics of the Tropical Middle Atmosphere. *Proceedings of the Canadian Summer School on the Middle Atmosphere* (J. Koshyk and T. Shepherd eds.) 212-256.

**1999**

**Papers in Refereed Journals**

**K. Hamilton.** Dynamical Coupling of the Middle and Lower Atmosphere: Historical Background to Current Research. *Journal of Atmospheric and Solar-Terrestrial Physics, 61*, 73-84.


**Unrefereed Publications**


**2000**

**Papers in Refereed Journals**


**Refereed Book Chapter**


**2001**

**Papers in Refereed Journals**


**Refereed Encyclopedia Article**

Unrefereed Publications


2002

Papers in Refereed Journals


Refereed Encyclopedia Article


Unrefereed Publications


2003

Publication Edited


Papers in Refereed Journals


Unrefereed Publications


2004

Papers in Refereed Journals


Unrefered Publications


2005

*Paper in Refereed Journal*


Unrefered Publication


2006

*Papers in Refereed Journals*


Engineering Assessment of Breaching Failure at Ka Loko Dam

By Lelio H. Mejia, Ph.D., PE, GE

December 28, 2006
Introduction

This report presents my engineering assessment of the breaching failure of Ka Loko Dam in support of an investigation of the disaster by Mr. Robert Godbey, appointed a Special Deputy Attorney General to investigate the failure. The report summarizes my findings and opinions regarding the possible causes of the failure and presents my recommendations on possible government actions that might prevent such type of incident in the future. The work was performed in accordance with URS’ proposal to Mr. Godbey’s law firm, Godbey Griffiths Reiss Chong (GGRC), dated October 27, 2006.

The objectives of this assessment were to: a) examine the possible modes of failure of the dam, b) if possible, identify the probable mode of failure, c) review and evaluate current inspection procedures required by state statute under the Hawaii Dam Safety Act and the role that dam inspections might have played in preventing the failure, and d) identify and recommend possible actions intended to prevent future similar incidents.

The findings and opinions presented herein are based on: a) review of information provided by GGRC regarding the characteristics of the dam and reservoir and the circumstances of the failure, b) observations made during a visit to the dam site, and c) analysis and evaluation of such information and observations. During the course of the work, I held discussions with Messrs. Godbey and Chad Iida of GGRC and with Mr. Michael Stevens, who is also consultant to GGRC on the investigation of the failure.

Information Reviewed

The information reviewed for this assessment included the following: documentation on the history of the dam and reservoir and their operation; photographs of construction of the dam; aerial photographs of the reservoir before and after the failure; photographs of the dam site after the failure, legal complaints filed by parties involved in litigation surrounding the failure; Title 12 Chapter 179D, Dams and Reservoirs, of the Hawaii Revised Statutes (HRS); Title 13 Chapter 190, Dams and Reservoirs, of the Hawaii Administrative Rules (HAR); data posted on the Internet for the Ka Loko Reservoir Flood from hydrologic surveys by the US Geological Survey (USGS) and the Department of Land and Natural Resources (DLNR); and various other documents compiled by GGRC from files of the DLNR, the Department of Health Clean Water Branch (DOH), the Public Utilities Commission (PUC), the US Army
Corps of Engineers (ACE), the US Department of Agriculture National Resources Conservation Service (NRCS), and the US Environmental Protection Agency (EPA).

Site Visit

The site visit was conducted on November 28, 2006 in the company of Mr. Michael Stevens, Messrs. Jess Griffiths and Chad Iida of GGRG, Drs. David Sykora and Phillip Shaller of Exponent, Inc., and Mr. Wesley Ching, attorney for the owner. The weather was clear and sunny through most of the visit, except for a short shower in the early afternoon.

The group visited the areas of the right and left abutments, the embankment remnants north and south of the breach, the breach, and the outlet works notch exposed just above the water level in the north reservoir bank (see Photograph 1). The group also walked from the south abutment area to the Ka Loko ditch, and for a short distance around the elevated esplanade on the north side of the reservoir. In the company of Dr. Sykora, I also walked down the embankment slope to the downstream groin of the embankment remnant south of the breach, and for a short distance along the groin.

Photograph 1. Aerial view of dam breach
(Original photograph by Hawaii Aviation)

The reservoir level was below the upstream lip of the breach. Within the area of the breach, I observed the topography and geometry of the breach, and the characteristics of the materials
exposed at the base and on the sides of the breach. With exception of vegetation growth and minor surface erosion, the main features of the breach did not appear to have changed significantly relative to their appearance in photographs taken by the Kauai Fire Department the day of the failure, March 14, 2006, and by the ACE a few days after the failure. The physical characteristics of the breach are described below.

The downstream slope and groin of the embankment remnant south of the breach were heavily vegetated with large trees and dense brush. The embankment crest was covered with ankle- to knee-high grass. However, there was no significant grass cover on the slope or groin. The surface soil along a short stretch of the groin appeared to be very loose, soft, and wet. The surface soil on the slope appeared to be firm and moist although no seepage was observed emanating on the slope. No rutting, gullies, or any other evidence of significant erosion on the slope, or the crest of the embankment remnant, was observed. Likewise, I saw no signs of cracking on the slope or crest.

The section of Ka Loko ditch visited was free of obstructions or dense vegetation. Flow in the ditch was very small, almost a trickle. In comparison, the Kilauea Sugar Plantation Company (KSPC) recorded flows of up to 145 cubic feet per second (cfs) in the ditch for the period between 1949 and 1953. A USGS Internet site states that the peak rate of inflow from the ditch into the reservoir in the days just preceding the failure was computed to be 205 cfs.

No spillway (also referred to as emergency spillway) could be seen at the location where a previous spillway is shown in aerial photographs dating to 1965 and in engineering sketches by the Soil Conservation Service (SCS), dated February 1982. The channel of that previous spillway appeared to have been filled in, and there is no other spillway elsewhere around the reservoir rim.

**Description of Ka Loko Dam and Reservoir**

**Dam and Reservoir Configuration**

Ka Loko Dam is an earthfill embankment located at the headwaters of Wailapa stream in the northeast of the Island of Kauai. The dam closes off the natural outlet of a volcanic crater to retain Ka Loko Reservoir. A KSPC drawing indicates that the reservoir had a storage capacity of about 1255 acre-feet (about 409 million gallons) at the crest elevation of the previous spillway. The aforementioned SCS engineering sketches indicate that the previous spillway crest elevation was about 747 feet relative to mean sea level (MSL). The 1984 Kilauea Agricultural Water Management Study (KAWMS) Report by the SCS, Forest Service, and DLNR states that sedimentation had decreased the reservoir storage to about 1200 acre-feet.

Very limited information is available on the design, construction, and performance of the dam. An accurate topographic plan of the dam prior to the failure was not available for this engineering assessment. Only approximate dam dimensions, slopes, and crest elevations prior to the failure are available. Likewise, limited information on the engineering characteristics of the embankment or foundation materials were available for this assessment.

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1 All elevations in this report are given in feet and refer to MSL datum, unless otherwise noted.
The aforementioned SCS engineering sketches show the dam crest being 770 feet long and about 15 feet wide. The sketches include three cross sections of the embankment surveyed by the SCS at distances of 185, 530, and 647 feet from the location of the previous spillway. Those sections show the crest elevation to be about 749.6, 749.8, and 750.7, at the location of each section respectively. The sketches also indicate that the crest elevation at a distance of 245 feet from the previous spillway was 748.5 (1.5 feet above the spillway crest elevation) and suggest that this was the low point on the dam crest. Those sections also indicate that the embankment had a maximum height of about 40 feet and that the inclination of the downstream slope was about two horizontal to one vertical.

**Dam Construction**

Photographs of the dam construction date to the early 1900’s. The annual reports of KSPC for the year ending December 1912 indicate that the dam was raised between 1911 and 1912 by 12 feet to the current crest elevation. The photographs of construction indicate that the main body of the dam was built by sluicing, a method of hydraulic filling. The dam materials appear to have been borrowed from local sources immediately north and south of the site, and to have been excavated with the aid of water jets and transported to the site by wooden flumes in a slurry. The materials were discharged at the site by the flumes and spread with the aid of hand labor. The photographs indicate that the upstream face of the dam was finished by compaction with a roller.

Some of the materials observed at the base of the breach appeared to be compacted embankment fill, suggesting that bottom portions of the embankment were placed by methods other than sluicing. Non-sluiced fill dikes would likely have been used to retain the sluiced materials in between the upstream and downstream edges of the embankment as it was raised.

**Observed Embankment and Foundation Materials**

Although the dam could generally be characterized as a homogeneous embankment, the method of construction led to marked horizontal stratification of the embankment, which was clearly visible as layers and lenses in the embankment materials left in place at the base and on the sides of the breach. The observed layers in the embankment remnants varied in thickness between about 8 and 24 inches. They included layers of predominantly coarse-grained soils often juxtaposed with layers of fine-grained soils (see Photograph 2).

The coarse-grained soil layers consisted of particles up to several inches in dimension within a matrix of finer-grained soils. In general, the larger particles in those layers had low strength, and some appeared to be friable. No voids or openings were seen in those layers, suggesting that the coarse materials were generally mixed with the fine materials during deposition and spreading.

The fine-grained soil layers consisted of predominantly clay and silt soils that would classify as clayey silt of high plasticity. Those soils did not appear to be highly susceptible to internal erosion by seepage, although it is difficult to ascertain that aspect of their behavior without laboratory test data. Based on their appearance, the fine-grained soil layers would be
expected to have a significantly lower permeability than the coarse-grained soil layers, and the latter would be expected to carry most of the seepage through the embankment.

![Photograph 2. View of coarse- and fine-grained embankment soil layers at base of breach, looking north](image)

### Dam Past Performance

Limited information is available on the past performance of the dam. No reports of instability, deformation, erosion, or required repairs or high maintenance were found within the available information. Thus, it may be said that the dam performed acceptably through its 100-year history prior to the failure, while being subjected to normal reservoir loads.

Records by KSPC for the period between 1940 and 1953 indicate that the reservoir filled to at least elevation 747 numerous times. The reservoir reached that elevation every year between January and April from 1946 through 1953 and was continuously full for periods up to one month long. The records also show instances when the reservoir filled completely in less than two months after having been at low levels for over three months.

No reports of internal erosion or piping of the embankment were found within the available information. The SCS engineering sketches indicate that high seepage was observed at the downstream toe of the embankment, and the KAWMS report called the stability of the dam questionable based on those observations and the dense vegetation growth on the downstream slope. Such statement would seem to indicate concern on the part of the SCS about the stability of the dam, which seems reasonable in view of the dam’s design characteristics and the potential detrimental effects of dense vegetation growth on embankment dams.

However, neither the KAWMS report nor the SCS sketches note the seepage water as being muddy or dirty, which would constitute evidence of internal erosion or piping within the
embankment. The seepage observations documented by the SCS are consistent with the zoning of the embankment resulting from the methods and materials used for its construction, and should not be construed as evidence that the dam failed as a result of seepage.

**Physical Characteristics of Breach**

A topographic plan of the breach was not available for this assessment. The location along the dam axis, dimensions, and geometry of the breach were approximately estimated based on the field observations and aerial photographs.

The breach was visually estimated to be approximately 250 feet wide in between the north and south remnants of the dam crest. The width of the eroded channel narrows down significantly downstream as the streambed curves slightly to the north. The upstream lip of the breach was estimated to be about 200 feet wide. Based on the aerial photographs, the breach appears to be roughly centered, along the dam axis, at the location of the low point on the dam crest estimated from the SCS sketches.

The base of the breach channel has three levels, or benches, which step down to the west (i.e. downstream, see Photographs 3 and 4). The upper bench exposes embankment fill and native foundation soil, possibly alluvium. Foundation materials and apparent remnants of embankment fill were observed on the surface of the middle bench. The observed foundation materials are weathered volcanic deposits. The lower bench exposes weathered volcanic rock.

The lower bench is partially enclosed on the northwest side by a strong ridge of weathered volcanic rock. Likewise, a ridge of weathered rock partially encloses the lower bench on the southwest side. The gap between those two ridges is several tens of feet wide. The lower bench ends downstream at this gap, where there is a high and steep drop-off in the streambed (see Photograph 3).

Photograph 3. View of lower bench at base of breach and gap between ridges of weathered rock, looking west (Photograph by Chad Iida)
Based on the observed erosion of the ground surface, it is clear that a substantial volume of water flowed over the ridge on the northwest side of the lower bench, probably beginning prior to exposure of the entire bench by erosion. The appearance of the vegetation on the south bank of the eroded channel facing the lower bench, and of the vegetation inland of the channel (see Photograph 1), indicates that water flowed over that bank of the channel and over the ridge on the southwest side of the lower bench for some distance inland.

The embankment remnant on the south side of the breach shows a pocket of erosion located immediately north of the crest remnant (see Photograph 4). That pocket sits in between a remnant of the dam upstream slope and a small ridge approximately located along the southward projection of the downstream edge of the middle bench. The crest of the dam is missing over a length of a few tens of feet in this pocket, whereas the embankment slope immediately upstream remains in place. This feature suggests that water flowed over this area causing erosion of the crest until the reservoir level dropped below the top of the upstream slope remnant.

Photograph 4. View of erosion pocket on embankment remnant and of benches at base of breach, looking south

Breach Failure Mechanism

The mechanism of the breach failure is not known with certainty and can only be inferred from available evidence. Generally, possible modes of failure of embankment dams such as Ka Loko Dam include: a) overtopping of the embankment, b) internal erosion and piping, c) structural instability and excessive deformation, and d) variants or combinations of the above. Most past failures of embankment dams can be classed into those modes of failure.

The aforementioned USGS Internet site states that the peak flood stage in Ka Loko Reservoir was determined to be elevation 750.65. This elevation is about 2.1 feet higher than that of the lowest point on the dam crest as surveyed by the SCS in 1982. It is also about 0.9 feet
higher than the crest elevation at two of the sections surveyed by the SCS in the area of the breach. Thus, this information would indicate that the dam was overtopped, provided that the dam crest had not been modified and raised since 1982 and that the surveys are accurate to the degree implied by the noted elevation values.

Although the above information would indicate that the dam likely failed by overtopping, it seems useful to review the possible modes of failure identified above because an understanding of such modes is important in developing recommendations aimed at preventing future similar dam failures in Hawaii.

**Embankment Overtopping**

This mode of failure consists of overtopping of the dam by a raised reservoir level and erosion of the embankment by the overtopping flows. Simplistically, the mechanism of failure may be described by the following sequence of events.

Overtopping begins as the reservoir level rises above the dam crest. As water flows over the crest and downstream slope, it starts to erode the dam face and the foundation materials at the toe, provided they are erodible. Typically (although not necessarily), erosion will begin at or near the downstream toe of the embankment and move up the slope towards the crest. Slope erosion will progress into a series of cascading overfalls leading to a headcut at the downstream crest edge. With continued flow, the headcut will migrate from the downstream to the upstream edge of the crest. Once the headcut reaches the upstream edge, lowering of the crest begins and the rate of embankment and foundation erosion increases rapidly until the breach is fully formed.

The final size and geometry of the breach will depend on numerous factors including: the reservoir volume, the dam height, the characteristics of the embankment and foundation materials, and the geometry of the embankment and downstream channel. Overtopping will occur first at the lowest point on the crest, and the width of overtopping prior to lowering of the crest will depend primarily on the crest profile and the flow discharge (flow volume per unit time) over the crest.

This mode of failure is clearly plausible because the reservoir lacks a spillway and possible inflows into the reservoir would have been sufficient to exceed the likely minimum overflow required to start erosion of the embankment. Such inflows would have been at least as large as those carried by the Ka Loko ditch, which, as computed by the USGS, could have been as high as 205 cfs. It is less clear, though, how inflows of that magnitude could have raised the reservoir to the flood stage elevation determined by the USGS, if the dam crest elevation was as surveyed by the SCS. Nonetheless, the failure mechanism is compatible with the observed characteristics of the breach and the estimated location of the low point on the dam crest, as described above.

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\(^2\) A minimum height of overtopping is required to cause flows with sufficient power to start erosion of the embankment materials. Such minimum height is related to the type of materials and vegetation cover on the embankment crest, the downstream slope, and the foundation toe, as well as on the height of the embankment and inclination of the slope.
Internal Erosion and Piping
This mode of failure would involve internal erosion of the embankment and/or foundation materials (where the latter are erodible) by seepage leading to formation of a conduit(s) or pipe(s) through the embankment and/or foundation and eventual collapse of the crest. For a non-erodible foundation, the mechanism of failure may be described as follows.

Seepage through the embankment initiates internal erosion by dislodging soil particles into voids within the embankment or at the downstream face. This process leads to increased seepage gradients and upstream migration of the internal erosion towards the reservoir (following a path of least resistance), resulting in the formation of a conduit(s) through the embankment. As the upstream end of the conduit approaches or reaches the reservoir, the gradients through the conduit increase leading to increased flow velocities and rates of internal erosion. The increased rates of erosion lead to enlargement of the conduit and eventual unrestricted flow from the reservoir to the downstream face. Typically (although not necessarily), the conduit will continue to enlarge under sustained flows until the embankment collapses into the conduit causing collapse of the crest. Once the crest collapses, release of the reservoir occurs as flow through a weir, with continued erosion of the embankment and enlargement of the breach.

Although this failure mechanism is possible, it does not appear to be consistent with the observed characteristics of the breach. Such a failure mechanism would seem unlikely to have led to the aforementioned erosion pocket located north of the crest remnant. It is also difficult to envisage how a piping failure would have caused large flows over both rock ridges enclosing the lower bench, given the reservoir volume released and the final size of the breach. However, because the actual failure mechanism appears to have been very complex, a piping failure mechanism cannot be dismissed with full confidence without determination of the crest elevation profile prior to the breach, further examination of the breach characteristics, and detailed analytical modeling of the failure.

A variant of a piping mechanism would be one resulting from transverse cracks that might extend across the embankment crest. If the reservoir level were to rise above the bottom of the cracks, internal erosion would be initiated by seepage through the cracks. The cracks would be progressively enlarged by the seepage flows eventually leading to release of the reservoir. Such type of cracks could result from desiccation of the embankment materials under a prolonged period of dry weather. However, this mode of failure seems inconsistent with the past performance of the dam given past recorded episodes of rapid reservoir filling. The failure mechanism would also seem unlikely to have led to the previously noted erosion pocket.

Structural Instability and Deformation
This mode of failure would be initiated by structural instability, slumping, or excessive deformation of the embankment resulting in lowering of the crest. If the crest were to be lowered below the level of the reservoir (or the reservoir were to rise above the level of the lowered crest), overtopping would lead to breaching of the embankment. Alternatively, cracking resulting from the dam deformation could lead to a piping failure.
The statistics of past dam failures are such that structural instability and excessive deformation under normal static loads has been seen less frequently in embankment dams after many years of operation than otherwise. Thus, those statistics would indicate that on the average, and assuming all other conditions remain constant, the likelihood of structural instability and excessive deformation under normal loads decreases as the age of embankment dams increases.

In addition, this mode of failure would seem inconsistent with the past performance of the dam. Although, it is possible that it could have been initiated by progressive changes in seepage patterns that would have led to embankment instability. There is no evidence, however, that such changes occurred or were in progress.

Although not the case in the Ka Loko Dam failure, structural instability and excessive deformation may be induced by extreme loads such as earthquakes. Past experience with the performance of embankment dams during earthquakes indicates that structural instability and deformation are of particular concern for dams built by hydraulic filling (such as Ka Loko Dam) subjected to strong earthquake shaking.

Discussion
Because the evidence and time available for this assessment were limited, the mechanism of failure cannot be inferred with certainty herein. However, other assessments may provide greater confidence by gathering additional evidence or further analysis. Key evidence may be obtained from recent topographic plans of the embankment before the failure and by comparison of such plans with the USGS measurements of maximum flood stage in the reservoir. Further evidence may also be obtained from topographic plans of the embankment after the breach, geotechnical and geologic studies, additional observation and scrutiny of the physical characteristics and details of the breach, and detailed modeling and analytical studies of the breach mechanism.

Although the mechanism of failure cannot be inferred with certainty at this time, recognizing the potential failure modes described above provides guidance for developing recommendations to prevent this type of failure in the future. The potential failure modes illustrate the types of risks that dams in Hawaii face, and an understanding of such modes is helpful in determining the types of future actions that can be taken to minimize those risks.

The evidence discussed above suggests that Ka Loko Dam failed due to overtopping probably as a result of the lack of a spillway in the reservoir. Thus, the dam failure is a harsh reminder of the need to require dam reservoirs to have an adequate spillway capable of passing potential inflows into the reservoir without dam overtopping or other detrimental effects. The circumstances of this incident and the characteristics of the dam also highlight the need to consider other potential failure modes such as internal erosion and piping, and structural instability and deformation, and the need to require actions to prevent such failure modes from developing in other dams in the future.

For example, the evidence discussed above indicates that Ka Loko Dam was constructed, at least in part, by hydraulic filling. Historical evidence suggests that other dams in Hawaii
were built by the same method. Because past experience shows that hydraulic fill dams may fail due to earthquakes, the circumstances of this incident highlight the need to consider such types of failures in developing recommendations to improve dam safety in the State.

**Role of Dam Inspections**

Dam inspections are a common tool of state dam safety programs in the United States, aimed at monitoring the condition of dams and their ability to safely retain their reservoirs. Dam inspections are also a common element of international practice in dam safety management. The Hawaii Dam Safety Act of 1987, HRS 179D, authorizes the DLNR to conduct such inspections in Hawaii. The Hawaii Administrative Rules of 1989, HAR 190, require that the DLNR conduct inspections of dams and reservoirs not less than once every five years for purposes of determining their safety.

Because of budgetary constraints, Hawaii’s dam safety inspections program suffered setbacks that limited the number of inspections and the timely updating of the State’s dam inventory. DLNR conducted inspections of high hazard dams from 1993 to 1998 using external contracts with consulting firms, and using in-house resources thereafter.

The information reviewed for this assessment indicates that, between 1999 and 2001, DLNR requested the owner of Ka Loko Dam for assistance in conducting a visual dam safety inspection of the reservoir. However, no record that such inspection took place was found in the documents reviewed. Thus, a key question surrounding the dam failure is whether a safety inspection(s) of the dam might have prevented the failure.

In my opinion, it is likely that a visual safety inspection of the dam and its appurtenant facilities by qualified persons would have identified the lack of a spillway in the reservoir. Furthermore, because of the limited discharge capacity of the outlet works and the need for human intervention to operate them, it is likely that the lack of a spillway would have been recognized as a safety deficiency. It also seems that such recognition could have triggered action on the part of the State to require the owner to implement modifications to the dam and reservoir facilities or to implement other actions that may well have prevented the failure.

It is noteworthy that government representatives had visited the area of the reservoir several days before the failure and at other times in connection with grading and/or environmental violations in the area immediately east of the reservoir. However, the records reviewed indicate that the persons conducting those visits either did not observe the reservoir and the area of the dam, or did not note the lack of a spillway, or did not raise the absence of a spillway as a safety issue. Thus, those circumstances indicate that, to be effective as a safety management tool, visual inspections of dams must focus specifically on dam safety issues and must be conducted by qualified persons with proper dam safety training.

It is also important to note that visual inspection of dams is a necessary but not sufficient element of dam safety inspections. In addition to a visual inspection of the dam and its appurtenant facilities, dam safety inspections should include a comprehensive review of all
safety aspects of dam operation and a thorough assessment of the potential failure modes of a dam. The need for such review and assessment is illustrated by the fact that the answer to the following question requires evaluation of safety considerations beyond those that can be evaluated during a visual inspection. Would the Ka Loko Dam failure have been averted if the previous spillway shown in the aerial photographs dating to 1965 had been functional on March 14, 2006? Such question could not likely be answered by a visual inspection of the dam and spillway facilities alone. Its answer would likely require an evaluation of the discharge capacity of the previous spillway, of potential inflows into the reservoir, and of resulting maximum reservoir levels in relation to the dam crest elevation.

The records reviewed for this assessment suggest that the question of whether the previous spillway was capable of passing potential inflows into the reservoir was not raised by the SCS after visual inspection of the dam in 1982. That is in spite of the fact that the SCS noted a low point on the dam crest that was only 1.5 feet higher than the elevation of the spillway crest. Such circumstance highlights the need for dam safety inspections to consider design, construction, operations, and maintenance aspects of dam safety, and to consider all possible failure modes of a dam.

Not withstanding the above questions, in my opinion, a more aggressive program of dam inspections under HRS 179D that would have included regular safety inspections of Ka Loko Dam, would probably have allowed for early identification of the potential for failure of the dam and allowed correction of the deficiencies leading to such failure.

**Dam Safety Program**

Based on a cursory review of HRS 179D and HAR 190, it seems to me that the elements of Hawaii’s dam safety program appear to be generally similar to those of other states in the US, for example, California. Other documents reviewed suggest, however, that the program may have recently lacked adequate funding to be fully effective. The lack of funding has apparently led to difficulties in management of the program and in implementation and enforcement of the program’s requirements.

The Engineering Division of the DLNR is charged with administering the dam safety program. The current program budget allows for about one-and-one-half full time staff to manage and implement the program. In spite of the lack of funding, I understand that the staff manages to conduct dam safety inspections and to notify owners of information or permits required and of repairs needed, and to review plans for such repairs. In addition, DLNR presents periodic workshops on dam safety to address some of the operational and maintenance challenges and concerns of dam owners and operators. The last round of workshops was conducted in 2002.

One aspect of the program that does not seem to have received an adequate level of attention is that of maintaining an updated State dam inventory including an up-to-date hazard classification of each dam. Between 1978 and 1981, the ACE conducted inspections of “high hazard” category dams throughout the State, in accordance with the National Dam Inspection Act of 1972. The dam was not inspected at that time because it was not considered to be a
“high hazard” dam, and the dam’s classification appears to have remained in that status thereafter. However, in view of the loss of life and considerable property damage caused by the dam failure, it may be surmised that the dam’s classification should have been higher at the time of the failure, and thus, should have been revised beforehand. This situation highlights the need for the program to allow for timely updating of the State’s dam inventory including dam hazard classifications. The process for updating of the inventory should include periodic review of a dam’s hazard classification, possibly as part of each safety inspection, to account for changes in downstream land use and economic development.

Thus, it appears that the main issue associated with the State’s dam safety program is the lack of funding necessary to facilitate implementation and enforcement of the program’s requirements. In addition, funding appears to be required to increase efforts in education of dam owners on their responsibilities regarding public safety.

One technical aspect of the dam safety statute, HRS 179D-4(b), that merits further review and consideration is the apparent exemption of owners from liability for damages resulting from natural causes such as earthquakes, hurricanes, or extraordinary rains with recurrence intervals greater than 250 years. Such recurrence interval seems inconsistent with intervals considered in dam engineering practice in other states and internationally in developing design loads representing natural events for the safety evaluation of “high hazard” dams. Generally, recurrence intervals longer than 1,000 years would be considered for developing design earthquake loads for such dams, and even longer recurrence intervals would be considered for developing design precipitation and inflow flood loads.

Another aspect of the program that merits review and further consideration is the requirement in HAR 13-190-40 to conduct dam inspections not less than once every five years. That required frequency of inspections seems reasonable for comprehensive safety reviews including assessment of possible failure modes. However, it does not seem adequate for visual inspections, particularly of high hazard dams. In view of Hawaii’s climatic conditions (which promote rapid vegetation growth and are associated with a high potential for hurricanes, episodes of intense precipitation, high rates of erosion, and weathering of man-made materials), significant and high hazard dams should be visually inspected at least once every two years. Additional funding for the program is likely to be required to increase the frequency of dam visual inspections and for updating of the State’s dam inventory on a periodic basis.

**Recommendations**

Based on the above assessment and discussion, the following recommendations are offered for possible government action.

The level of funding for the State’s dam safety program should be increased to allow for effective implementation and enforcement of the program’s requirements including regular dam safety inspections and periodic updating of the State’s dam inventory to accommodate changes in the hazard classification of dams. Funding should also allow for increased efforts in education of dam owners regarding their responsibilities to public safety.
The process for updating of the State’s dam inventory should allow for periodic review of the hazard classification of dams and for timely updating of such classification to reflect changes in a dam’s physical and ambient conditions. Changes in physical and ambient conditions to be considered include physical changes to the dam and reservoir facilities, watershed and climatic changes affecting potential reservoir inflows, changes in downstream conditions affecting the extent of potential inundation areas, and changes in downstream land use and economic development. To allow efficient evaluation of possible changes in downstream conditions, inundation maps will be required for all dams within the State’s jurisdiction. Such maps are required as part of the emergency preparedness plan required of dam owners by HAR 13-190-42.

Dam safety inspections should include comprehensive safety reviews and visual inspections. Comprehensive safety reviews should consider design, construction, operations, and maintenance aspects of dam safety, and should include thorough assessments of potential failure modes. Visual inspections of dams should focus on dam safety issues and should be conducted by qualified personnel with adequate dam safety training. Visual inspections of “significant and high hazard” dams should be conducted at least once every two years. Comprehensive safety reviews of “significant and high hazard” dams should be conducted once every five years.

The guidelines for safety inspection of dams published by DLNR in 1992\(^3\) are a suitable general reference for dam safety inspections in the State. Nonetheless, it is recommended that those guidelines be reviewed with a view to develop more streamlined dam inspection procedures that are better fit to the budgetary constraints of the State’s dam safety program. Such procedures should allow for periodic comprehensive safety reviews and visual inspections, as discussed above, within the framework of dam safety inspections called for by HAR 13-190.

It is recommended that consideration be given to developing guidelines for instrumentation monitoring of “high hazard”, and perhaps “significant hazard”, dams. Instrumentation monitoring should be required to the extent needed for comprehensive safety review and assessment of potential failure modes of such dams.

The dam safety statute, HRS 179D-4(b), should be reviewed to re-consider the recurrence interval of natural events for which owners are exempt from liability for damages resulting thereof. Such recurrence interval, currently stated as 250 years, seems inconsistent with intervals considered in dam engineering practice elsewhere for developing design loads used to represent natural events for the safety evaluation of “high hazard” dams.

Lelio H. Mejia, Ph.D., P.E., G.E.
Principal, Vice President

Overview
Dr. Mejia has been involved with a broad range of geotechnical, earthquake, dam, and foundation engineering projects. He has directed numerous dynamic response analyses and seismic stability and design studies of earth structures, dams, and foundations. He has extensive experience in the evaluation of soil liquefaction and the use of ground treatment methods to mitigate the effects of liquefaction. He has also conducted soil-structure interaction analyses of hydraulic structures, power plant and harbor facilities, and has performed seismic risk analyses and engineering characterization of earthquake ground motions for dams, industrial facilities, bridges, and high-rise buildings.

He has directed the investigations and seismic stability studies of over 25 large earth dams and has been involved in the design and construction of over 15 major dam projects. In addition, he has managed the design and overseen the construction of several dam seismic rehabilitations including projects over $50 million in construction cost. Many of those projects are located in California and have involved review by the California Division of Safety of Dams (DSOD). He successfully led those projects through the regulatory approval process of DSOD, and other agencies such as the Federal Energy Regulatory Commission (FERC).

While at the University of California he developed numerical techniques for the three-dimensional dynamic response analysis of rock and earthfill dams and applied these methods to study the dynamic behavior of dams in narrow canyons. He recently conducted research on the applicability of fully nonlinear finite element methods to the dynamic response analysis of earth structures and dams. In addition, he has previously conducted research on the mechanisms of liquefaction failure during the 1989 Loma Prieta, California earthquake.

He is a Secretarial Appointee to the Advisory Committee on Structural Safety of Department of Veterans Affairs Facilities and has been a Lecturer of Geotechnical Earthquake Engineering at the University of California at Davis, CA, an Extension Instructor in Geotechnical Engineering at the University of California at Berkeley, CA, and a member of the editorial board for the ASCE Journal of Geotechnical and Geoenvironmental Engineering. He has served as a National Science Foundation Panelist for the CAREER Program and other NSF research programs in Geotechnical and Geohazards Systems, and has served on technical review boards for the US Bureau of Reclamation, the US Army Corps of Engineers, and the California Department of Water Resources on various dam projects, and for other owners on foundation engineering projects.

Areas of Expertise
- Geotechnical Engineering
- Earthquake Engineering
- Dam Engineering
- Seismic Risk
- Soil Dynamics
- Foundation Engineering

Years of Experience
- With URS: 21 Years
- With Other Firms: 4 Years

Education
- Ph.D./Earthquake Engineering/
  1981/University of California, Berkeley
- MS/Geotechnical Engineering/
  1978/University of California, Berkeley
- BS/Civil Engineering/1977/
  Universidad Javeriana, Bogota, Colombia

Registration/Certification
- 1985/Civil Engineer/CA/#39772
- 1993/Civil Engineer/WA/#30592
- 1989/Geotechnical Engineer/
  CA/#2210
- 1977/Ingeniero Civil/Colombia
Project Specific Experience

Dam Projects

Project Manager, Seismic Stability Evaluation of Success Dam Modifications, CA, USACE Sacramento District, 2006, $300,000: The dam is a 140-foot-high, 3,400-foot-long earth and rock embankment with a central clay core built in the early 1960’s. The work included field investigations and geophysical surveys, development of design acceleration time histories, and analysis of embankment seismic stability and deformations in support of the design of seismic modifications to the dam. The seismic deformation analyses were performed using nonlinear finite element procedures with the computer program FLAC.

Project Manager, Seismic Stability Evaluation of Estates Dam, CA, East Bay Municipal Utility District, 2005, $250,000: The dam is a 90-foot-high, 300-foot-long earth embankment built in the early 1900’s by teams of horses and wagons. The stability analyses include detailed analysis of embankment seismic deformations using nonlinear finite element procedures and three-dimensional analysis methods. The project is under jurisdiction of the California DSOD.

Project Manager, Seismic Stability Evaluation of Chabot Dam, CA, East Bay Municipal Utility District, 2004-2005, $550,000: The dam is a 150-foot-high, 500-foot-long earth embankment built in the late 1800’s by teams of horses and wagons and hydraulic filling. The stability analyses include detailed analysis of liquefaction potential and of embankment seismic deformations using nonlinear finite element procedures. The project is under jurisdiction of the California DSOD.

Project Manager, Earthquake Study of Enid Dam, MS, USACE Vicksburg District, 2000-2005, $300,000: Directed and managed seismic hazard evaluation, geotechnical data review, development of seismic design criteria, liquefaction evaluation, and deformation analysis of dam using non-linear procedures and the computer code FLAC. The dam is a 110-foot-high, 1½-mile-long zoned earth embankment founded on recent alluvium and tertiary deposits.

Peer Reviewer, Design of Pelona Vista Detention Basin Dam, Palmdale, CA, City of Palmdale, 2005, $500,000: Project included field and laboratory investigations of foundation conditions and borrow sources, development of design criteria, conceptual design, stability analysis, and plans and specifications for construction.

Peer Reviewer, Evaluation of Alternatives, Conceptual Design, and Final Design of Calaveras Dam Replacement Project, Santa Clara County, CA, San Francisco Public Utilities Commission, 2003-2006, $12,000,000: The dam is a 210-foot-high, 1,200-foot-long hydraulic fill embankment built in 1925, which has been found to be vulnerable to strong earthquake shaking. Reviewed engineering analyses, alternatives...
analysis reports including foundation investigations and design criteria reports. Currently reviewing analysis and design activities for final design.

**Project Director, Seismic Safety Evaluation of Aviemore Dam, New Zealand, Meridian Energy, 2000-2003, $2,000,000:** Project is a 55-m-high composite dam with a 370-m-long concrete gravity section and a 430-m-long sloping core gravel-fill embankment section, located in the South Island of New Zealand. Work involved extensive geologic and seismologic studies to evaluate the seismic hazard at the dam site; comprehensive field and laboratory investigations of the foundation and concrete dam and embankment materials; and extensive studies of: the dam response to foundation fault rupture and strong earthquake shaking, the potential for dam overtopping by earthquake-induced seiche, and the seismic performance of the appurtenant works.

**Project Manager, Engineering Review of Physical Plant, Middle Fork American River Hydroelectric Project, CA, Advanced Energy Strategies, 2005, $25,000:** Performed an engineering review of this 220 MW hydropower generation project in support of a due-diligence financial review. The project includes two large dams and storage reservoirs, five long power tunnels and penstocks, and five powerhouses. Performed a site inspection, assessed the working condition of the project components, and evaluated potential contingencies to test the financial reliability of the project.

**Principal-In-Charge, Conceptual Design of Remedial Measures, Fordyce Dam, CA, Pacific Gas and Electric, 2001, $75,000:** Evaluation of remedial measures to improve the seepage cut-off and minimize the potential for piping of Fordyce Dam. The structure is a 145-foot-high, 1200-foot-long concrete face rockfill dam partially founded on an upstream earthfill embankment. The rockfill dam has upstream and downstream slopes of 1:1 and 1.3:1 and retains a 50,000 acre-foot reservoir.

**Principal-In-Charge, Design and Construction of Seismic Upgrade, Lopez Dam, San Luis Obispo, CA, County of San Luis Obispo, 1997-2001, $2,000,000:** The dam is a 200-foot-high embankment founded on recent alluvium up to 110 feet deep consisting of loose to medium dense silty to gravelly sands. The work involved analysis of alternatives, preliminary and final design of the selected alternative, preparation of the design drawings and specifications, and engineering and inspection services during construction. The selected remediation measure included densification of the foundation alluvium with stone columns and construction of a downstream buttress.

**Project Engineer, Safety Review of Cosseys Dam, Auckland, New Zealand, WaterCare, 1999-2001, $500,000:** Project is a 41-m-high rolled earthfill dam. The safety review included a field inspection of the facilities and an assessment of the safety of the project. This included an evaluation of the potential for piping of the embankment and of possible
earthquake-induced failure of the dam and its outlet tower. Peer-reviewed the design of the dam modifications to rehabilitate the dam.

Peer Reviewer, Safety Evaluation of Waranga Basin Dam, Victoria, Australia, Murray Gold Water, 2001: The dam is a 7-km-long 15-m-high earth embankment with a puddle clay core and founded on medium dense alluvium, and which has had several incidents of piping.

Peer Reviewer, Safety Evaluation and Design of Seismic Upgrade Works, Yarrawonga Weir Dam, Victoria/New South Wales, Australia, Murray Gold Water, 2002: The dam is approximately 500 m long and 18 m high. It consists of a main embankment, a concrete regulating structure, and a second embankment. The embankments and a second regulating structure are founded on recent alluvium, which required treatment with stone columns to ensure adequate structural behavior under seismic loading.

Project Manager, Safety Evaluation and the Design of Remediation Measures, Matahina Dam, New Zealand, ECNZ, 1995-1998, $4,000,000: Project is a 240-foot-high rockfill dam located on the active Waiohau fault. The safety evaluation of the dam included a comprehensive seismotectonic study of the dam region and an in-depth analysis of the seismic stability of the embankment and its appurtenant structures. The studies included extensive seismologic, geologic, geophysical, and site geotechnical investigations. Manager of design engineering during construction of the remediation measures.

Team Leader, Independent Review of Seismic Hazard Evaluation and Development of Seismic Design Criteria, Nechi Hydroelectric Project, Antioquia, Colombia, Integral SA, 1996-1997, $80,000: Assignment included review of studies by the designer, consultation on operation of a micro-seismic network, and preparation of recommendations for additional geologic, seismologic, and engineering studies to develop the seismic design criteria for a 130-meter-high RCC dam and associated power-generation facilities.

Team Leader, Seismic Evaluation of Gatun Dam, Panama, Panama Canal Commission, 1992-1993, $30,000: Reviewed data on the design and construction of the dam, and the results of recent geotechnical investigations of the embankment and foundation conditions. Performed a preliminary evaluation of the seismic stability of the dam and developed recommendations for a full evaluation. The dam is a 110-foot-high, 2-mile-long hydraulic fill and retains Gatun Lake, the main waterway of the Panama Canal.

Project Director, Site and Embankment Characterization Investigations, Lake Almanor and Butt Valley Dams, Plumas County, CA, Pacific Gas and Electric, 1994-1996, $250,000: The work included extensive field investigations including SPT, CPT and Becker Penetration Tests, geophysical surveys with downhole techniques, the
seismic cone, and the OYO downhole P-S logger, and extensive laboratory testing including cyclic triaxial and simple shear tests. The work was performed under the review of the California Division of Safety of Dams (DSOD) and the Federal Energy Regulatory Commission (FERC).

**Project Director, Design of Remediation Measures, Butt Valley Dam, Plumas County, CA, PG&E, 1995-1998, $600,000:** Dam is a 100-foot-high hydraulic fill embankment. The work included evaluation of alternatives, preliminary design and analysis studies, and preparation of contract plans and specifications. The work was performed under the review of the California Division of Safety of Dams (DSOD) and the Federal Energy Regulatory Commission (FERC).

**Project Manager, Seismic Safety Evaluation, Fena Dam, Guam, Marianas Islands, U.S. Navy, 1993-1994, $400,000:** Dam is a 135-foot-high rockfill. The evaluation included a comprehensive seismotectonic study of the region and an in-depth analysis of the seismic stability of the embankment and its appurtenant structures. The studies included extensive seismologic, geologic, geophysical, and site geotechnical investigations, and an evaluation of the dam’s performance during the 1993 Guam earthquake.

**Project Manager, Seismic Safety Evaluation, Evaluation of Remediation Alternatives, Design and Construction Inspection, Tolt Regulating Basin South Dam, WA, Seattle Water Department, 1990-1994, $500,000:** The dam has a structural height of 60 feet and is founded on a 40-foot thick deposit of soft clay. The seismic remediation consisted of reinforcing the foundation with 4.5-foot diameter stone columns and constructing a buttress downstream of the dam to increase stability, reduce deformations, and provide additional crest width. The work was performed under the review of the Federal Energy Regulatory Commission (FERC).

**Consultant, Seismic Stability Evaluation and Remediation, Sardis Dam, MS, USACE Vicksburg District, 1989-1993, $300,000:** Dam is one of the largest hydraulic fill dams in the U.S. Project manager for the analysis and preliminary design of stability remediation measures and the design of a test section to evaluate the feasibility of using driven piles for stabilization of the upstream shell of the dam.

**Project Manager, Feasibility and Siting Studies, Jameson Canyon Reservoir, Napa County, CA, City of Vallejo, 1989-1990, $100,000:** Study involved evaluation of about 10 sites for siting of reservoirs up to 10,000 acre-feet, and dams up to 150 feet high.

**Project Manager, FERC Inspection and Safety Evaluation, Tolt Dam, WA, Seattle Water Department, 1987-1992, $500,000:** Directed feasibility studies to raise the 200-foot-high earthfill dam an additional 30 feet. Managed an in-depth seismic hazard and seismic stability analysis of Tolt Dam and two auxiliary dams, and the design and installation of an
automated data acquisition system and TV surveillance system for the project. The work also included design of repairs of the spillway and fixed-wheel diversion gate.

Task leader, Stability Evaluation and Embankment Design, Los Vaqueros Dam, Contra Costa County, CA, CCWD, 1988-1993, $5,000,000: Responsible for design of embankment cross-section and dam stability analysis. Additionally, task leader for evaluation of seismic design criteria including earthquake ground motion characterization.


Project Manager and Engineer, Various Projects and Clients, 1981-1998: Directed seismic safety evaluation and seismic stability studies for Lake Madigan Dam, Lake Frey Dam, and Lake Curry Dam in Solano County, Fleming Hill Dam and Summit Dam in Vallejo, Conn Dam in Napa County, Stanford Heights Reservoir in San Francisco, Berryman Reservoir in Berkeley, Mallard Reservoir Dam in Contra Costa County, and Little Lake Dam in Riverside County, California, under review by the California Division of Safety of Dams (DSOD). Directed seismic stability studies for Kemmerer Dam in Wyoming, Ashton Dam in Idaho, and Kingsley Dam in Nebraska.

Project Engineer, Various Projects and Clients, 1985-1995: Directed seismic stability and deformation analyses for Ice House Dam, Loon Lake Main and Auxiliary Dams, and Elderberry Dam in California. Peer-reviewed finite element analysis of Drum Afterbay Arch dam in California. Studies were performed in response to FERC requirements and were reviewed by FERC.

Project Manager and Engineer, Various Projects and Clients, 1980-1990: Directed static and dynamic finite element analyses of Ririe Dam, Idaho, for the U.S. Army COE Waterways Experiment Station. Conducted dynamic finite element analyses of Oroville Dam, Los Vaqueros Dam, and Stafford Dam in California, Sardis Dam in Mississippi, Alicura Dam in Argentina, and Tarbela Dam in Pakistan.

Project Engineer, Various Projects and Clients, 1982-1985: Engineer for the design of the South Fork earthfill dam in Nevada and the feasibility analysis and design of the Sulphur Creek concrete arch dam in The Geysers, California.

Dam Review Boards

Review Board Member, Various, California Department of Water Resources, 2004-2005: Member of the Independent Consulting Review
Board to the California Department of Water Resources (DWR) for the design of the new Dyer Dam and Reservoir. Member of the Independent Consulting Review Board to the DWR for the design of the Patterson Reservoir Modifications Project.

**Review Board Member, Various, US Bureau of Reclamation,** 1997-2005: Member of Independent Review Boards to the US Bureau of Reclamation for the design and construction of remedial measures to Wickiup Dam (100-foot-high, 14,200-foot-long earthfill) in Oregon, the seismic stability evaluation and risk analysis of Echo Dam (200-foot-high, 800-foot-long earthfill) in Utah, and the seismic evaluation and the design of remediation measures for Lost Creek Dam (200-foot-high earthfill) in Utah, Salmon Lake Dam (35-foot-high earthfill) in Washington, and Mann Lake Dam (60-foot-high earthfill) in Idaho.

**Consultant, Various, USACE, Vicksburg District,** 1992-2004: Consultant on the seismic stability evaluation of Enid Dam (110-foot-high, 1½-mile-long earthfill) and Arkabutla Dam (100-foot-high, 1-mile-long earthfill) in Mississippi. Provided guidance on geotechnical field investigations, laboratory studies, and seismic stability and deformation analyses.

**Dam Safety Programs**

**Project Director, Update of Seismic Design Loads, Multiple Dams, New Zealand, Meridian Energy Limited, 2005, $300,000:** Updated seismic criteria for the dams on the Waitaki River Hydroelectric System in the South Island of New Zealand: Pukaki Dam, Ruataniwha Dam, Benmore Dam, Aviemore Dam, and Waitaki Dam. The work included characterizing the seismic sources and earthquake ground motion attenuation, conducting probabilistic ground motion and fault displacement analyses, and developing acceleration time histories for analysis.

**Project Engineer, Development of Dam Safety Program Guidelines, Auckland New Zealand, Watercare, Inc., 2001, $50,000:** Developed dam safety guidelines for major dam owner. Work involved a review of guidelines by other owners in New Zealand and internationally, definition of dam safety policy drivers, and benchmark testing of the draft guidelines.

**Project Director, Development of Seismic Design Loads, Multiple Dams, New Zealand, ECNZ, 1999-2001, $1,000,000:** Developed seismic criteria for the following dams on the Waikato and Waitaki Hydroelectric Systems in the North and South Islands of New Zealand: Ohakuri Dam, Atamuri Dam, Whakamaru Dam, Maraetai Dam, Waipapa Dam, Arapuni Dam, Pukaki Dam, Ruataniwha Dam, Benmore Dam, Aviemore Dam, and Waitaki Dam. The work included defining the criteria for evaluation of seismic design loads; characterizing the seismic sources that could affect the facilities, characterizing earthquake ground
motion attenuation, assessing topographic effects, and conducting probabilistic ground motion and fault displacement analyses.

**Hydraulic Structures**

Principal-In-Charge, Seismic Stability Analysis of Lake Almanor Dam Outlet Tower, CA, Pacific Gas and Electric, 2003-2004, $200,000: The tower a 120-foot-high circular reinforced concrete structure built in the 1920’s. The studies included linear and nonlinear analyses of the dynamic response of the tower using advanced finite element procedures.

Task Leader, Design of Improvements to Almaden Dam Outlet Tower, Santa Clara County, CA, Santa Clara Valley Water District, 2003, $100,000: Directed dynamic soil-structure interaction analyses for the design of improvements to the outlet tower. SSI analyses were used to evaluate the seismic performance of the tower under the MCE and optimize its seismic design.

Project Manager, Seismic Safety Evaluation, Evaluation of Remediation Alternatives, Design and Construction Inspection, South Fork Tolt River Dam Intake Tower, WA, Seattle Water Department, 1993-1998, $600,000: The intake tower is a 170-foot-high, 18-foot-wide freestanding structure with three intake ports. The seismic remediation consisted of installing six 2,000-kip high-strength-steel tendons drilled through the tower walls into rock to post-tension the structure and increase its seismic structural capacity. The work was performed under the review of the Federal Energy Regulatory Commission (FERC).

**Tailing Dams**

Task leader, Feasibility-Level Seismic Stability Analysis of Primary Sulfide Project Tailing Embankment, Cerro Verde Mine, Peru, Phelps-Dodge Corporation, 2003-2004, $150,000: The tailing embankment will have a maximum height of 260 m and include an 85-m-high rockfill starter dam. The work involved selecting the design earthquake motions, evaluating the results of field and laboratory testing, and analyzing the static and seismic stability of the tailing impoundment during construction and in its final configuration.

Task leader, Seismic Hazard and Seismic Stability Evaluation, Chino Tailings Dam (Pond No. 7), NM, Phelps-Dodge Corporation, 1989-1992: This is a 200-foot-high hydraulic-fill tailings embankment approximately 24,000 feet long. The project included extensive field exploration, laboratory testing, and stability analyses.


**Levees**

Peer Reviewer, Delta Risk Management Strategy, CA Department of Water Resources, 2006, $2,000,000: Evaluation of the risk to the levees of the Sacramento River Delta in the California Central Valley. Study considered all aspects of risk including seismic, flood, and operation loads, and the impacts on risk reduction of different management strategies for the Delta.


Project Engineer, Seaport Center Levees, Redwood City, CA, Seaport Center, 1984: Conducted non-linear dynamic response analyses to study the seismic stability and deformation of the levees in Redwood City.

**Bridges and Surface Transportation Facilities**

Task Leader and Peer-reviewer, Characterization of Design Earthquake Ground Motions and Soil Structure Interaction Studies, East Passaic River Bridge, NJ, 2001: Bridge is a 2.5-km-long multiple-span steel girder structure over the Passaic River and several railways and roadways. The project involved site response analyses to evaluate the amplification of ground motions by the soil conditions, finite-element soil-structure interaction analyses to evaluate the effects of the main-span caissons on the ground motions, and development of foundation impedances for structural analysis of the bridge.

Task Leader, Development of Design Ground Motions, Woodrow Wilson Bridge Replacement, Potomac River, Washington D.C, FHWA, 1997-1999, $250,000: The work involved a site-specific probabilistic analysis of ground motions to develop design rock acceleration response spectra, field explorations and geophysical surveys to evaluate the dynamic characteristics of the subsurface soils, dynamic site response analyses, and development of the design acceleration response spectra.

Task Leader, Development of Design Ground Motions, Cape Girardeau Bridge, Mississippi River, MO, HNTB, 1996, $100,000: The work involved a site-specific probabilistic analysis of ground motions to develop equal-hazard design rock acceleration response spectra, field explorations and geophysical surveys to evaluate the dynamic
characteristics of the subsurface soils, dynamic site response analyses, and development of the design acceleration time histories. The time histories modeled the effects of spatial variability of ground motions between bridge supports.

**Peer-Reviewer, Development of Design Ground Motions, Evaluation of Foundation Stability, Delaware Memorial Bridge, DE, 2001:** Bridge is composed of twin suspension structures. The work involved field explorations and geophysical surveys to evaluate the engineering characteristics of the subsurface soils, dynamic site response analyses, development of the design acceleration response spectra, evaluation of liquefaction potential, and evaluation of foundation stability.

**Peer-Reviewer, Evaluation of Liquefaction Potential, Development of Foundation Recommendations, Light-Rail System, San Jose, CA, City of San Jose, 1996:** Project included field explorations and laboratory testing, and evaluations of foundation conditions, foundation types, and mitigation of liquefaction potential.

**Project Manager, Various, CA, Caltrans, 1990-1997:** Seismic retrofit of state bridges in California for Caltrans. The projects included seismic evaluation and retrofit of 30 bridges in the Los Angeles Basin, the San Fernando Valley, Oakland, Mountain View and Petaluma. The work included development of seismic design criteria, evaluation of potential for liquefaction, ground failure, or seismic settlement, and evaluation of foundation design criteria for seismic retrofit of state bridges in accordance with Caltrans guidelines.

**Project Manager, Geotechnical Seismic Evaluation, I-40 Bridge, Mississippi River, Memphis, TN, TDOT, 1994-1998, $500,000:** Project involved field and laboratory testing, evaluation of liquefaction potential and embankment stability, and soil-structure interaction analysis of the main truss-arch span caisson foundations.

**Oil and Gas Facilities**

**Project Manager, Development of Earthquake Ground Motion Criteria, Chevron Oil Refinery, Richmond, CA, SGH, 2002, $40,000:** Developed criteria for the risk evaluation of various production facilities. Project included extensive analysis of dynamic site response to evaluate the effects of soft soils on the ground motions at the refinery.

**Task Leader, Site Response Analysis and Development of Earthquake Ground Motion Criteria, Yankee Gas LNG Distribution Facility, Waterbury, Connecticut, Yankee Gas, 2005, $20,000:** Directed seismic site response analyses to evaluate site effects on surface acceleration response spectra and develop earthquake ground motion design criteria for new 120-foot-diameter LNG tank.
Hospital Facilities

Principal-In-Charge, Geotechnical Investigation, Richmond Medical Center Expansion, Richmond, CA, Kaiser Hospitals, 2003: Project expansion consisted of a new operation room and clinical ancillary facilities.

Project Manager, Development of Seismic Design Criteria, VA Hospital, San Juan, Puerto Rico, Department of Veterans Affairs, 1997: Project involved geologic and seismologic studies to characterize the seismic sources that could affect the hospital, an evaluation of ground motion attenuation, and a probabilistic analysis of ground motions to develop design acceleration response spectra for seismic evaluation of the hospital building.

Principal-In-Charge, Geotechnical Investigation VA Replacement Hospital, Palo Alto, CA, 1991-1993: Directed geotechnical investigation for new replacement hospital building on VA campus in Palo Alto to replace old hospital building damaged by the 1989 Loma Prieta earthquake. Work included extensive field investigations, laboratory testing, engineering analysis, development of recommendations, review of plans and specifications, and construction inspection services.

Project Manager, Seismic Design Criteria VA Replacement Hospital, Palo Alto, CA, 1991-1993: Directed and managed studies to develop seismic design criteria for new replacement hospital building on VA campus in Palo Alto to replace old hospital building damaged by the 1989 Loma Prieta earthquake. Work included probabilistic and deterministic analysis of ground motions and comprehensive analyses of soil structure interaction in support of seismic design of building by the structural engineer.

Educational Facilities

Principal-In-Charge and Peer Reviewer, Development of Seismic Criteria, Stanford University, Palo Alto, CA, Stanford University, 1990-1993: Directed probabilistic and deterministic ground motion analyses to develop acceleration response spectra for evaluation, design and retrofit of campus buildings.

Peer Reviewer, Development of Seismic Design Criteria, U.C. Berkeley Campus, Berkeley, CA, UC Berkeley, 1997-1999: Criteria consist of equal-hazard acceleration response spectra for selected probabilities of exceedance to be used in the evaluation and retrofit of campus buildings.

Principal-In-Charge and Peer Reviewer, Geotechnical Investigation and the Development of Foundation Recommendations, Art Museum, UC Berkeley, CA, 1998: Responsible for geotechnical studies in support of the seismic retrofit of the existing Art Museum building and
the new Seismic Replacement Building No. 1 at the U.C. Berkeley campus.

**Building Facilities**

**Review Panel Member, One Rincon Hill Project, San Francisco, CA, San Francisco DBI, 2005, $35,000:** Member of the Structural Advisory Committee (SAC) in charge of reviewing the design of the One Rincon Hill Project on behalf of the City of San Francisco Department of Building Inspection. The project consists of two twin 60-story-high towers with central concrete cores and outrigger buckling resistant frames founded on 12-foot-thick concrete mats. Because of the nature of the project design, the City required a “blue-ribbon panel” to review the safety aspects of the design including the geotechnical design criteria and the design of the structure foundations.

**Project Manager, Seismic Retrofit of the China Basin Building, San Francisco, CA, SGH, 2004, $30,000:** Evaluation of design earthquake ground motions for the building located along the wharf at China Basin. Project included extensive analysis of dynamic site response to evaluate the effects of the soft site soils on the ground motions.

**Principal-In-Charge, Geotechnical Investigations, Seismic Retrofit of Buildings 44 and 46, Hewlett-Packard Campus, Palo Alto, CA, HP Solutions, 1998-2000, $100,000:** Investigations included full-scale load test of large diameter drilled piers to support the buildings' lateral bracing systems.

**Project Engineer, Various Projects and Clients, 1990-2002:** Directed probabilistic seismic hazard analyses and evaluation of design ground motions for the Oakland Federal Building, the Lake Point Towers in Oakland, the 1111 Broadway building in Oakland, the San Francisco State Residence Hall, and the Laguna Honda State Hospital in San Francisco.

**Project Manager, Geotechnical Investigations, Hewlett-Packard, 1990-1992:** Responsible for development of foundation design recommendations for seismic retrofit of buildings at the Hewlett-Packard campuses in Palo Alto and Santa Rosa after the 1989 Loma Prieta earthquake.

**Project Engineer, Various Projects and Clients, 1981-1985:** Conducted probabilistic seismic hazard analyses and evaluated ground motions for seismic design of the 33 New Montgomery building in San Francisco, the South Gateway building in South San Francisco, the Metro Center in San Mateo, and numerous other high-rise buildings in California.

**Project Engineer, Various Projects and Clients, 1983-1988:** Directed numerous geotechnical-engineering investigations involving subsurface exploration, laboratory testing, engineering analysis, plan review, and construction inspection for harbor and waterfront facilities, industrial and
commercial facilities, and high-rise buildings. Examples of these include geotechnical investigations for mooring improvements at the U.S. Coast Guard Station in San Francisco, the 10-story Hyatt Regency Hotel in Burlingame, California, and the Silicon Valley Financial Center, Block 2, San Jose, California.

**Miscellaneous Project Facilities**

**Project Engineer, Seismic Design of Bay Division Tunnel and Access Shafts, San Francisco Public Utilities Commission, San Francisco, CA, 2006, $200,000:** Project consisted of developing the seismic design criteria and performing the dynamic response analysis for seismic design of a 5-mile long, 15-foot diameter tunnel, a 120-foot deep, 50-foot diameter access shaft and a 100-foot deep, 30-foot diameter access shaft. The tunnel and access shafts deliver water beneath San Francisco Bay as part of the City of San Francisco water supply system. The work included development of the design earthquake motions, site response analyses at various locations along the tunnel, and dynamic soil-structure interaction analyses of the shafts using three-dimensional non-linear finite element techniques with the computer program FLAC3D.

**Project Engineer, Seismic Design Criteria for Water Supply System Capital Improvements Program, San Francisco Public Utilities Commission, San Francisco, CA, 2006, $80,000:** Project consisted of developing the system wide seismic design criteria for a $4,000 million capital improvements program for the City of San Francisco water supply system. Responsible for development of the design earthquake ground motion criteria and the guidelines for evaluation of geological hazards including soil liquefaction. Reviewed and supplemented guidelines for design of dams and underground system facilities.

**Project Manager, Airfield Rehabilitation and Realignment Project – Phase A, San Francisco International Airport, San Francisco, CA, 2005-2006, $350,000:** Project includes the evaluation of seismic stability of the runways and airfield areas of San Francisco’s international airport under a nearby Magnitude 8 earthquake and development of remedial designs to mitigate the seismic risk from large earthquakes. The airport is sited over filled ground covering several thousand acres on the shores of San Francisco Bay. The fill is 10 to 30 feet thick and is underlain by soft deposits of San Francisco Bay Clay up to 80 feet thick. Evaluation of the airfields stability included field investigations, development of an extensive database of SPT and CPT test data, and analysis of the potential for liquefaction in the fill and excessive deformation of the Bay Clay and of settlements and deformations of the airport runways and retaining dikes.

**Peer-Reviewer, Wharf and Embankment Strengthening Program (WESP Project), Port of Oakland, CA, 1998-2000, $300,000:** Phase I of the project involves the assessment of liquefaction potential, embankment stability, wharf performance, and seismic risk at 14 berths at...
the Port of Oakland in California. Phase II consists of developing modification concepts and designs to retrofit the wharves and embankments to acceptable standards. The project is driven by the need to modify the existing wharves to accommodate 10 feet of dredging of the harbor and updated seismic design criteria.

Review Panel Member, Pacific Bell Ball Park, San Francisco, CA, San Francisco DBI, 1995, $20,000: Member of the Structural Advisory Committee (SAC) in charge of reviewing the design of the Pacific Bell Ballpark on behalf of the City of San Francisco DBI. The stadium, with a seating capacity of over 40,000, is the new home of the San Francisco Giants. Because of the nature of the project as a critical structure, the City required a “blue-ribbon panel” to review the safety aspects of the design including the geotechnical design criteria and the design of the structure foundations and soil improvement.

Principal-In-Charge, Evaluation of Seismic Design Criteria, U.S. Army Blue Grass Chemical Depot, Richmond, KY, USACE, 1999, $70,000: Design acceleration response spectra were developed in accordance the USACE manual TI-809-04.

Task Leader, Site Response Studies, Nuclear Waste Repository, TX, Fluor Corporation, 1987, $500,000: Directed site response studies for the development of criteria for the seismic design of the exploratory and production shafts for the proposed Nuclear Waste Repository project in salt rock.

Landslides

Peer Reviewer, Evaluation of Stability and Stabilization Measures for Wailupe Landslide, City of Honolulu, Hawaii, 2001, $400,000: Evaluated stability of 300-foot high landslide in the Wailupe Valley, north of Honolulu, monitored slope movements, and developed conceptual stabilization measures.

Principal-in-charge and Peer Reviewer, Design and Construction of Stabilization for Fleming Hill WTP Landslide, City of Vallejo, 1998, $100,000. Analyzed stability of landslide, developed concepts for stabilization, developed plans and specifications for landslide stabilization with a compacted fill buttress and subdrain blanket, and provided engineering services during construction.

Peer-Reviewer, Evaluation and Remediation Design, Keller Canyon Landfill Landslide, Contra Costa County, CA, BFI, 1999, $200,000: Services included extensive geologic and geotechnical investigations, and engineering analyses using state-of-the-art methods, to evaluate the static and seismic stability of the landslide and develop remediation alternatives and design plans and specifications.
Peer-Reviewer, Evaluation of Stability and Seismic Deformations, Penitencia Water Treatment Plant Landslide, Santa Clara Valley Water District, 1996, $100,000. Reviewed extensive monitoring data on slope deformations and data on subsurface conditions, developed model for analysis of landslide stability, and performed non-linear finite element analyses of seismic deformations.

Liquefaction Studies


Project Manager and Engineer, Moss Landing Marine Laboratory, California State University, 1990-1992, $40,000: Conducted an investigation of the liquefaction failure of the California State Moss Landing Marine Biology Laboratory in Monterey Bay during the 1989 Loma Prieta Earthquake. Performed a survey of damage and liquefaction failure throughout the area affected by the earthquake.

Project Engineer, Seismic Safety Element, Contra Costa County, CA, 1986: Revised liquefaction potential and ground motion section of the Contra Costa County (California) Seismic Safety Element. Evaluated liquefaction potential at over 600 sites throughout the county and revised county administrative maps of liquefaction potential.

Seismic Risk Studies

Project Manager, Seismic Risk Evaluation, Hells Canyon Hydroelectric Complex, Snake River, Hells Canyon, ID, Idaho Power Company, 1992-1993, $50,000: Study included an evaluation of seismic hazards, a 1-week field inspection, and seismic analysis of: Brownlee Dam, a 400-foot-high rockfill, Oxbow Dam, a 200-foot-high rockfill, Hells Canyon Dam, a 300-foot-high concrete gravity dam, and all appurtenant structures and power generation facilities.

Task Leader, Prioritization of Seismic Retrofit Program, IL, IDOT, 1995-1997, $500,000: Responsible for the development of seismic hazard maps, soil amplification factors, and guidelines for the evaluation of liquefaction potential, for seismic retrofit of state bridges for the Illinois Department of Transportation.
Project Manager, Various Projects and Clients, 1982-1992: Directed probabilistic seismic hazard analyses and earthquake risk assessment studies for Kaiser hospitals in Santa Clara and Hayward, California, the Colmac Biomass Power Plant in Mecca, the Serramonte Shopping Center in Daly City, and the U.S. Navy Apra Harbor Facilities in Guam.

Project Manager, Seismic Risk, BAPI Pipeline, Chevron Pipeline Co., 1988, $30,000: Directed probabilistic seismic risk and structural vulnerability studies to evaluate the potential for damage to Chevron's BAPI pipeline from fault displacement at a crossing of the Calaveras fault in Alameda County, California.


Principal-in-Charge, Seismic Vulnerability Study, CCC, CA, CCWD, 1996: Directed evaluation of earthquake engineering and related geotechnical hazards for a preliminary study of the vulnerabilities of the Contra Costa Water District utility system. The issues included earthquake source characterization, and evaluation of liquefaction susceptibility and earthquake-related landsliding in the project area.

**Soil-Structure Interaction Studies**

Principal-in-Charge and Peer-Reviewer, Soil-Structure Interaction Analysis, Point Fortin LNG, Trinidad and Tobago, Raito Inc., 2002-2003, $30,000: Analysis of pile-supported mat foundation for the LNG Tank. Work involved soil-structure interaction analysis using the computer code SASSI of concrete mat supported on 2,000 piles driven through soft soils, to evaluate the dynamic stiffness of the foundation under strong earthquake loading.

Principal-in-Charge and Peer-Reviewer, Soil-Structure Interaction Analysis, LNG Plant Train 4 Facilities, Trinidad and Tobago, Raito Inc, 2002-2003, $30,000: Services included finite-element analysis of the vibration characteristics of 50m by 50m foundations supported on a grid of deep-soil-mixing columns through liquefiable soils for frequencies of up to 80hz. Developed a procedure for effective modeling of DSM grids using the computer code SASSI.

Project Manager, Various Projects and Clients, 1990-1995: Foundation investigation, earthquake ground motion characterization and soil-structure interaction analyses of the 18-story Pacific Bell towers in Oakland, CA. Directed soil structure interaction analyses of the 1,000,000-square-foot VA Replacement Hospital in Palo Alto, CA. Principal investigator for California SMIP research grant on the evaluation of...
soil-structure interaction effects on the seismic response of buildings and the development of code guidelines to account for soil-structure interaction in building design.

**Project Engineer, SSI studies, Diablo Canyon Nuclear Power Plant, San Luis Obispo, CA, PG&E, 1983:** Conducted soil-structure interaction and hydro-dynamic interaction studies including the analysis of non-safety-related Class II water tanks and safety-related Class I diesel fuel tanks at the Diablo Canyon Nuclear Power Plant. Directed dynamic soil-structure interaction studies for the VA replacement hospital in Palo Alto and the Pacific Bell towers in Oakland, California.

**Professional Societies/Affiliates**
- American Society of Civil Engineers, Member of the Publications Committee of the Geo-Institute
- Earthquake Engineering Research Institute
- United States Society on Dams (USSD)
- Structural Engineers Association of Northern California, Member of the Seismology and Foundations Committees
- International Society of Soil Mechanics and Foundation Engineering

**Awards**
- Fulbright Scholar, 1977-1981
- Project Management Award, Woodward-Clyde Consultants, 1996
- Secretarial appointee to the Advisory Committee on Structural Safety (ACSS) of Department of Veterans Affairs (VA) Facilities, 2001-2003
- National Science Foundation Panelist for the CAREER Program in Geotechnical and Geohazards Systems, 2003

**Languages**
- English, Spanish

**Specialized Training**
- 1996/Executive Management Action Program

**Publications**
The seismic stability evaluation of Enid Dam (with S. Stacy and W. Forrest), Proceedings, Dam Safety 2006, Association of State Dam Safety Officials Annual Conference, Boston, Massachusetts, September.

Seismic safety evaluation of dam for foundation faulting (with J. Walker and M. Gillon), Proceedings, 8th National Conference on Earthquake Engineering, 100th Anniversary Earthquake Conference Commemorating the 1906 San Francisco Earthquake, San Francisco, California, April 2006.


Seismic upgrade of hydraulic fill dam by buttressing (with J. Sun and K. Leung), Soil Dynamics and Earthquake Engineering, Vol. 25, 7-10, pp 571-579, August 2005.


Seismic evaluation of Aviemore Concrete Dam (with G. Lund and J. Walker), Proceedings, USSD 2005 Annual Meeting and Conference, Salt Lake City, Utah, June 2005.


Safety assessment for active faulting within the Aviemore Dam foundation and reservoir, New Zealand (with J. Walker and M. Gillon), Proceedings, ANCOLD Conference on Dams, Sydney, Australia, November 2004.

Stone column construction stabilizes liquefiable foundation at Lopez Dam (with M. Forrest, S. Callan, T. Feldsher, G. Lawton, and P. Ogren),


Rehabilitation of the Matahina Dam for foundation fault trace displacements (with M. Gillon and S. Everitt) Proceedings, ICOLD Symposium on Rehabilitation of Dams, New Delhi, India, November 1998.


Design criteria for fault rupture at the Matahina Dam, New Zealand (with M. Gillon, S. Freeman, and K. Berryman) International Journal on Hydropower and Dams, Volume 4, Issue 2, 1997, pp. 120-123.

Seismic vulnerability assessment, approach and techniques for open channels such as the Contra Costa Canal (with S. Salah-Mars, R. Kulkarni, and E. Avila) Proceedings, TCLEE Conference, ASCE, 1997.


Seismic analysis of Los Vaqueros Dam, California (with G. Lawton, J. Sun, R. Green and D. Hughes) Proceedings, ASDSO Western Regional Technical Seminar, Sacramento, California, April 11-12, 1996.


Damage patterns and response of deep stiff clay in Oakland (with S. Chang, J. Bray, and J. Sun) Proceedings, Third International Conference on Case Histories in Geotechnical Engineering, June 1-4, 1993, pp. 1611-1616.

Calibrated dynamic response analysis of Stafford Dam (with R. Boulanger) Proceedings, Third International Conference on Case Histories in Geotechnical Engineering, June 1-4, 1993, pp. 321-328.


Measured and calculated dynamic response of rock-fill dam (with D. Sykora, M. Hynes, K. Fung, and J. Knester). Presented at the Second...
International Conference on Geotechnical Earthquake Engineering and Soil Dynamics, University of Missouri-Rolla, St. Louis, Missouri, March 1991.


A computer program for the three-dimensional dynamic analysis of earth dams (with T. Kagawa, H.B. Seed, and J. Lysmer). Report No. UCB/EERC-81/14, Earthquake Engineering Research Center, University of California, Berkeley, 1981.


**Chronology**

1/85 - Present: URS Corporation, Senior Engineer to Principal and Vice President, Oakland, CA
9/81 - 6/85: Harding Lawson Associates, Associate Engineer, San Francisco, CA
9/78 - 8/81: University of California, Berkeley, Teaching and Research Assistant, Berkeley, CA
6/76 - 12/76: Inacon, Engineering Assistant, Bogota, Columbia

Contact Information
URS Corporation
1333 Broadway, Suite 800
Oakland, CA 94612-1924
Tel: 510.893.3600
Direct: 510.874.3246
Fax: 510.874.3268
lelio_mejia@urscorp.com
Report of Imagery Analysis

By Harley Powers Parks

December 29, 2006
Godbey•Griffiths•Reiss•Chong (GGRC) contracted with HI-Tech Urban Solutions Inc. (HITUS) to provide geospatial visualization services as part of the Ka Loko Dam Breach Investigation being conducted by GGRC. The intent was to visually detect elevation changes along the dam, spillway, and the north side of the Ka Loko Reservoir using 3D ground models from different years.

The U. S. Geological Survey’s (USGS) digital terrain model (DEM) for the Anahole quadrangle were used to provide elevations in a 10 meter grid extracted from USGS topo map contours. The DEM provides baseline elevation measurements which are useful for creating orthophotography, vertical control point elevations, slope maps, aspect maps, and 3D ground models. Historic stereo photography provides a view of ground cover, changes to cover from cut or grubbing operations, and potentially more specific elevation measurements. USGS Ka Loko Reservoir Ground Based Tripod Light Detection and Ranging (T-LIDAR) provides highly accurate ground survey along the breach and within the reservoir. In lieu of a field survey, Quickbird Satellite orthorectified imagery and USGS DEM were used to acquire ground control points which are useful for spatial orientation of aerial photography and the T-LIDAR data set.

The aerial stereo photography (8 stereo pairs) was captured from 1955 to 2006 and can be used to make elevation measurements; however, a ground control point survey would improve the quality and provide a more reliable measure of accuracy. Earlier reports show the low point in the Ka Loko Dam was only 1.5 ft. difference from the spillway in 1982 USDA study. The USGS topography maps indicate the maximum height of the reservoir water level and spill way, at about 747 feet, while the top of the hill on the north side of the reservoir (north hill) is about 800 feet. The low point of the dam could be assumed to be about 749 feet. Based on this information, it would be difficult to trust the vertical measurements taken from the existing aerial photography survey for the spillway and dam. However, it may be possible to measure the cut material from the hill and fill material on the spillway.

The T-LIDAR data set consist of 12 million points of data measured from 4 different locations within the reservoir and breach. An animation is provided that demonstrates the point cloud created from this survey. Note that different shades were used to denote each of the 4 surveys. Exact measurements can be taken from anywhere in this data set making it very useful for making profiles and 3D models. Additionally, figures are provided of the data set and the USGS survey of Ka Loko Reservoir.

The 3D ground models show enough relief in the project vicinity to allow interpretation of elevation rise or drop, slope, and aspect of the terrain, as well as, photo realistic views of historic conditions. Ideally, any site characterization changes would be perceptible in the 3D model to a viewer. Additionally, as part of the production process, orthorectified imagery is generated to provide a map view of each year. The geospatial visualization of the 3D model is provided as an animation and as a web based 3d interactive viewer.
Harley Powers Parks
2924 Eugene Place, Honolulu Hawaii 96816 Ph: 741-7465, Email: harley@hitushawaii.com

Objective

- Develop 3-D visualization and simulation applications for urban environments.
- Promote project quality and profitability through project management experience and tools.

Professional Experience

**Hi-Tech Urban Solutions** 1/01 - Present
*Geospatial Visualization Director.* Write project plans, specifications, implement photogrammetry methods and database technology to create the Oahu 3D Urban Model and geo-database for the City and County of Honolulu.

**Carter – Burgess, Honolulu** 5/98 - 12/01
*Geographic Information Systems Analyst/Project Manager.* Propose, plan, develop, implement, and manage enterprise spatial information system solutions using Oracle, Oracle Spatial, ArcIMS, ArcGIS, ArcSDE, ArcView, AutoCAD, Microstation, GeoMedia. Plan and implemented multiple projects worth more than 2.2 million dollars for the City & County of Honolulu and Hawaii Department of Transportation Airports Division.

**City & County of Honolulu, Environmental Services** 9/97 - 5/98
*Geographic information Systems Analyst III.* Assist with the daily operations of the City’s wastewater information management system utilizing Oracle, Arc/Info, ArcView.

**Ogden Environmental** 5/94 - 6/97
*Project Manager/Geographic Information Systems Analyst.* Develop environmental database and mapping applications, implement and manage map production for environmental assessments for Navy CLEAN projects.

**GeoInsight International** 8/92-5/94
*Geographic Information Systems Analyst.* Develop CAD based GIS applications for Hawaii Projects.

**University California Santa Barbara** 8/91-6/92
*Assistant.* Perform habitat mapping of transects utilizing zoom transfer scope imagery, field maps and field observations for the California GAP analysis project.

**McDonnald Douglass** 5/88-9/88
*Avionics and electrical inspector.* Inspect communication, navigation, electrical components, and other avionics in accordance with commercial and military drawings and specifications.

**United States Marine Corps** 10/80-3/88
*Sergeant, Communication Navigation Electronic Counter Measure Avionics Technician & Reconnaissance Marine.* Performed installation, testing and operation of avionics. Carried out field data gathering and mapping.

Education & Training

1992: B.A., Geography, University of California Santa Barbara; Santa Barbara, California
1996: Introduction to PL/SQL Programming – Oracle, Honolulu, HI.
1996: Oracle Database Design – Oracle, Honolulu, HI.
1998: Customization of GeoMedia using Visual Basic, Intergraph, Honolulu, HI.
2001: Creating and Managing Geodatabases Using ArcGIS, ESRI, Honolulu, HI.
2001: Designing Geodatabases
2003: Nverse Photo and 3D Studio Max – Modeling Structures, Precision Lightworks, Melbourne, FL.
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2924 Eugene Place, Honolulu Hawaii 96816 Ph: 808.74.7465, Email: harley@hitushawaii.com

Organizations

Hawaii Geographic Information Coordinating Council, Honolulu, Hi., 1993 – present

Technical Skills

Geospatial/Photogrammetry:
3DS Max, Nverse Pro, ERDAS Ortho Base Pro,
ArcGIS, ArcScene, ArcView, ArcIMS,
AutoCAD, GeoMedia Pro, GeoMedia Web Map,
MicroStation, MS Access, MS Excel,

Database Management Systems:
Oracle, Oracle Spatial Cartridge, ESRI Spatial Database Engine, SQLSERVER.

Web/Graphics:
Internet Information Server, NewAtlanta Servlet Exec, Apache-Frontpage, Macromedia Dreamweaver,
Flash, Fireworks, Adobe Photoshop, ACDSEE, CorelDraw Suite

Scheduling/Project Management:
MS Project, Primavera, SureTrak, Rational Requisite Pro, MS Word

Operating Systems:
VMS, AIX, DOS, SunOS, UNIX, Windows 2000 Server, Windows 95, 98, NT, 2000, XP

Programming/RAD/CASE Tools:
SQL, Visio, Visual Basic, Visual Studio, ASP, AML, AutoLISP, AVENUE, ER/STUDIO, HTML, Coda, Script,
Pascal, Perl, PL/SQL, ER Studio

Qualifications

Mr. Parks has 20 years of experience in information technology, spatial data processing, and visualization. He is responsible for the daily operation and administration of the acquisition, storage, retrieval, analysis, and visualization of Hi-Tech Urban Solutions’ 2D and 3D Geospatial Information System.

His career path has provided him the opportunity to design, develop, and implement information systems for strategic projects, enterprise wide projects, internet projects, and 3D Geospatial Visualization Solutions.

As the Project Manager, Mr. Parks coordinates and performs the acquisition and production of aerial photography, imagery, ground control points, LIDAR, orthophotography, 3D modeling, video editing, 3D animations, image composites, simulations, and 3D web applications. His recent project highlights for the City and County of Honolulu include:

- The Honolulu 3D Building Footprint Geo-Database;
- Oahu Terrain and Building Ortho-rectified photography, and
- 3D Visualizations & Animations:
  - Contra Flow Transit,
  - 20 mile Proposed Transit Corridor,
  - Trains Entering Proposed Station and Urban Vicinity.
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Project List

- **Building Footprint Geo-Database Project, Honolulu; Senior Systems Analyst.** The 3-Dimensional GIS is developed utilizing aerial photography, terrestrial photography, and stored in a Geo-Database in MS Access and then ported thru SDE into Oracle 9i.

- **URS Corporation, Honolulu, HI; Systems Analyst.** Developed an MS Access database and reporting of Wake Island soil, water, and biological sampling. This application created complex cross-tap reports on multiple sites, environmental constraints based on constituents, and chemistry lab results.

- **City & County Document Scanning Project, Honolulu, HI; Senior Systems Analyst.** Developed, managed, and implemented Integrated Document Management System. The project utilized a team approach to implement a $1.6 million document conversion project which inventoried, imaged, indexed permits, plans, as-built drawings on microfilm, aperture cards and hard copy media before storing as TIF images. Established contracts with vendors to support the document imagining. Developed workflow for back loading imaged documents into an Oracle database. Developed VB application for integration of Microsoft Access data and Excel data into a custom Oracle database. The Oracle database was developed utilizing CASE tool ER Studio. Used the existing electronic document management system to retrieve the imaged documents. Programmed ArcIMS and Oracle 9i to demonstrate the ability to retrieve imaged documents via web map interface. Planned and implemented all aspects of project based on system development processes using Rational tools.

- **DWMM On-Call Services, Honolulu, HI; Project Manager.** Provided technical support on Wastewater Information Management System (WIMS) software architecture and database relationships. Required an on-call basis from May 1998 to November 1998 to provide technical support to limited city WIMS/GIS staff in accomplishing the identification, development and execution planning for maintaining an operational and functional WIMS system.

- **Hawaii Airports GIS Maintenance, Honolulu, HI; Project Manager.** Led the CIP-funded project, which calls for the installation of Oracle 8i Spatial, migration and population of GIS databases for all 16 state-managed airports, and the enhancement of developed software applications. This project underscores the successful implementation of previous GIS development work accomplished for the state of Hawaii and provides support to staff and consultants.

- **Hawaii Statewide Airport Facility Inventory & GIS, Honolulu, HI; GIS Specialist.** Provided development of a statewide GIS-based facilities management system and asset inventory. Used Oracle Spatial, ER Studio, Microstation, MGE, GeoMedia Professional, Visual Basic and GeoMedia Web Map to provide an integrated, turn-key solution for asset management within the State of Hawaii Airports Division. Integrated MicroPAVER, Lease Management, Property Management, Environmental and Noise Management, Operations and Maintenance and Capital Improvement Program development into a single integrated application suite.

- **MapOn! - Interstate Pipeline Soil Survey Analysis, Honolulu, HI; GIS Analyst.** Subcontracted to develop GIS applications to automate the analysis, reporting, mapping, and
distribution of GIS products of right-of-way impacts. The survey required generation of reports, tables, and maps for an interstate pipeline route.

- **Ogden Environmental and Energy Services, Honolulu, HI; GIS/CAD Analyst.** Developed Ogden's Geographic Information System, an integrated system using state of the art network and GIS solutions. Responsible for the daily administration, operation, technical support, coordination, and productivity of Ogden's GIS and computer assisted drafting department.

- **Ogden Environmental and Energy Services - CLEAN, Naval Air Facility, Midway Atoll, Honolulu County, HI; GIS/CAD Analyst-Lead.** Developed visual basic application to provide random sample location within a grid. Developed Avenue scripts for creating logarithmic bar charts within individual polygons comparing contaminants found in algae, carnivorous fish, herbivorous fish, and crustaceans. Created maps of graduated point symbol size and surface contours of contaminates.

- **Ogden Environmental and Energy Services - CLEAN, Site Investigation Report, Naval Air Facility, Midway Atoll, Honolulu County, HI; GIS/CAD Analyst - Lead.** Coordinated and participated in the development and operation of applications to create over 500 maps. Time restraints required delivery of all maps within 100 days. Maps reflected generalized site characteristics, sample locations, and call-out boxes containing table of potentially hazardous contaminants at 36 sites on Midway Atoll.

- **Ogden Environmental and Energy Services - CLEAN, Site Investigation Report, Naval Air Station, Barbers Point, Honolulu County, HI; GIS/CAD Analyst - Lead.** Coordinated and participated in map compilation, thematic organization, and map production for multiple sites.

- **Ogden Environmental and Energy Services - Kahoolawe Ordinance Removal Seminar Demonstration, Honolulu County, HI; GIS/CAD Analyst - Lead.** Coordinated data conversion of U.S. Geological Survey Data, U.S. Navy target and range maps, images of ordinance, images of cultural features, and Nature Conservancy Endangered Species data and coverage. Demonstrated Intergraph MGE and Vista Map to show image retrieval hill shading, analysis of cultural features located within a buffer area along roads, and ordinance locations.

- **Ogden Environmental and Energy Services - Ordinance Removal Plan, Kassic Impact Range, Ulupalakua Army National Guard, Honolulu County, HI; GIS/CAD Analyst - Lead.** Integrated U.S. Geological Survey digital line graphs, GPS data, field notes, and air photos all in UTM zone 4 NAD27.

- **Ogden Environmental and Energy Services-Comprehensive Management of Coastal Resources, Phase I Office of State Planning, Honolulu County, HI; GIS/CAD Analyst - Lead.** Converted hard copy maps, provided coverages, drawings, and master images for integration with the State of Hawaii's GIS database. The project of adherence to state data standards and specifications. Databases developed include: Fishing Management Areas; Marine Life Conservation Districts; harbors and boat ramps; fish ponds; coral reefs; water quality; and ocean recreation areas.

- **Ogden Environmental and Energy Services - Army Base Cultural Assessment, HI; GIS/CAD Analyst - Lead.** Scanned and geo-registered USGS and Map Defense Agency maps for use as base maps. Compiled state archeological points, locations, and field mapping data. Maps depict archeological sites, archeological site attributes, base boundaries, survey areas, and culturally significant areas.

- **Ogden Environmental and Energy Services - CLEAN, Aiea Navy Laundry Facility, Aiea, HI; GIS/CAD Analyst - Lead.** Implemented the acquisition, configuration, and operation of
Intergraph hardware and software for a three month period to visualize the contaminate plume beneath the facility.

- **GeoInsight International - Department of Land and Natural Resources, Stream Protection and Management, Honolulu, HI; GIS Analyst.** Assisted in the integration of the Hawaii Stream Assessment Database with the State database. Developed routines to extract perennial streams and ditches from digital line graphs.

- **GeoInsight International - Pearl Harbor Submarine Base, U.S. Navy, HI; GIS Analyst.** Provided drafting support on AutoCAD drawings development. Converted data from film, paper, and aerial photos to AutoCAD. Created base maps consisting of building footprints, roads, coast lines, and other structural features.

- **GeoInsight International - Spatial Database Development for the Kawai‘Nui Marsh Master Plan - Office of State Planning, HI; GIS Analyst.** Responsible for data extraction, database design, and data conversions. Work included: digitizing of data layers, classifying entities, establishing a control point system, creating lookup tables, and writing System Macro Language (SML) and AML routines. Maintained a close working relationship with the client to ensure product quality; and provided technical support.

- **GeoInsight International, Honolulu, HI; GIS/CAD Analyst.** Designed and developed Kawai‘nui Marsh Database. Assisted GIS development for a nature conservancy and for Kaneohe Marine Corps Air Station Environmental Branch.

- **University of California, Department of Geography - California Gap Analysis and Biodiversity Analysis, Santa Barbara, CA; Research Assistant I.** California Fish and Wildlife Association. Transferred high aerial photography with transect classifications to U.S. Geological Survey 7.5 minute quadrangles, scanned vegetation maps, performed edge matching tasks, participated in field reconnaissance of transects and processed transects to incorporate into existing database.

- **University of California, Department of Geography - Expert System Development, Santa Barbara, CA; Research Assistant I.** Converted parcel date into a suitable format for processing. Wrote LISP routines to process parcel data in an expert system. Assisted in digitizing and editing maps.

- **University of California, Department of Geography - Southern California Earthquake Hazard, Santa Barbara, CA; Research Assistant I.** Designed maps showing faulting, geology, and quake epicenters using AML programming. Wrote the code to reformat Southern California’s earthquake epicenter data from the periods between 1930 to 1990.

- **University of California, Department of Geography - Biodiversity Project - NASA, Santa Barbara, CA; Research Assistant I.** Assisted in analysis of Advanced Very High Resolution Radiometry satellite imagery by providing control points for Normalized Difference Vegetation Index Composites for image-to-image registration. Provided root mean square error for each point for each image and produced graphs depicting registration errors. Evaluated 21 NDVI composites for use as an image registration base for future studies.

- **University of California, Santa Barbara - Department of Geography, Santa Barbara, CA; Research Assistant.** Assisted GIS development for California Gap Analysis and prototype city parcel mapping expert system.

- **McDonnell Douglas, Long Beach, CA; Avionics Technician.** Avionics quality assurance. Performed inspection and operational checks on all avionics systems on commercial and military aircraft.
- **United States Marine Corps, San Diego, CA; Sergeant.** Supervised five to thirteen marines to provide avionics support as an Avionics Technician and field mapping support as a Field Reconnaissance Marine.

- **Navy Public Works Center  Work Site Locator. GIS Analyst.** Developed navigation interface for querying of 4 spatial data sets and the location of geographic features in ArcView 3.1.

- **Aircraft Gate Docking Study. Department of Transportation Airports Division. GIS Analyst.** Developed Master Data List, presented GIS solutions, and created data specifications for data processing of airport information into the airport GIS.

- **Residential Hurricane Insurance Policy Application. Zephyr Insurance Company, Hawaii; GIS Analyst/Programmer.** Developed application for the data processing and analysis of geocoded policy holders and aggregation by zip code. This required the creation of a (1) URL Business Model of existing and modified processes; (2) custom ArcGIS 8 application extension and interface, in Visual Basic; (3) data preparation of U.S. Census Bureau Tiger Line 2000.

- **Sewer Flow Estimating Model. City of Los Angeles; GIS Analyst.** Developed system and data requirements, specifications and master data list for sewer flow estimating model. This include sewer mains, laterals, population, population projections, and vicinities.

- **Historic Document Conversion and Imaging Project. City & County of Honolulu, Hawaii; Project Manager.** Responsible for the planning, design, and implementation of a document conversion system that had a total operational budget of 1.8 million dollars. The project required the creation of a document conversion system that would “bulk load” documents and data into an Oracle 8i relational database management system. Orchestrated and developed a web site, Internet Map Services, server configuration, software, databases, policy, and procedures for data acquisition, storage and retrieval, display, editing, and reporting. Along with 6 key staff and multiple subcontractors the project provided scanning services to image drawings, plans, maps, permits, correspondence, and other documents for more than 1 million documents.

- **Airport Pavement Survey - State DOT/Airports Division, Honolulu, HI; GIS Project Manager.** Assisted the Pavement Survey of Honolulu International, Kahului, Molokai, and Lanai Airports by providing Field Map Templates, bulk population of Pavement Management System (PMS), Maintenance & Rehabilitation Maps, Predictive PSI. maps, and Oracle spatial data integration application. Developed the Spatial Data Specifications that defined the criteria for developing GIS data for pavement management system and GIS integration.