

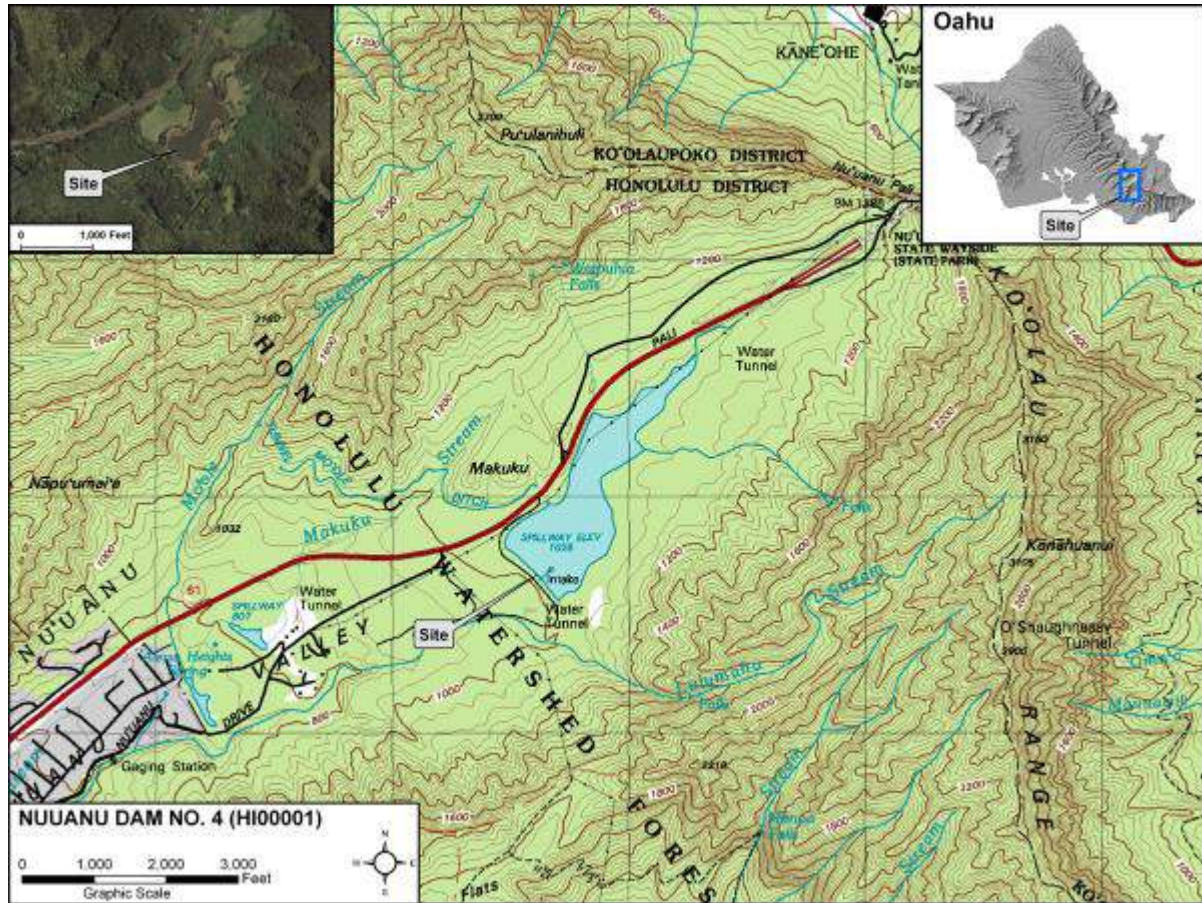
# Emergency Action Plan (EAP)

for

## NUUANU DAM NO. 4

State ID # OA-0001

HONOLULU, Oahu, Honolulu



Submitted By:

Michael Matsuo, P.E., Land Administrator

Copy \_\_\_\_\_ of \_\_\_\_\_

**(OA-0001) EAP for NUUANU DAM NO. 4**

Instructions for use in preparing hard copy EAP binders

1. Obtain ½”~1” white view binder.
2. Print one copy of EAP for each report set.
3. Sign both copies of cover sheet and fill in copy number
4. Cut out binder spine and insert into binder spin.
5. Insert one copy of coversheet in binder cover view.
6. Collate EAP tabs and EAP report together.
7. Insert into binder and distribute.

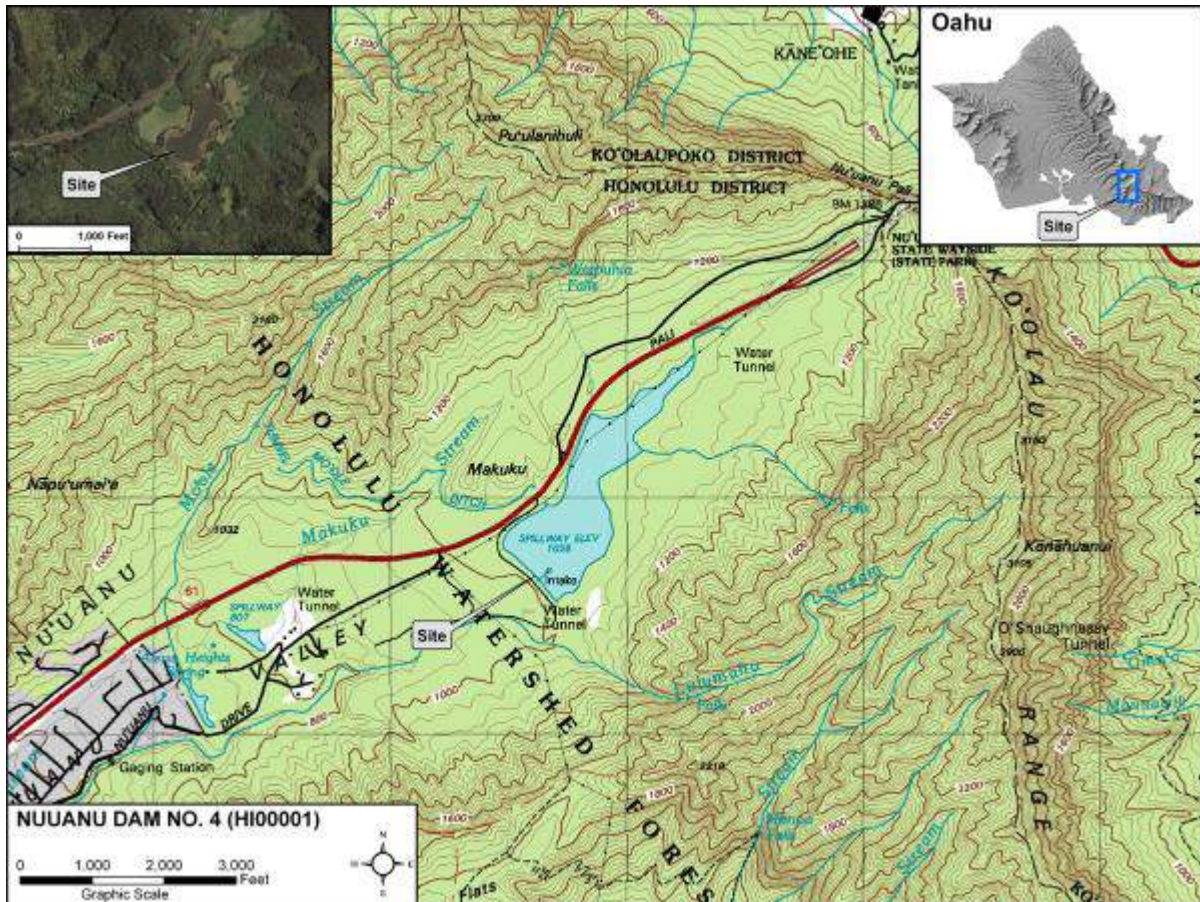
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## **I. Introduction**

### **Purpose**

This EAP outlines procedures to minimize risks to life and property when the integrity of the subject dam facility may be in jeopardy. This EAP considers unusual and emergency situations, both natural and manmade, and identifies appropriate responses and details roles and responsibilities before, during and following an emergency event. This EAP was specifically developed for the named facility only, and is not intended for use with any other facility.

Categories of unusual and emergency situations that may trigger activation of this EAP include (but are not limited to):

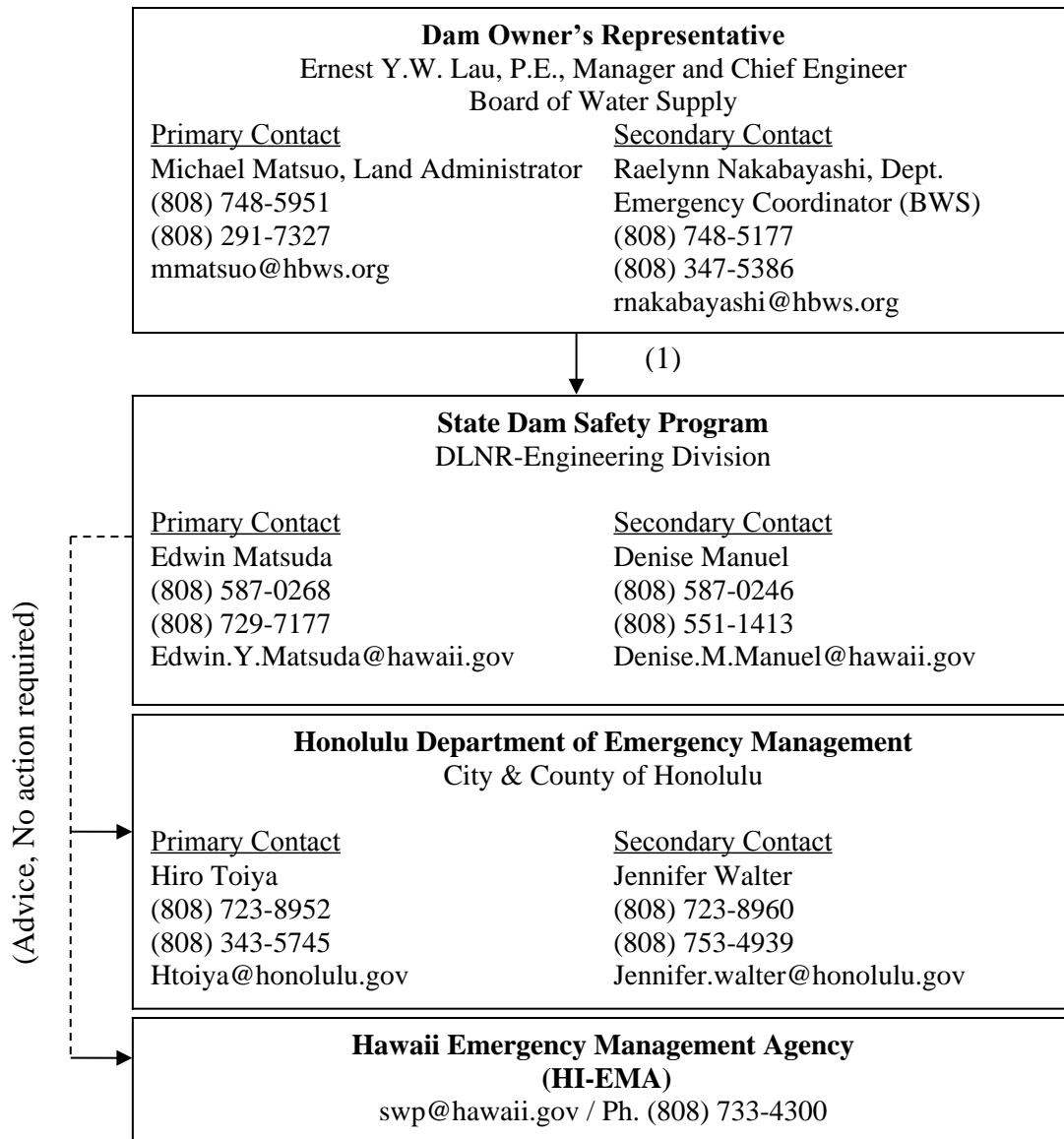
- Earthquake
- Sudden Reservoir Level Rise
- Flow through Spillway
- Embankment Overtopping
- Seepage
- Sinkholes
- Piping
- Damage of Spillway or Outlet Works
- Embankment Cracks
- Embankment Movement
- Abnormal Instrumentation Readings
- Security Threat
- Sabotage or Vandalism
- Hurricane or Heavy Rain Storm Event

**Roles and Responsibilities**

The following roles and responsibilities have been assigned for implementation of this EAP:

<b>Person or Agency</b>	<b>Responsibility</b>
Dam Owner / Dam Owner's Representative	Inspect, monitor and operate dam. Detect unusual/emergency situation. Determine Notification Level for situation. Notify appropriate agencies by activating EAP. Monitor/Remediate situation. Provide status updates to other agencies. Develop EAP. Initiate and coordinate update and testing of EAP. Provide technical advice for the owner.
911 Dispatch / State Warning Point	Notify emergency responders of notifications received from owner or other sources. Participate in update and testing of EAP.
Police Department	Open communication with Department of Emergency Management/Civil Defense Agency, and other agencies pertinent to an emergency. Participate in update and testing of EAP.
Fire Department	Open communication with Department of Emergency Management/Civil Defense Agency, and other agencies pertinent to an emergency. Participate in update and testing of EAP.
Honolulu Department of Emergency Management, Kauai/Maui County Emergency Management Agency, County of Hawaii Civil Defense	Open communication with other agencies pertinent to an emergency. Terminate Level 2/3 (Emergency) event. Participate in update and testing of EAP.
Hawaii Emergency Management Agency (Hawaii State Civil Defense)	Operate State Warning Point. Assist local community as necessary. Participate in update and testing of EAP.
State Dam Safety Program	Assist agencies as necessary. Assess restrictions or other actions when deemed appropriate. Terminate Level 1 (Non-Emergency) event. Participate in update and testing of EAP.

**Level 1 Notifications**  
**NON-EMERGENCY**  
**Unusual Event; Slowly Developing**



**Suggested Pre-Scripted Statement – Level 1 - Dam Owner to State Dam Safety Program:**

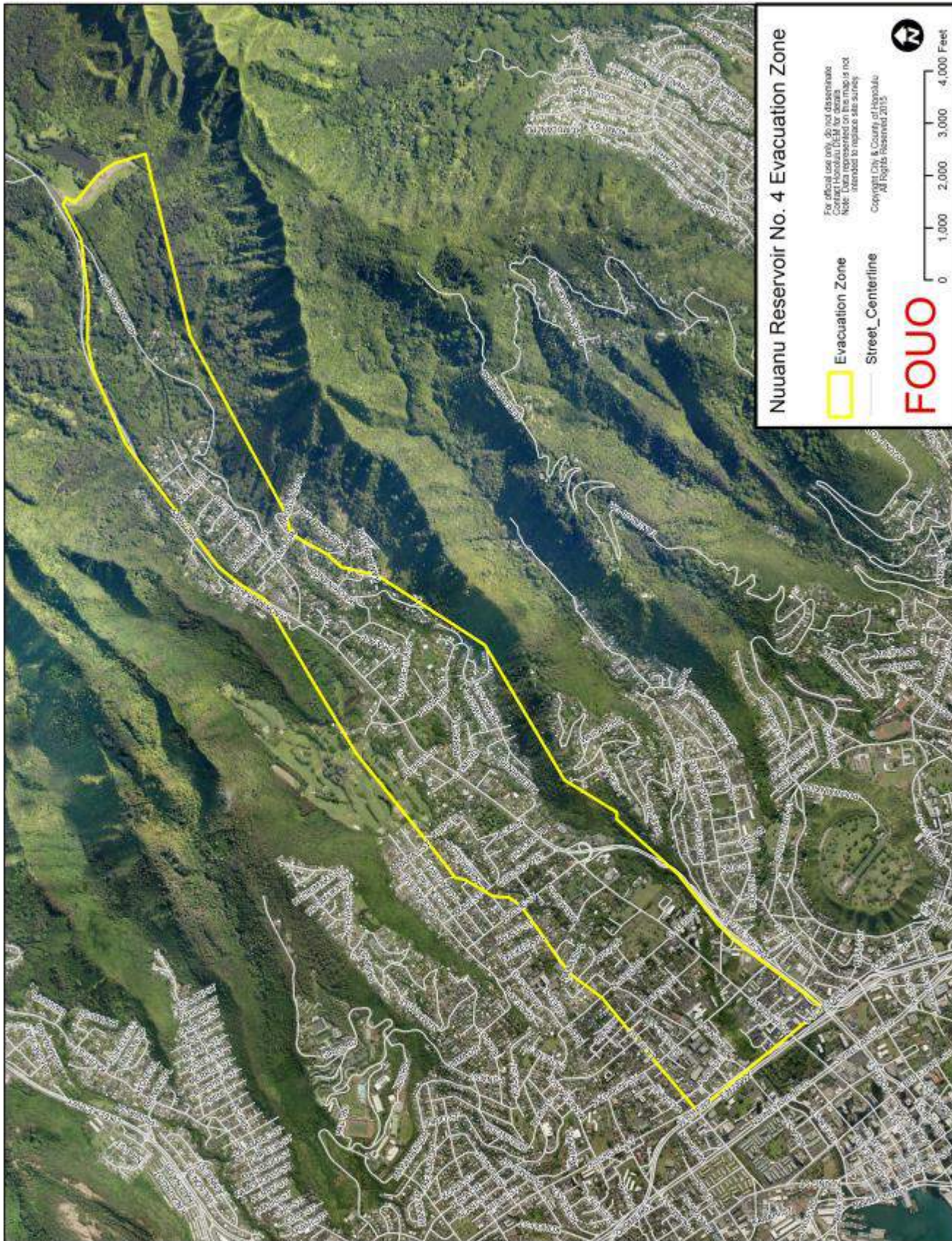
- This is [Name of Caller] from [Company you represent].
- We have a **LEVEL 1 Non-Emergency, Non-Failure situation** at [**NUUANU DAM NO. 4, OA-0001**]
- The type of unusual event is [describe unusual situation, i.e. maintenance work, change of outlet].
- The dam is located in [description of location, town neighborhood, address].
- The unusual event is expected to last [provide how long, i.e. week, month] and we will advise you of any changes to the status and when we are completed.
- My name is [Name of Caller] and I may be reached at [phone number] or alternate phone number [phone number].





- This is [Name of Caller] from [Company you represent].
- We have a **LEVEL 3 Emergency, Imminent or In-Progress Dam Failure** at [NUUANU DAM NO. 4, OA-0001]
- The type of emergency concern is [describe failure mode – i.e. overtopping or seepage/embankment failure problem].
- The dam is located in [description of location, town neighborhood, address].
- The dam is being monitored by our staff [provide how often – continuously or hourly/every 2hours].
- My name is [Name of Caller] and I may be reached at [phone number] or alternate phone number [phone number].

V. Evacuation Map  
a. Evacuation Map



b. Hazard Assessment Report



## Individual Assessment Report

### *1 Identification*

<b>Name of Dam:</b>	Nuuanu Dam No. 4
<b>National Id:</b>	HI00001
<b>Island:</b>	Oahu
<b>Nearest City/Town:</b>	Honolulu
<b>Name of affected stream:</b>	Nuuanu Stream
<b>Current DLNR risk classification:</b>	High
<b>Owner:</b>	Honolulu Board of Water Supply

### *2 Background*

<b>Location (latitude/longitude):</b>	21.36N 157.81W
<b>Miles to nearest city:</b>	1
<b>Year completed:</b>	1910
<b>Purpose/use:</b>	Flood control, recreation

### *3 Characteristics*

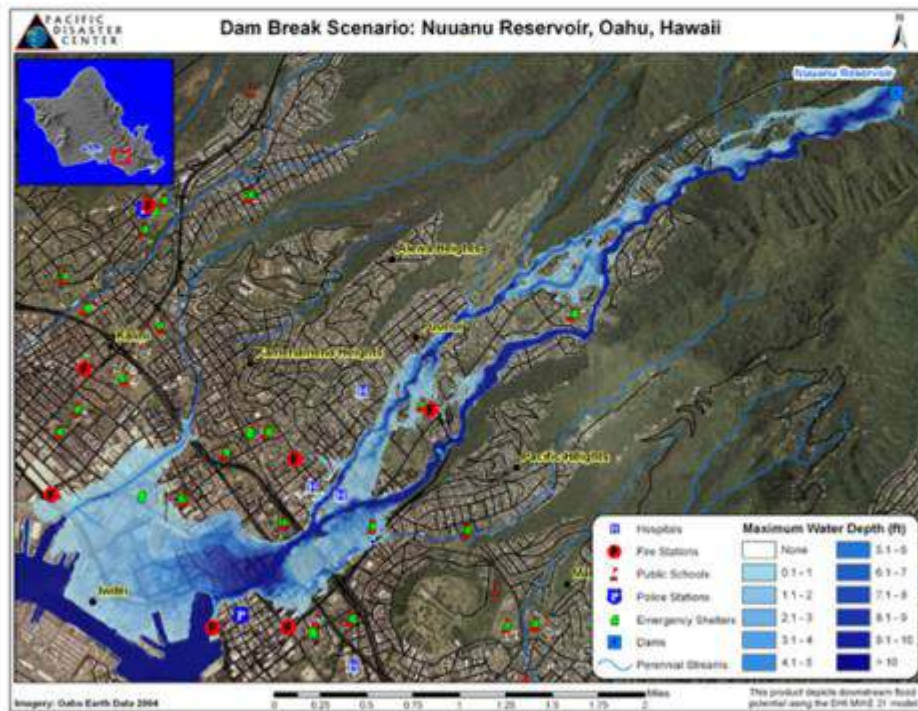
<b>Dam type:</b>	Earthen Dam
<b>Max. storage capacity (acre feet):</b>	3,600
<b>Dam height (feet):</b>	66
<b>Dam length (feet):</b>	1,730

## 4 Consequence Analysis

### 4.1 Scenario Parameters:

Parameters	Value	Unit of Measure
Reservoir volume prior to breach:	3,600	acre-feet
Duration of breach:	37	minutes
Breach width:	148	feet
Distance from dam to ocean:	4.60	miles
Type of dam:	Earthen Dam	n/a
Type of breach:	Piping breach originating halfway up the dam face	n/a

### 4.2 MIKE 21 Model Results – Inundation Map\*



\*While the best available GIS data have been utilized as input to the model and in visualizing model output, due to variations in their currency and accuracy, final product results should be interpreted as "best available estimates" only and not definitive in establishing inundation boundaries.

### 4.3 Model Assumptions

It is assumed that each dam fails by piping while at maximum capacity. It is further assumed that 1) the piping failure originates halfway up the dam face, 2) the dam fails under sunny day conditions with dry conditions downstream of the reservoir, and 3) no water is discharged from the spillway. The outflow (discharge hydrograph) from the breached reservoir is modeled using the NWS' DAMBRK model (within the Danish Hydrological Institute's MIKE 11 model), and data from historical breaches is used to estimate parameters controlling breach development. The DHI MIKE 21 model is used to route the reservoir discharge down the valley into the ocean. MIKE 21 routes unsteady two dimensional flows using the full Saint-Venant equations. Topography is described by USGS standard 10 meter DEMs. The inundation maps produced by MIKE 21 represent the maximum water depth experienced at any given location. The inundation maps are not snapshots in time because different locations experience maximum flooding at different times. MIKE 21 also provides information on the time of flooding and water velocities.

### 5 Model Output Statistics

Inhabited Areas Or Landmarks	Distance from breach (miles)*	Time from beginning of breach to first inundation (minutes)	Time from beginning of breach to maximum water depth (minutes)	Maximum flood depth (feet)
Nuuanu Valley	0.98	30	30	1
Alewa Heights	2.67	35	43	12
Paoua	3.62	35	47	1
Iwilei	4.45	43	57	9
Ocean Entry	4.60	43	57	2

\* Distance determined by Euclidean method defined as the straight line distance between two points.

### 5.1 Impact on Bridges

Bridge Identification	Distance from Breach (mi)	Time to First Inundation (min)	Time to Maximum Water Depth (min)	Maximum Water Depth (ft)
TMK=2-2-50	1.48	18	37	24
TMK=2-2-46	1.84	20	37	25
TMK=2-2-42,43	2.11	23	39	15
TMK=2-2-35	2.42	25	40	11
1200'W/NUUANU A/WYLLIE ST	3.03	38	46	12
0.48MI NE/PAUOA RD	3.06	29	43	18

Bridge Identification	Distance from Breach (mi)	Time to First Inundation (min)	Time to Maximum Water Depth (min)	Maximum Water Depth (ft)
200'E/PAUOA RD/NUUANU AVE	3.58	33	47	15
0.27MI NE/SCH ST	3.71	34	37	1
0.26MI NE/SCH ST	3.72	38	54	3
450'N/NUUANU/N KUAKINI ST	3.73	33	48	13
100'N/HUNA/N KUAKINI ST	3.75	45	50	11
0.21MI E/AALA ST EXT SEP	3.97	38	51	3
0.03MI E/AALA ST EXT SEP	3.97	35	51	37
0.23MI E/LILIHA ST	3.97	35	51	37
225'S/STILLMAN/N SCH ST	3.97	35	51	37
0.03MI E/AALA ST	4.15	38	52	15
0.29MI E/HOUGHTAILING ST	4.22	98	125	3
0.29MI E/HOUGHTAILING ST	4.22	98	125	3
0.29MI E/HOUGHTAILING ST	4.22	98	125	4
INT/KOKEA ST/N KING ST	4.36	84	124	4
INT/RIVER/BERETANIA ST	4.38	40	54	11
INT/RIVER ST/N HOTEL ST	4.49	40	56	11
INT/RIVER ST/N KING ST	4.52	31	56	15
0.06MI E/AWA ST	4.58	43	56	9
0.06MI E/AWA ST	4.58	20	56	19
0.25MI E/PACIFIC ST	4.62	45	58	4
BTWN KOHOU / KOKEA ST	4.70	70	89	5
0.25MI SE/WAIKAMILO RD	5.01	64	91	3
0.25MI SE/WAIKAMILO RD	5.01	64	91	3

## 5.2 Hydrologist's Significant Observations and Comments

This is a large reservoir that produces a large flood. In a number of locations the flood runs through a narrow canyon; in these canyons the flood is very deep and exceedingly swift. About halfway to the ocean the flood overtops a divide, causing part of the flood to

flow north across the Pali freeway and down another drainage. After the flood passes H1, it encounters the coastal plain, and it spreads out, becoming more than .62 miles wide.

## **6 Potential Scenario Consequences for HI00001 - Nuuanu Dam No. 4**

**Dam Location:** 21.36N 157.81W

**Dam Owner:** Honolulu Board of Water Supply

The following table summarizes the estimated population and infrastructure potentially at risk as a result of the modeled dam break scenario, which assumes dam failure at maximum capacity.

Potential Scenario Consequences**	Value
1. Total inundation area (acres)	1,155
2. Total Population at risk	12,947
3. Number of affected Properties:	
a. Total Parcels affected	2,077
b. Total Land Value	\$9,641,602,200
c. Total Building Value	\$2,323,602,400
4. Number of Critical Facilities affected:	
a. Total number affected	8
b. School total	3
c. Hospital total	2
d. Fire Station total	3
e. Police total	0
f. Government total	0
g. Airports and Seaports total	0
5. Emergency Operation Centers affected (total number):	0
6. Shelters affected (total number):	4
7. Infrastructure Affected:	
a. Number of Bridges	34
b. Length of Roads (miles)	25

\*\*Refer to Final Report for methodology used to derive values.

## **7 References**

DLNR Dams Spreadsheet, 14 March 2006.

## **8 Attachments**

Attachment 1: Location Index Map

Attachment 2: Model Results - Inundation Map

## **9 Project Deliverables**

This Individual Assessment Report is part of a Final Report, to be delivered to DLNR in April 2007, which will include:

- 1) Scientific methods for modeling
- 2) Methods for consequence assessment
- 3) Methods for risk evaluation

### **Disclaimer**

The intended audience for these Individual Assessment Reports is the State of Hawaii Department of Land and Natural Resources for which the reports were prepared under contract. The dam break scenarios depicted in the reports utilize the Danish Hydrological Institute's MIKE 21model. Model results, and products contained in these reports have been reviewed and approved by a consulting hydrologist. Best available data have been utilized in the reports and as input to the model, however, due to variations in data currency and accuracy, final products should be interpreted as "best available estimates" only.

The Pacific Disaster Center (PDC) does not assume any legal liability or responsibility for the information, apparatus, product, or process disclosed in this report or represent that its use would not infringe on privately owned rights. Reference therein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation. No warranty, expressed or implied, is made by the PDC as to the accuracy of the data or the functioning of the software beyond what is expressed by the original vendor(s). The act of distribution shall not constitute any such warranty, and no responsibility is assumed by the PDC in the use of these data, software, or related materials.

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# VI. Facility Information

## a. 2-page Facility Data Sheet

NUUANU DAM NO. 4		OA-0001	Oahu
1. General Information		2. Owner Information	
a. State Dam ID	OA-0001	a. Name of Owner	Honolulu Board of Water Supply
b. National ID	HI00001	b. TMK(s)	(1) 2-2-054.001
c. Dam Name	NUUANU DAM NO. 4	3. Hazard Potential Classification	
d. Other Name(s)	NUUANU RESERVOIR	a. Hazard Classification	High
e. Longitude / Latitude	-157.8078 / 21.3526	b. Emergency Action Plan	06/01/2009
f. County / Island	Honolulu / Oahu		
g. Type of Dam	Earthen		
h. Purpose	Flood Control, Recreation		
i. Completed / Last Modified	1910 /		
j. Nearest City / Town	HONOLULU (1 mile)		
k. Water Body Type	State Regulated Dam		
l. Dam Height	66 ft		
m. Dam Length	2,120 ft		
n. Drainage Area	1.40 sq. miles / 896 acres		
o. Size Classification	Intermediate		

## NUUANU DAM NO. 4

OA-0001

Oahu



Aerial Photo (04/06/2007)

## 4. Reservoir

a. Normal Storage	242 ac-ft / 79 MG
b. Maximum Storage	3,600 ac-ft / 1,173 MG
c. Surface Area	25.0 acres

## 5. Primary Spillway

a. Minimum Width	55 ft
b. Length	450 ft
c. Type	Channel
d. Protection	Concrete
e. Maximum Discharge	4,000 cfs

## 6. Primary Outlet Works

a. Works Type	Upstream Control in Tower
b. Maximum Discharge	
c. Size	24 in
d. Control Description	Upstream

## 7. Embankment

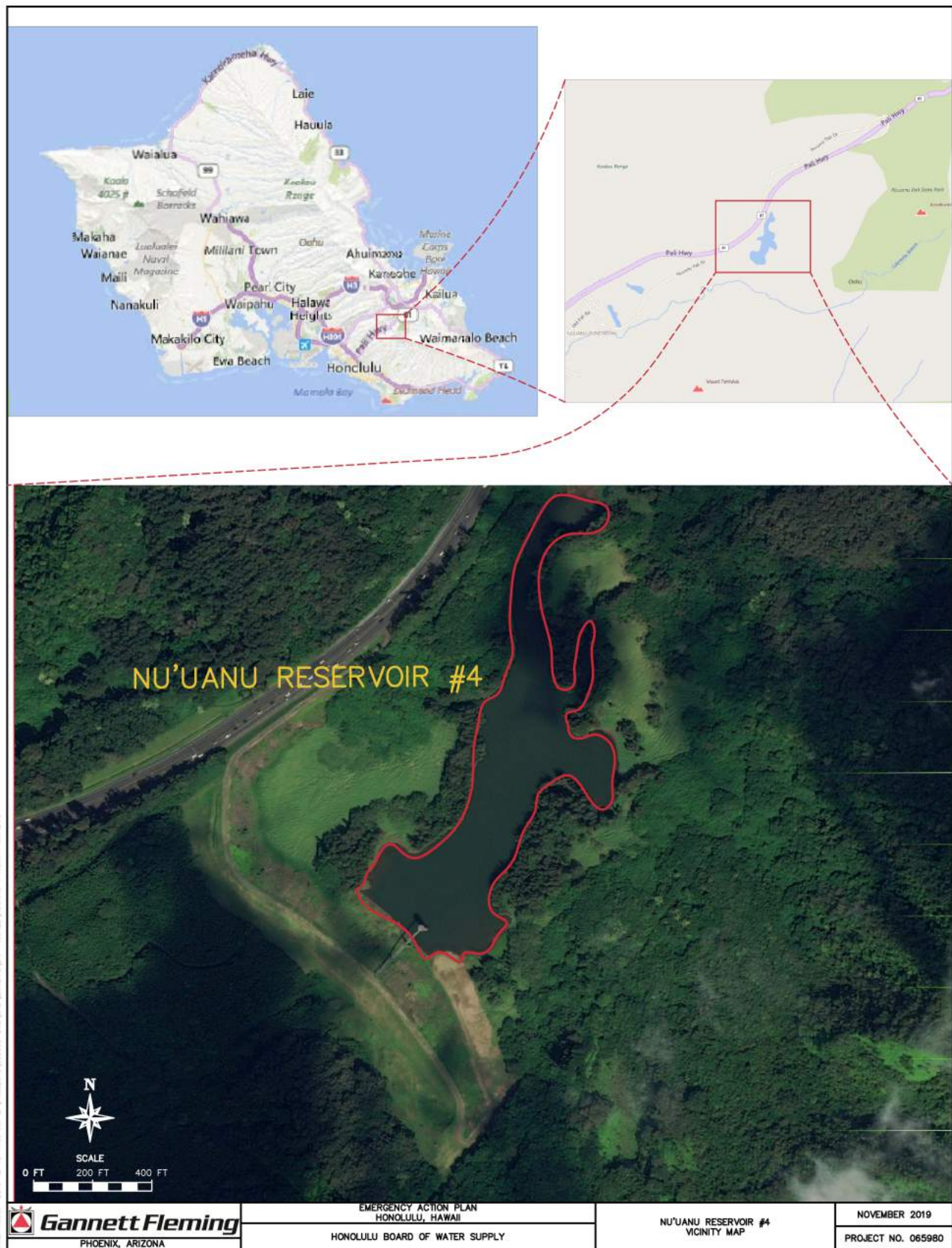
a. Type of Dam	Earthen
b. Minimum Crest Width	25 ft
c. Upstream Slope Grade	14' / 4:1
d. Upstream Slope Protection	Ungrouted Riprap
e. Downstream Slope Grade	45' / 1:1
f. Downstream Slope Protection	Bare Soil
g. Dam Height	66 ft
h. Dam Length	2,120 ft

## 8. Inflow Works

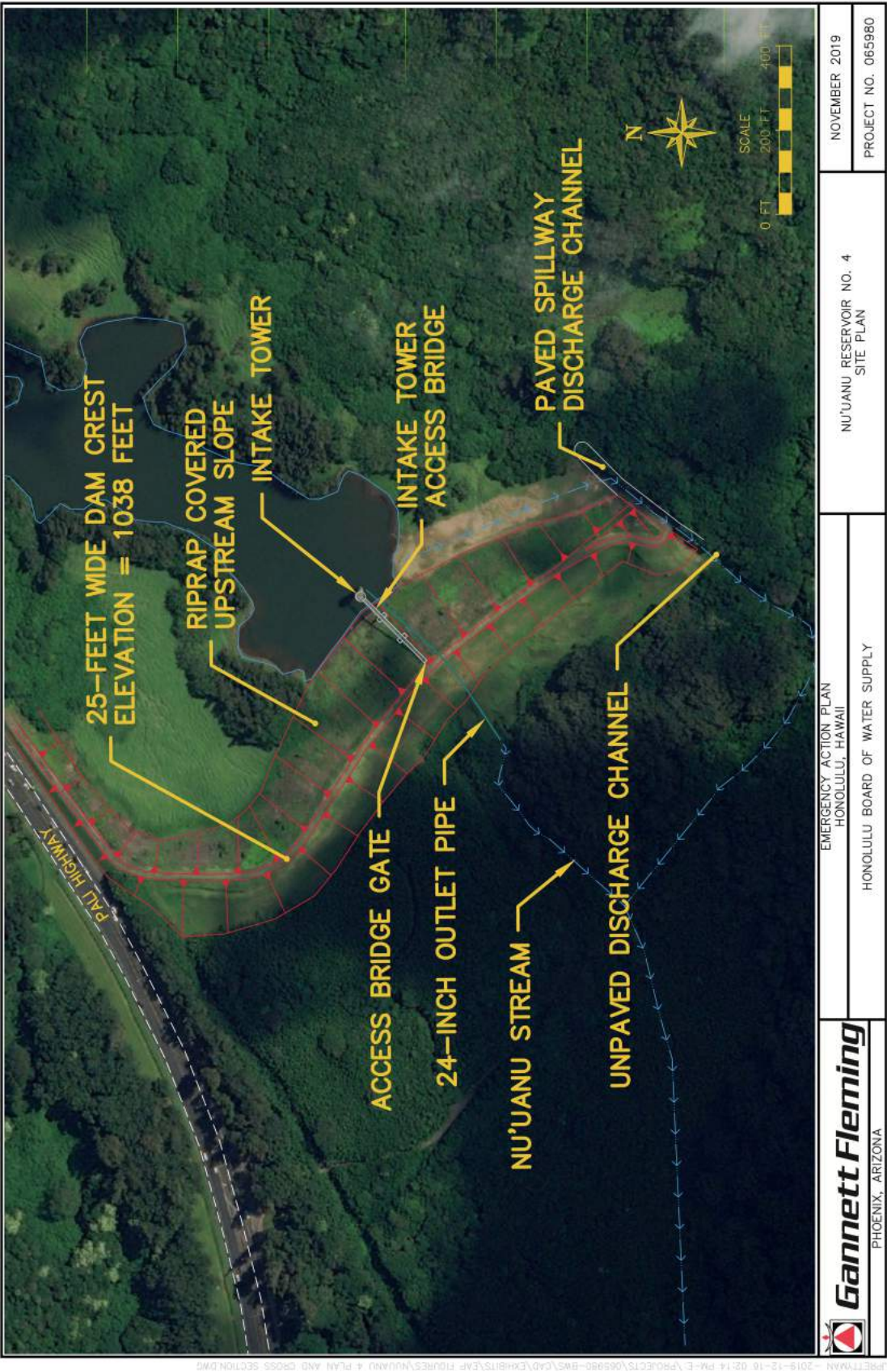
Type	Name	Controlled	Size
------	------	------------	------

None Specified.

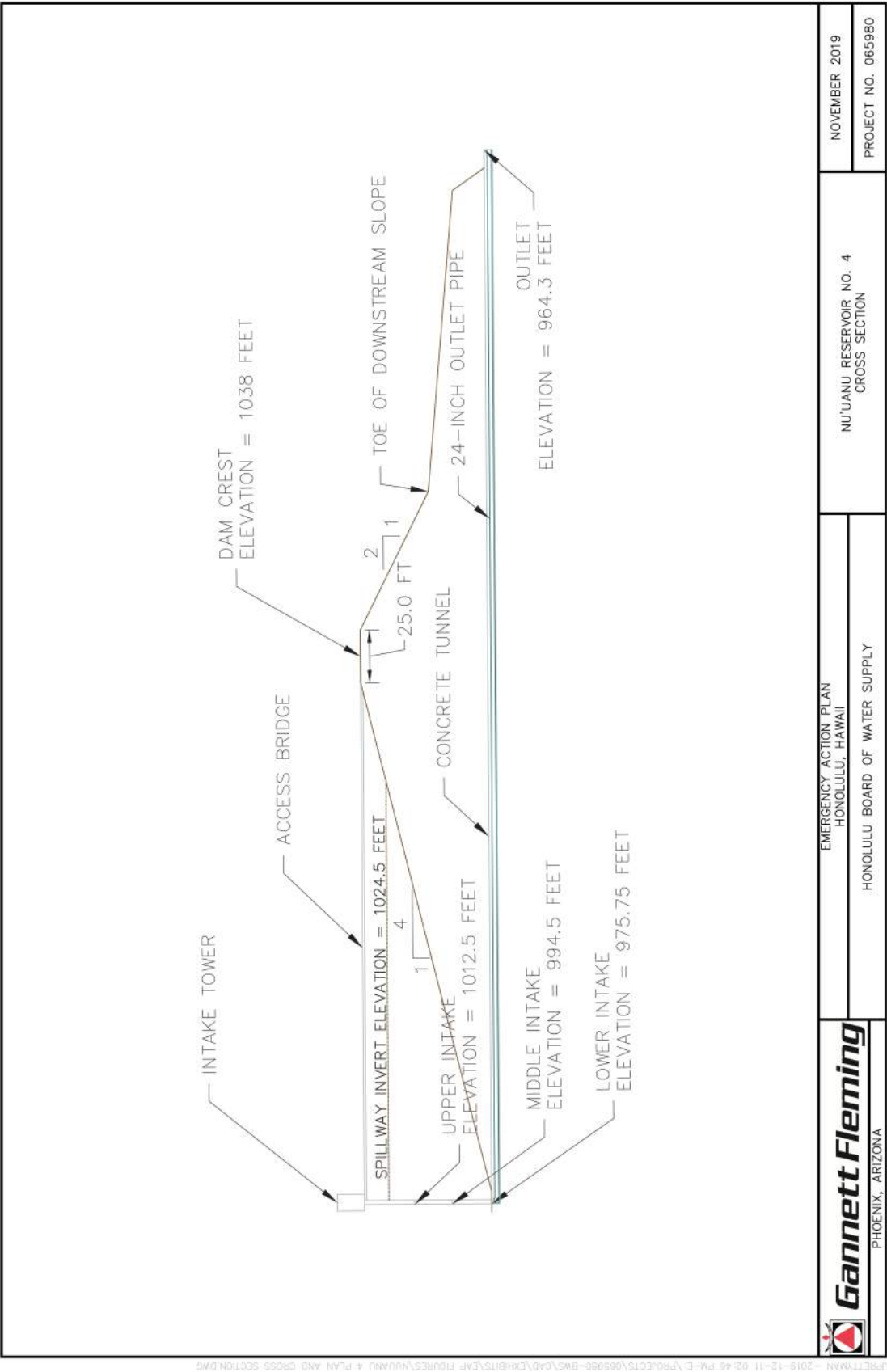
## b. Vicinity Map



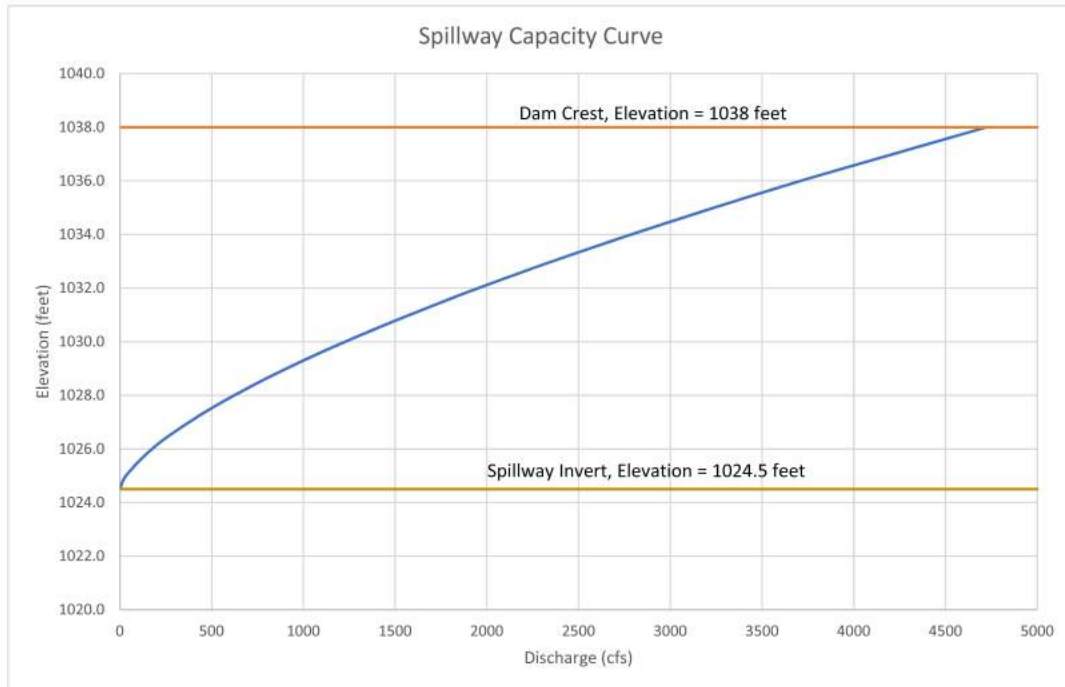
c. Site Plan or Drawing



d Cross Section or Drawing



e. Spillway Capacity Curve



Elevation (feet)	Discharge (cfs)	
1024.5	0.00	
1025.0	33.65	
1026.0	174.84	
1027.0	376.19	
1028.0	623.16	
1029.0	908.49	
1030.0	1227.56	
1031.0	1577.14	
1032.0	1954.75	
1033.0	2358.46	
1034.0	2786.67	
1035.0	3238.05	
1036.0	3711.48	Values calculated from Ernest K Hirata & Associates, Inc. 1999. <i>Phase II Dam Safety Investigation Nuuanu Reservoir No. 4</i> . Prepared for Honolulu Board of Water Supply
1038	4720.64	

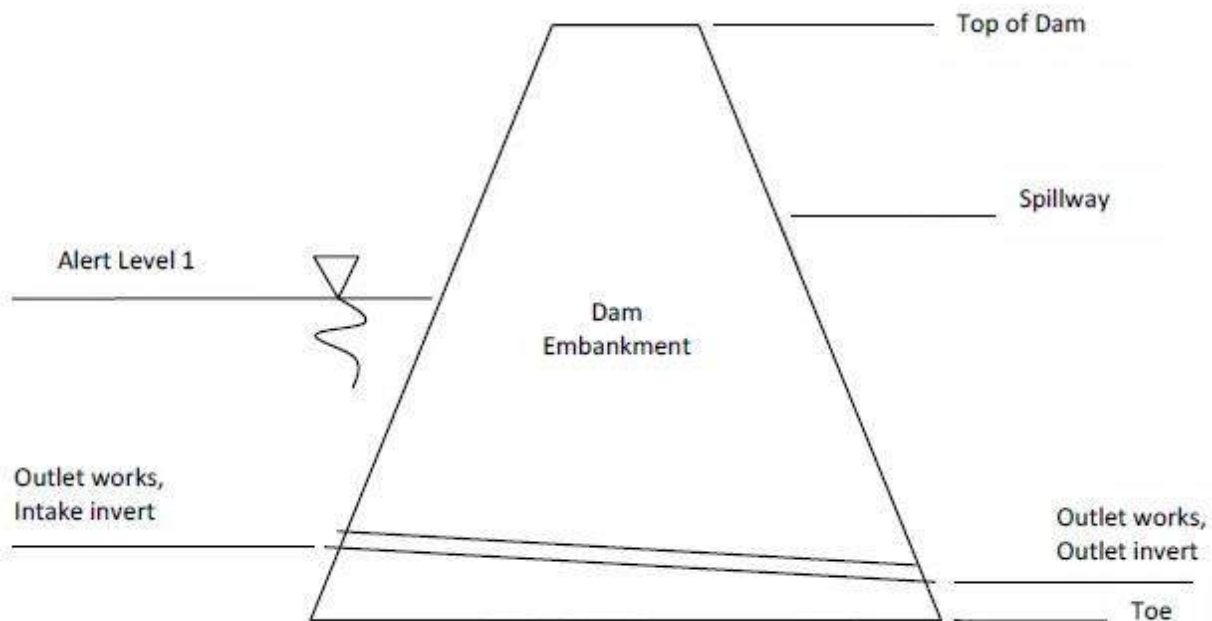
f. Outlet Capacity Curve

**NOT AVAILABLE**

g. Reservoir Drainage Chart

**NOT AVAILABLE**

h. Key Elevations



	<b>Fill in Elevations for:</b>	<b>Elevation</b>	<b>Staff Gage</b>
1	Top of Dam	1038	70
2	Spillway	1024.5	56.5
3	Normal Operating Level	993.5	25.5
4	Outlet Works, Upper Intake invert	1012.5	44.5
5	Outlet Works, Middle Intake invert	994.5	26.5
6	Outlet Works, Lower Intake invert	975.75	7.75
7	Outlet works, Outlet invert	964.3	-
8	Toe	972	4
9	PMF level	1035.1	67.1
10	EAP Alert Level 3 (See Section VIII)	1038	70
11	EAP Alert Level 2 (See Section VIII)	1024.5-1038	56.5-70
12	EAP Alert Level 1	1022.5	54.5

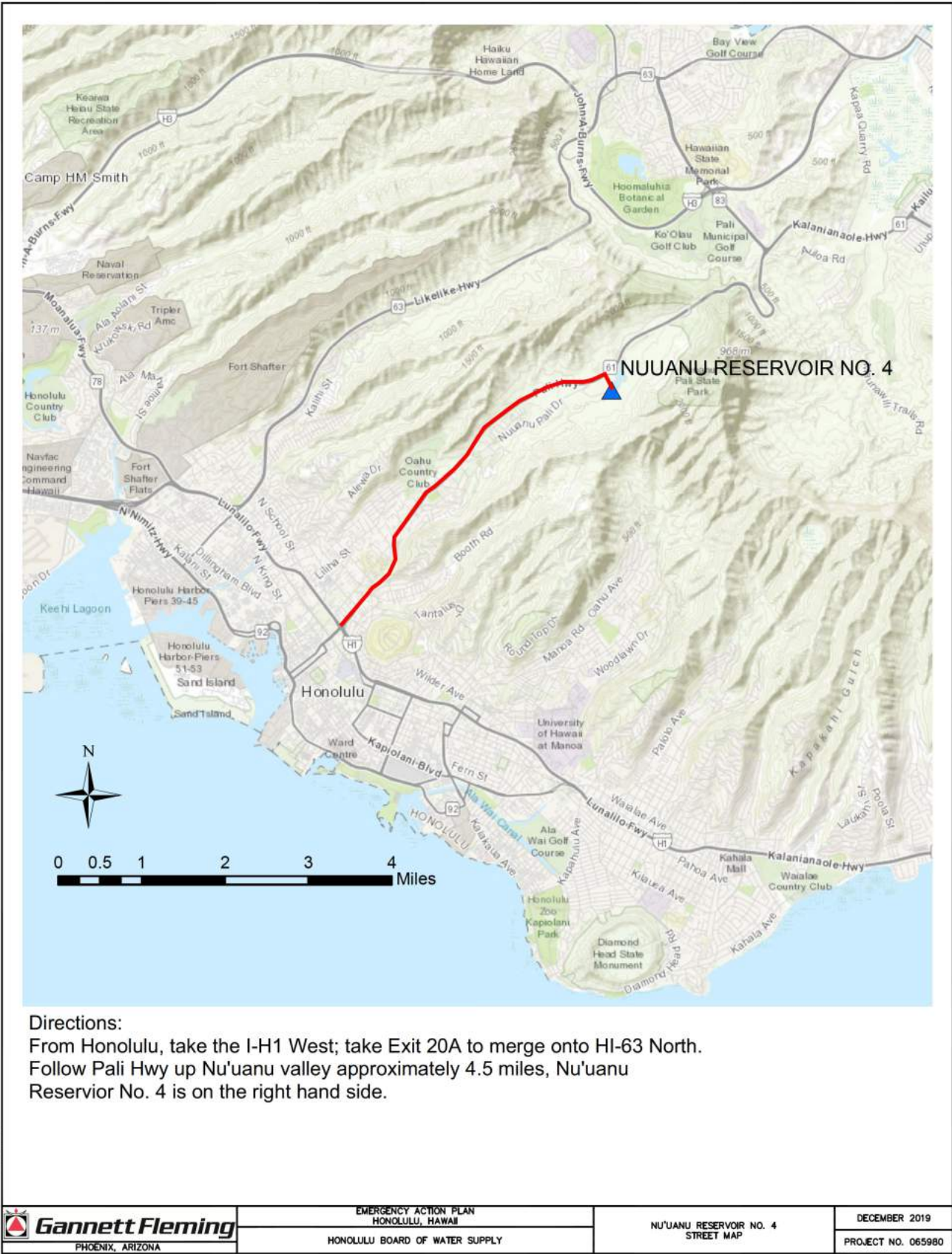
i. Other Dam Info/Operation

**VII. Directions to Site**

a. Directions to Dam Facility Site

Take Interstate H-1 Highway westbound. Exit H-1 at Exit 20A and turn left at traffic light onto H1-61 (Pali Highway). Proceed north on Pali Highway for 4.5 miles. The reservoir site will be on the right. Entry to the reservoir site is through a locked chain-link gate. To obtain the combination to the lock on the entry gate, call the Board of Water Supply (BWS) Security Center at (808) 748-5951. Entry to the suspension bridge and intake tower is also through several locked gates. To obtain the combination to the locks on the bridge and intake tower gates and door, call the BWS Security Center at (808) 748-5951. Authorization to access the reservoir site, suspension bridge and intake tower is required from the BWS Land Administrator prior to entry. The BWS Land Administrator can be reached at (808) 748-5951.

b. Street Map





## **VIII. Emergency Detection**

### **Guidance for Determining the Event Level at NUUANU DAM NO. 4**

**Note: This is a site-specific guide developed for use at the named facility only!**

Level 1: Non-Emergency, Unusual Event, Slowly Developing

Level 2: Emergency, Potential Dam Failure Situation

Level 3: Urgent Emergency; Imminent or In-progress Dam Failure

Event	Situation	Event Level		
Damage to Intake Tower / Outlet Works	Uncontrollable, erratic, or rapidly increasing leakage from concrete tunnel or 24" outlet pipe with transport of sediment			3
Damage to Intake Tower / Outlet Works	Observation of leakage from concrete tunnel or 24" outlet pipe with cloudy discharge possibly transporting sediment		2	
Damage to Intake Tower / Outlet Works	New cracks, joint separation, or visible movement observed at the outlet works tower, concrete tunnel or 24" outlet pipe with clear leakage	1		
Earthquake	Earthquake resulting in uncontrolled release of water from the dam			3
Earthquake	Earthquake resulting in visible damage to the dam or appurtenances that could result in an uncontrolled release of water from the dam		2	
Earthquake	An earthquake has been felt or is reported to have occurred in the area with Richter Magnitude (M) of 4.0M or greater within a 30-mile distance of the epicenter, 5.0M or greater within 60 miles, or 6.0M or greater within a 120 mile radius of the site. Look up magnitude here: <a href="https://earthquake.usgs.gov/earthquakes/map/">https://earthquake.usgs.gov/earthquakes/map/</a>	1		
Embankment Cracking / Movement	Sudden or rapidly proceeding slides of the embankment slopes resulting in an uncontrolled release of water			3
Embankment Cracking / Movement	Sudden or rapidly proceeding slides of the embankment slopes that do not result in an uncontrolled release of water but could if movement continues		2	
Embankment Cracking / Movement	New cracks in the embankment with seepage flowing through the crack (see section on “Seepage”)		2	
Embankment Cracking / Movement	Visible evidence of movement/slippage of the embankment slope	1		
Embankment Cracking / Movement	New cracks in the embankment greater than 1-inch wide without seepage	1		
Sabotage / Vandalism / Security Threat	Sabotage/damage to dam or appurtenances that has resulted in uncontrolled water release			3
Sabotage / Vandalism / Security Threat	Sabotage/damage to dam or appurtenances that may result in uncontrolled water release		2	
Sabotage / Vandalism / Security Threat	Modification to the dam or appurtenances that could adversely impact the functioning of the dam	1		
Seepage / Low Water Level	Uncontrollable, erratic, or rapidly increasing flow from seepage area with transport of sediment			3
Seepage / Low Water Level	Reservoir water level is falling without apparent cause		2	
Seepage / Low Water Level	Observation of boils or seepage areas with cloudy discharge possibly transporting sediment		2	

**CONFIDENTIAL – For Official Use Only**

Event	Situation	Event Level		
Sinkholes or Whirlpools	Rapidly enlarging sinkhole on dam or abutments to extent that failure appears imminent			3
Sinkholes or Whirlpools	Whirlpool or other evidence indicating that reservoir is draining rapidly through dam or foundation			3
Sinkholes or Whirlpools	Observation of new sinkhole in reservoir area or on embankment		2	
Spillway Flow / Overtopping	Water from the reservoir is flowing over the top (crest) of the dam (Elevation 1038 ft)			3
Spillway Flow / Overtopping	Spillway is flowing with an advancing headcut (erosion) that is threatening the control section			3
Spillway Flow / Overtopping	Spillway is flowing with high rate of rise of reservoir water surface elevation (concern that spillway may be inadequate for incoming flood flows)		2	
Spillway Flow / Overtopping	Spillway is flowing with active gully erosion		2	
Spillway Flow / Overtopping	Spillway flow could result in flooding of downstream roadways and/or inhabited structures if reservoir level continues to rise		2	
Spillway Flow / Overtopping	Reservoir water surface elevation two feet below spillway crest and rising (flow through spillway is anticipated).	1		

**IX. Local Resources**

**Local Resources Available at NUUANU DAM NO. 4**

**Note: This is a site-specific list developed for use at the named facility only!**

**The following owner/operator resources are available in the event of an emergency:**

<b>Quantity</b>	<b>Equipment/Resources</b>	<b>Contact Name/Telephone No.(s)</b>
1	Sump Pump 8 Inch 3240 GPM	Board of Water Supply (BWS)
2	Sump Pump 4 Inch 1200 GPM	BWS
2	Sump Pump 6 Inch 1400 GPM	BWS

**Other locally available resources include:**

<b>Resources</b>	<b>Suppliers</b>	<b>Telephone No.(s)</b>
Heavy Equipment Service and Rental	C&R Enterprise Inc.	(808) 239-9248
Sand and Gravel Supply	Ameron Hawaii Kapaa Quarry	(808) 266-2660
Ready-Mix Concrete Supply	West Hawaii Concrete Administration	(808) 329-3561
Sand Bags	Honolulu Bag Supply	(808) 841-8333
Pumps	Engineered Systems Inc.	(808) 263-2232
Driving Contractor	Advanced Towing and Recovery	(808) 456-8697
Lighting	Board of Water Supply, FO Division	(808) 748-5000
Generator	Board of Water Supply, FO Division	(808) 748-5000
Piping	Board of Water Supply, FO Division	(808) 748-5000

**X.     Contacts**

**Contact Names and Numbers for NUUANU DAM NO. 4**

<b>Role &amp; Responsibility</b>	<b>Primary Contact</b>	<b>Office Phone No.</b>	<b>Alternate Phone No.</b>	<b>Agency or Organization</b>	<b>Address</b>
<b>Dam Owner’s Representatives:</b>					
Primary EAP Contact	Michael Matsuo, Land Administrator	(808) 748-5951	(808) 291-7327	Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
Secondary EAP Contact	Raelynn Nakabayashi, Dept. Emergency Coordinator (BWS)	(808) 748-5177	(808) 347-5386	Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
Dam Owner	Ernest Y.W. Lau, P.E., Manager and Chief Engineer	(808) 748-5061		Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
Dam Owner	Ellen Kitamura, Deputy Manager and Chief Engineer	(808) 748-5066		Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
Dam Lessee					
Dam Operator	Kevin Ihu, Program Administrator, Water Systems Operations Division	(808) 748-5800	(808) 225-8446	Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
Dam Technical Representative	Nancy Matsumoto, Chief Hydro-Geologist (BWS)	(808) 748-5938		Board of Water Supply	630 South Beretania Street Honolulu, HI 96843
<b>State Dam Safety Program:</b>					
State Dam Safety Program	Edwin Matsuda	(808) 587-0268	(808) 729-7177	State DLNR	1151 Punchbowl St. Room 221 Honolulu, HI 96813
State Dam Safety Program	Denise Manuel	(808) 587-0246	(808) 551-1413	State DLNR	1151 Punchbowl St. Room 221 Honolulu, HI 96813
State Dam Safety Program	Jesse Colandrea	(808) 587-0277	(808) 729-7175	State of Hawaii DLNR	1151 Punchbowl Street, rm 221 Honolulu, HI 96813
<b>Honolulu Department of Emergency Management– City &amp; County of Honolulu:</b>					
Honolulu Department of Emergency Management	Hiro Toiya	(808) 723-8952	(808) 343-5745	Honolulu Department of Emergency Management	650 South King Street Honolulu, HI 96813
Honolulu Department of Emergency Management	Jennifer Walter	(808) 723-8960	(808) 753-4939	Honolulu Department of Emergency Management	650 South King Street Honolulu, HI 96813
<b>Hawaii Emergency Management Agency (Hawaii State Civil Defense):</b>					
Hawaii Emergency Management Agency	Luke P. Meyers	(808) 733-4300		Hawaii Emergency Management Agency	3949 Diamond Head Road Honolulu, HI 96816
<b>County Emergency Responders:</b>					
Police Department	Dispatch	911		Honolulu Police Department	801 South Beretania Street Honolulu, HI 96813
Police Department	Susan Ballard, Chief of Police	(808) 723-8782		Honolulu Police Department	801 South Beretania Street Honolulu, HI 96813
Fire Department	Manuel P. Neves, Fire Chief	(808) 723-7101		Honolulu Fire Department	636 South Street Honolulu, HI 96813

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Other	James D. Howe, Jr., Director	(808) 723-7800		Department of Emergency Services, City and County of Honolulu	3375 Koapaka Street, Suite H450 Honolulu, HI 96819
Other	James D. Howe, Jr., Director	(808) 723-7800		Department of Emergency Services, City and County of Honolulu	3375 Koapaka Street, Suite H450 Honolulu, HI 96819

**XI. EAP Holders**

**Official EAP Holders**

<b>Copy #</b>	<b>Organization</b>	<b>Person receiving copy</b>	<b>Concurrence Form Received</b>
1 Primary EAP Contact	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Michael Matsuo, Land Administrator	
2 Secondary EAP Contact	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Raelynn Nakabayashi, Dept. Emergency Coordinator (BWS)	
3 Dam Owner	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Ernest Y.W. Lau, P.E., Manager and Chief Engineer	
4 Dam Operator	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Kevin Ihu, Program Administrator, Water Systems Operations Division	
5 Dam Technical Representative	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Nancy Matsumoto, Chief Hydro-Geologist (BWS)	
6 Dam Owner	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843	Ellen Kitamura, Deputy Manager and Chief Engineer	
7 Police Department	Honolulu Police Department 801 South Beretania Street Honolulu, HI 96813	Dispatch	
8 Fire Department	Honolulu Fire Department 636 South Street Honolulu, HI 96813	Manuel P. Neves, Fire Chief	
9 Police Department	Honolulu Police Department 801 South Beretania Street Honolulu, HI 96813	Susan Ballard, Chief of Police	
10 State Dam Safety Program	State DLNR 1151 Punchbowl St. Room 221 Honolulu, HI 96813	Edwin Matsuda	

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11 Honolulu Department of Emergency Management	Honolulu Department of Emergency Management 650 South King Street Honolulu, HI 96813	Hiro Toiya	
12 Hawaii Emergency Management Agency	Hawaii Emergency Management Agency 3949 Diamond Head Road Honolulu, HI 96816	Luke P. Meyers	

**XII. Appendix A – Testing and Updating**

a. Testing

<b>Test Date</b>	<b>Test Type</b>	<b>Comments</b>

b. Updating

<b>Revision #</b>	<b>Date Published</b>	<b>Comments</b>
1	10/31/2019	

## **1. Training of Dam Owner’s Representative(s)**

The people involved in the implementation of the EAP should receive training to ensure that they are thoroughly familiar with all elements of the plan, the available equipment, and their responsibilities and duties under the plan.

Technically qualified personnel should be trained in the incident management process, including detection, evaluation, notification, and appropriate response actions during all emergency level determinations. A sufficient number of people should be trained to ensure adequate coverage at all times.

## **2. Testing the EAP**

Dam owners should exercise the Emergency Action Plan (EAP) in coordination with State, local and tribal emergency management authorities. Exercises promote prevention, preparedness, and response to incidents and emergencies and may also be extended to include recovery operations. Exercising also demonstrates the EAP’s effectiveness in an actual situation and demonstrates the readiness levels of key personnel. Periodic exercises result in an improved EAP as lessons learned are incorporated into the updated EAP document.

Dam owners should include State, local and tribal emergency authorities in exercise activities. This includes, but is not limited to, entities listed on the Notification Flowchart. To facilitate the participation of emergency management authorities, dam safety exercises also can be coordinated with, or integrated into, other event exercise scenarios for earthquakes, floods, hurricanes, and other hazards.

<b>Exercise Type</b>	<b>Brief Description</b>	<b>Frequency</b>
Seminar	Review EAP with staff and local emergency responders	Annual
Drill	Review EAP with principle staff and O&M personnel <ul style="list-style-type: none"><li>• Review of Contact List &amp; Phone Numbers</li><li>• Review of Critical deficiencies and notify plan holders if Level 1 exists</li><li>• Review EAP Guidance for Determination levels</li></ul>	Annual
Table Top	Drill several different scenarios, in a classroom type setting All plan holders should participate	Every 3-4 years
Functional		As required
Other	Review Hazard Assessment Classification Downstream Public Awareness Campaign	Every 5 years As required

### **Summary of Exercises**

There are various types of exercises to test the plans, discussion-based exercises and operations-based exercises. Discussion-based exercises familiarize participants with current plans, policies, agreements, and procedures, or may be used to develop new plans, policies, agreements, and procedures. Operations-based exercises validate plans, policies, agreements and procedures; clarify roles and responsibilities; and identify resource gaps in an operational

environment. The seminar, drill, tabletop exercise, and functional exercise should receive the most emphasis in an EAP exercise program.

- **Seminar.** A seminar is an informal discussion designed to orient participants to new or updated plans, policies, or procedures (e.g., a seminar to review a new Evacuation Standard Operating Procedure). Seminars should include internal discussions as well as coordination with emergency management authorities and other organizations with a role in EAP implementation.
- **Drill.** A drill is a coordinated, supervised activity usually employed to test a single operation or function within a single entity, such as testing sirens and warning systems, calling suppliers, checking material on hand, and conducting a call-down drill of those listed on the Notification Flowchart.
- **Tabletop Exercise.** A tabletop exercise involves key personnel discussing simulated scenarios in an informal setting. Tabletop exercises can be used to assess plans, policies, and procedures.
- **Functional Exercise.** A functional exercise examines and/or validates the coordination, command, and control between various multi-agency coordination centers, such as Emergency Operation Centers (EOCs) and Joint Field Offices. A functional exercise does not involve any “boots on the ground” such as first responders or emergency officials responding to an incident in real time.

Functional exercises are a comprehensive exercise that provides the necessary verification, training, and practice to improve the EAP and the operational readiness and coordination efforts of all parties responsible for responding to emergencies at a dam.

### **Evaluation of Exercises**

Emergency exercises and equipment tests should be evaluated orally and in writing. Any outdated telephone numbers on the Notification Flowchart, inundation maps with inaccurate information, and problems with procedures, priorities, assigned responsibilities, materials and equipment, and staff levels shall be corrected, the plan be updated and disseminated.

## EAP Emergency Incident Log

[illegible]

## EAP Inspection Checklist

<b>EAP Inspection Checklist</b>		<b>PAGE 1 of 2</b>
<b>Dam Name:</b>		<b>Inspected By:</b>
		<b>Date:</b>
<b>Weather Condition:</b>	<b>Event Triggering Inspection:</b>	
<b>Reservoir Water Level:</b>		
<b>Inspection Item:</b>	<b>Deficiencies/Comments:</b>	
<b>NOTE ANY PRE-EXISTING CONDITIONS (AGE, LOCATION) AND CHANGES OBSERVED:</b>		
<b>SPILLWAY:</b>		
	<b>General Condition</b>	
	<b>Cracks?</b>	
	<b>Leaning?</b>	
	<b>Seepage?</b>	
	<b>Overtopping?</b>	
	<b>Erosion?</b>	
	<b>Other Comments?</b>	
<b>GATES/STOPLOG BAYS:</b>		
	<b>General Condition</b>	
	<b>Cracks?</b>	
<b>EMBANKMENT CREST:</b>		
	<b>Visual Settlement?</b>	
	<b>Misalignment?</b>	
	<b>Cracking?</b>	
<b>EMBANKMENT UPSTREAM SLOPE:</b>		
	<b>Erosion? Condition of Ground Cover?</b>	
	<b>Settlement, depressions, bulges?</b>	
	<b>Longitudinal/Vertical Cracks?</b>	

<b>EAP Inspection Checklist</b>		<b>PAGE 2 of 2</b>
<b>Dam Name:</b>		<b>Inspected By:</b>
		<b>Date:</b>
<b>EMBANKMENT DOWNSTREAM SLOPE:</b>		
	<b>Erosion? Condition of Ground Cover?</b>	
	<b>Settlement, depressions, bulges?</b>	
	<b>Longitudinal/Vertical Cracks?</b>	
	<b>Soft spots or boggy areas?</b>	
	<b>Movement at or beyond toe?</b>	
	<b>Boils at toe?</b>	
<b>SEEPAGE:</b>		
	<b>Location</b>	
	<b>Does seepage contain fine soil particles?</b>	
	<b>Approximate flow rate (garden hose, full blast = approx. 5 gal/min)</b>	
<b>RESERVOIR:</b>		
	<b>Observed vortex?</b>	
	<b>Sinkhole?</b>	
<b>ABUTMENT CONTACTS:</b>		
	<b>General Condition</b>	
	<b>Cracks?</b>	
	<b>Leaning?</b>	
<b>OTHER OBSERVATIONS OR COMMENTS:</b>		

## EAP Emergency Termination Log

<b>Dam Name/State ID:</b>		<b>County:</b>
<b>Dam Location:</b>		<b>Stream/River:</b>
<b>Date/Time:</b>		
<b>Weather Conditions:</b>		
<b>General Description of Emergency Situation:</b>		
<b>Area(s) of Dam Affected:</b>		
<b>Extent of Damage to Dam and Possible Causes:</b>		
<b>Effect on Dam Operation:</b>		
<b>Initial Reservoir Elevation/Time:</b>		
<b>Maximum Reservoir Elevation/Time:</b>		
<b>Final Reservoir Elevation/Time:</b>		
<b>Description of Area Flooded Downstream / Damage / Loss of Life:</b>		
<b>Justification for Termination of Dam Safety Emergency:</b>		
<b>Other Data and Comments:</b>		
<b>Report Prepared by: (Printed Name and Signature)</b>		
<b>Date:</b>		

## EAP Concurrence Form

### EAP CONCURRENCE FORM

I have received the latest copy of the Emergency Action Plan (EAP) for the State Regulated Dam listed below, and concur with the tasks and responsibilities assigned herein for this agency in the event of an emergency and during testing of the EAP.

Dam Name: \_\_\_\_\_

State Dam ID: \_\_\_\_\_

EAP Revision Date: \_\_\_\_\_

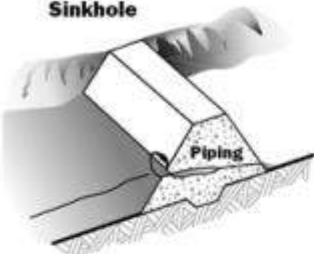
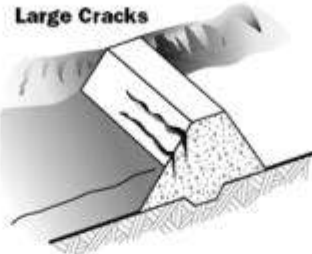

Signed: \_\_\_\_\_ Date: \_\_\_\_\_

Representing \_\_\_\_\_  
(Title, Agency Name)

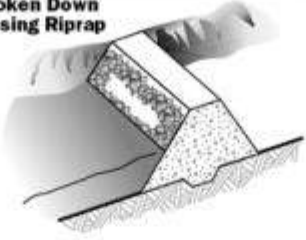
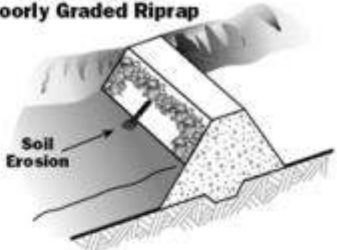
Please return completed form to the owner at their address.

#### XIV. Appendix C – Mitigative and Preparedness Actions

##### 1. Inspection Guidelines & Remedial Actions


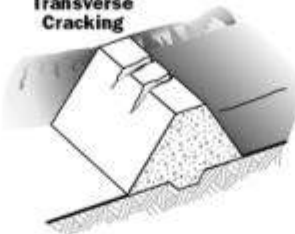

Inspection Guidelines – Upstream Slope		
Problem	Probable Cause and Possible Consequences	Recommended Actions
 <p><b>Sinkhole</b></p>	 <p><b>Large Cracks</b></p>	 <p><b>Slide, Slump, or Slip</b></p>
Sinkhole	Piping or internal erosion of embankment materials or foundation causes a sinkhole. The cave-in of an eroded cavern can result in a sinkhole. A small hole in the wall of an outlet pipe can develop into a sinkhole. Dirty water at the exit indicates erosion of the dam. Piping can empty a reservoir through a small hole in the wall or can lead to failure of a dam as soil pipes erode through the foundation or a pervious part of the dam. Dispersive soils are particularly susceptible to sinkholes.	Inspect other parts of the dam for seepage or more sinkholes. Check seepage and leakage outflows for dirty water. A qualified engineer should inspect the conditions, identify the exact cause of sinkholes, and recommend further actions. Depending on the location in the embankment, the reservoir may need to be drawn down.  DLNR NOTIFICATION REQUIRED
Large Cracks	A portion of the embankment has moved because of loss of strength, or the foundation may have moved, causing embankment movement. Indicates onset of massive slide or settlement caused by foundation failure.	Depending on embankment involved, draw reservoir level down. A qualified engineer should inspect the condition and recommend further actions.  DLNR NOTIFICATION REQUIRED
Slide, Slump, or Slip	Earth or rocks move down the slope along a slippage surface because of too steep aslope, or the foundation moves. Also, look for slide movements in reservoir basin. A series of slides can lead to obstruction of the inlet or failure of the dam.	Evaluate extent of the slide. Monitor slide. Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions.  DLNR NOTIFICATION REQUIRED

Inspection Guidelines - Upstream Slope


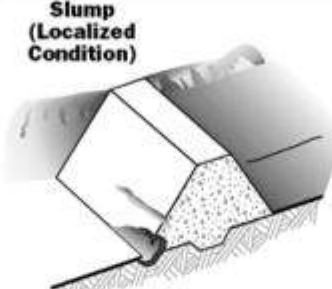
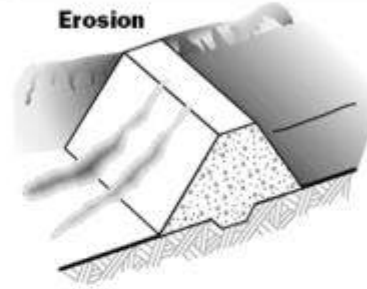
Problem	Probable Cause and Possible Consequences	Recommended Actions
	<p><b>Broken Down Missing Riprap</b></p> 	<p><b>Erosion Behind Poorly Graded Riprap</b></p> 
<b>Scarps, Benches Oversteep Areas</b>	Wave action or local settlement cause soil and rock to erode and slide to the lower part of the slope, forming a bench. Erosion lessens the width and possible height of the embankment and could lead to seepage or overtopping of the dam.	Determine exact cause of scarps. Do necessary earthwork, restore embankment to original slope, and supply adequate protection (bedding and riprap).
<b>Broken Down Missing Riprap</b>	Poor-quality riprap has deteriorated. Wave action has displaced riprap. Round and similar-sized rocks have rolled downhill. Wave action against these unprotected areas decreases embankment width.	Reestablish normal slope. Place bedding and competent riprap.
<b>Erosion Behind Poorly Graded Riprap</b>	Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil. Soil is eroded away from behind the riprap. This allows riprap to settle, offering less protection and decreased embankment width.	Reestablish effective slope protection. Place bedding material.  DLNR NOTIFICATION REQUIRED for design – for graduation and size for rock for bedding and riprap. A qualified engineer should inspect the conditions and recommend further actions.

Inspection Guidelines - Upstream Slope

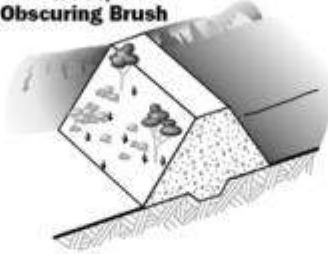

Inspection Guidelines – Downstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Slide/Slough</b> 	<b>Transverse Cracking</b> 	<b>Cave In/Collapse</b> 
<b>Slide or Slough</b>	<p>Lack loss of strength of embankment material. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation. Massive slide cuts through crest or upstream slope reducing freeboard and cross-section. Structural collapse or overtopping can result</p>	<ol style="list-style-type: none"> <li>1. Measure extent and displacement of slide. If continued movement is seen, begin lowering water level until movement stops.</li> <li>2. Have a qualified engineer inspect the condition and recommend further action.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Transverse Cracking</b>	<ol style="list-style-type: none"> <li>1. Uneven movement between adjacent segments of the embankment.</li> <li>2. Deformation caused by structural stressor instability.</li> </ol>	<ol style="list-style-type: none"> <li>1. Inspect crack and carefully record crack location, length, depth, width and other pertinent physical features. Stake out limits of cracking. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition.</li> <li>2. Excavate slope along crack to a point below the bottom of the crack. Then, backfill excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. This should be supervised by engineer. Continue to monitor crest routinely for evidence of future cracking.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

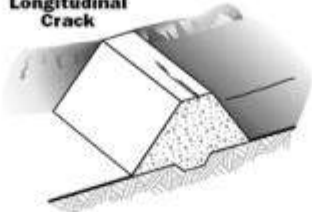
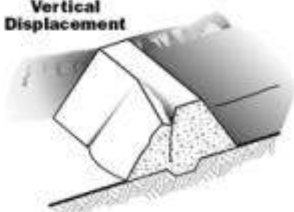
Inspection Guidelines - Downstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Cave-in or Collapse</b>	<ol style="list-style-type: none"> <li>1. Lack of adequate compaction.</li> <li>2. Piping through embankment or foundation.</li> <li>3. Presence of dispersive soils.</li> </ol> <p>Indicates possible washout of embankment.</p>	<ol style="list-style-type: none"> <li>1. Have a qualified engineer inspect the condition and recommend further action.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p><b>Longitudinal Cracking</b></p> </div> <div style="text-align: center;">  <p><b>Slump (Localized Condition)</b></p> </div> <div style="text-align: center;">  <p><b>Erosion</b></p> </div> </div>		
<b>Longitudinal Cracking</b>	<ol style="list-style-type: none"> <li>1. Drying and shrinkage of surface material.</li> <li>2. Downstream movement or settlement of embankment.</li> </ol> <ol style="list-style-type: none"> <li>1. Can be an early warning of a potential slide.</li> <li>2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment.</li> <li>3. Settlement or slide, showing loss of strength in embankment that can lead to failure.</li> </ol>	<ol style="list-style-type: none"> <li>1. If cracks are from drying, dress area with well-compacted material to keep surface water out and natural moisture in.</li> <li>2. If cracks are extensive, a qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Slump (localized condition)</b>	<p>Preceded by erosion undercutting a portion of the slope. Can also be found on steep slopes. Can expose impervious zone to erosion and lead to additional slumps.</p>	<ol style="list-style-type: none"> <li>1. Inspect area for seepage.</li> <li>2. Monitor for progressive failure.</li> <li>3. Have a qualified engineer inspect the condition and recommend further action.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Downstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Erosion</b>	Water from intense rainstorms or snowmelt carries surface material down the slope, resulting in continuous troughs. Can be hazardous if allowed to continue. Erosion can lead to eventual deterioration of the downstream slope and failure of the structure.	<ol style="list-style-type: none"> <li>1. The preferred method to protect eroded areas is rock or riprap.</li> <li>2. Reestablishing protective grasses can be adequate if the problem is detected early.</li> </ol>
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p><b>Trees/ Obscuring Brush</b></p>  </div> <div style="text-align: center;"> <p><b>Livestock/ Cattle Traffic</b></p>  </div> </div>		
<b>Trees, Obscuring Brush</b>	Natural vegetation in area. Large tree roots can create seepage paths. Large trees can blow over during storms and damage dam or cause breach. Bushes can obscure visual inspection.	<ol style="list-style-type: none"> <li>1. Remove all brush and trees less than 4" in diameter. Larger trees may be allowed to stay until they die. At that time, the tree, with its root system, should be removed and the void properly filled with compacted soil.</li> <li>2. Control vegetation on the embankment that obscures visual inspection.</li> </ol>
<b>Livestock (such as cattle) Traffic</b>	Excessive travel by livestock especially harmful to slope when wet.  Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.	<ol style="list-style-type: none"> <li>1. Fence livestock outside embankment area.</li> <li>2. Repair erosion protection, i.e. riprap, grass.</li> </ol>

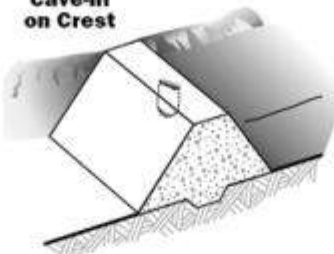
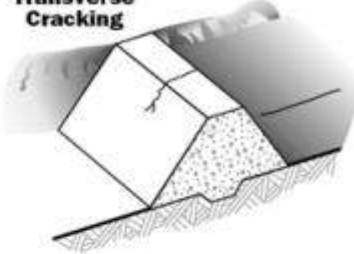
Inspection Guidelines - Downstream Slope

Inspection Guidelines – Crest		
Problem	Probable Cause and Possible Consequences	Recommended Actions
	<p><b>Longitudinal Crack</b></p> 	<p><b>Vertical Displacement</b></p> 
Longitudinal Crack	<ol style="list-style-type: none"> <li>1. Uneven settlement between adjacent sections or zones within the embankment.</li> <li>2. Foundation failure causing loss of support to embankment.</li> <li>3. Initial stages of embankment slide.</li> <li>1. Creates local area of low strength within an embankment. Could be the point of initiation of future structural movement, deformation or failure.</li> <li>2. Provides entrance point for surface runoff into embankment, allowing saturation of adjacent embankment area and possible lubrication which could lead to localized failure.</li> </ol>	<ol style="list-style-type: none"> <li>1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out limits of cracking. Monitor frequently.</li> <li>2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger to dam and correct condition.</li> <li>3. Effectively seal the cracks at the crest surface to prevent infiltration by surface water.</li> <li>4. Continue to routinely monitor crest for evidence of further cracking.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
Vertical Displacement	<div><div><div>1. Vertical movement between adjacent sections of the embankment.</div><div>2. Structural deformation or failure caused by structure stress or instability, or by failure of the foundation.</div></div><div><div>1. Creates local area of low strength within embankment which could cause future movement.</div><div>2. Leads to structural instability or failure.</div><div>3. Creates entrance point for surface water that could further lubricate failure plane.</div><div>4. Reduces available embankment cross-section.</div></div></div>	<div><div>1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length and other physical features. Immediately stake out limits of cracking.</div><div>2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition.</div><div>3. Excavate area to the bottom of the displacement. Backfill excavation using competent material and correct construction techniques, under supervision of engineer.</div><div>4. Continue to monitor areas routinely for evidence of cracking or movement.</div></div> <div>DLNR NOTIFICATION REQUIRED</div>

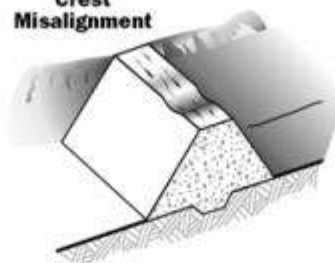
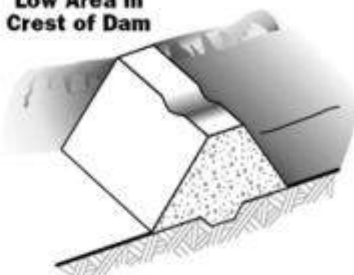
Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
		
Cave-in On Crest	<ol style="list-style-type: none"> <li>1. Hole in outlet conduit is causing erosion of embankment material.</li> <li>2. Internal erosion or piping of embankment material by seepage.</li> <li>3. Breakdown of dispersive clays within embankment by seepage waters.</li> <li>1. Void within dam could cause localized caving, sloughing, instability or reduced embankment cross-section.</li> <li>2. Entrance point for surface water.</li> </ol>	<ol style="list-style-type: none"> <li>1. Carefully inspect and record location and physical characteristics (depth, width, length) of cave-in.</li> <li>2. Engineer should determine cause of cave-in and supervise all steps necessary to reduce threat to dam and correct condition.</li> <li>3. Excavate cave-in, slope sides of excavation and backfill hole with competent material using proper construction techniques. This should be supervised by engineer.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
Transverse Cracking	<ol style="list-style-type: none"> <li>1. Uneven movement between adjacent segments of the embankment.</li> <li>2. Deformation caused by structural stressor instability.</li> <li>1. Can provide a path for seepage through the embankment cross-section.</li> <li>2. Provides local area of low strength within embankment. Future structural movement, deformation or failure could begin.</li> <li>3. Provides entrance point for surface runoff to enter embankment.</li> </ol>	<ol style="list-style-type: none"> <li>1. Inspect crack and carefully record crack location, length, depth, width and other pertinent physical features. Stake out limits of cracking.</li> <li>2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition.</li> <li>3. Excavate crest along crack to a point below the bottom of the crack. Then backfilling excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. This should be supervised by engineer.</li> <li>4. Continue to monitor crest routinely for evidence of future cracking.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

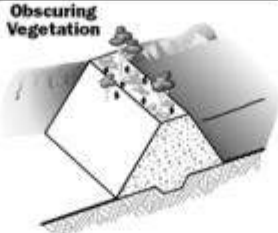
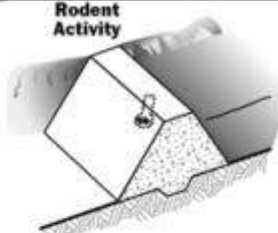
**Inspection Guidelines - Crest**

Problem	Probable Cause and Possible Consequences	Recommended Actions
	<p><b>Crest Misalignment</b></p>	
Crest Misalignment	<ol style="list-style-type: none"> <li>1. Movement between adjacent parts of the structure.</li> <li>2. Uneven deflection of dam under loading by reservoir.</li> <li>3. Structural deformation or failure near area of misalignment.</li> </ol>	<ol style="list-style-type: none"> <li>1. Establish monuments across crest to determine exact amount, location, and extent of misalignment.</li> <li>2. Engineer should determine cause of misalignment and supervise all steps necessary to reduce threat to dam and correct condition.</li> <li>3. Following remedial action, monitor crest monuments according to a schedule to detect any movement.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
	<ol style="list-style-type: none"> <li>1. Area of misalignment is usually accompanied by low area in crest which reduces freeboard.</li> <li>2. Can produce local areas of low embankment strength which may lead to failure.</li> </ol>	

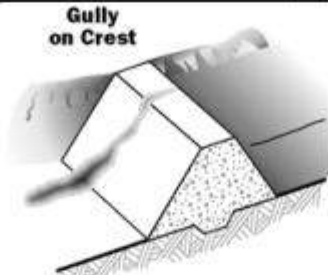
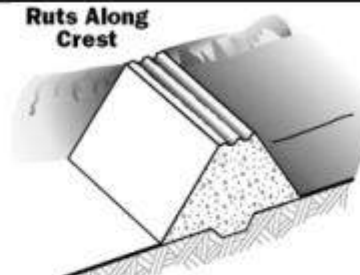
Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
Low Area in Crest	<ol style="list-style-type: none"> <li>1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest.</li> <li>2. Internal erosion of embankment material.</li> <li>3. Foundation spreading to upstream and/or downstream direction.</li> <li>4. Prolonged wind erosion of crest area.</li> <li>5. Improper final grading following construction. Reduces freeboard available to pass flood flows safely through spillway.</li> </ol>	<ol style="list-style-type: none"> <li>1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest.</li> <li>2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat to the dam and correct condition.</li> <li>3. Reestablish uniform crest elevation over crest length by filling in low area using proper construction techniques. This should be supervised by engineer.</li> <li>4. Reestablish monuments across crest of dam and routinely monitor monuments to detect any settlement.</li> </ol>

Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
 <p><b>Obscuring Vegetation</b></p>	 <p><b>Rodent Activity</b></p>	
Obscuring Vegetation	<p>Neglect of dam and lack of proper maintenance procedures.</p> <ol style="list-style-type: none"> <li>Obscures large parts of the dam, preventing adequate, accurate visual inspection of all parts of the dam. Problems which threaten the integrity of the dam can develop and remain undetected until they progress to a point that threatens the dam's safety.</li> <li>Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations.</li> <li>Prevents easy access to all parts of the dam for operation, maintenance and inspection.</li> <li>Large trees can blow over during storms, resulting in damage and possible breach of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>Remove all damaging growth from the dam. This would include removal of trees (4-inches or less in diameter), bushes, brush, conifers and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface runoff. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should backfilled with well-competent, well-compacted material.</li> <li>Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program.</li> <li>All cutting or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin. An engineer should be involved if the tree removal process poses a threat to the dam.</li> </ol>



Inspection Guidelines - Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
		
Gully on Crest	<ol style="list-style-type: none"> <li>1. Poor grading and improper drainage of crest. Improper drainage causes surface runoff to collect and drain off crest at low point in upstream or downstream shoulder.</li> <li>2. Inadequate spillway capacity which has caused dam to overtop.</li> </ol>	<ol style="list-style-type: none"> <li>1. Restore freeboard to dam by adding fill material to low area, using proper construction techniques.</li> <li>2. Regrading crest to provide proper drainage of surface runoff.</li> <li>3. If gully was caused by overtopping, create adequate spillway that meets current design standards. This should be done by engineer.</li> <li>4. Reestablish protective cover.</li> </ol>
	<ol style="list-style-type: none"> <li>1. Can reduce available freeboard.</li> <li>2. Reduces cross-sectional area of dam.</li> <li>3. Inhibits access to all parts of the crest and dam.</li> <li>4. Can result in a hazardous condition if due to overtopping. Heavy vehicle traffic without adequate or proper maintenance or proper crest surfacing</li> </ol>	

Inspection Guidelines - Crest

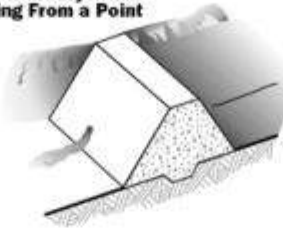
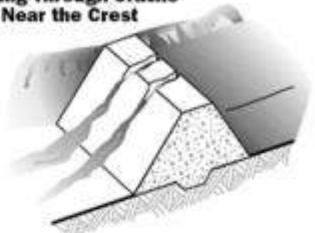
Problem	Probable Cause and Possible Consequences	Recommended Actions
Ruts Along Crest	<ol style="list-style-type: none"> <li>1. Inhibits easy access to all parts of crest.</li> <li>2. Allows continued development of rutting.</li> <li>3. Allows standing water to collect and saturate crest of dam.</li> <li>4. Operating and maintenance vehicles can get stuck.</li> </ol>	<ol style="list-style-type: none"> <li>1. Drain standing water from ruts.</li> <li>2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope.</li> <li>3. Provide gravel or road base material to accommodate traffic.</li> <li>4. Periodically maintain and regrade to prevent ruts reforming.</li> </ol>

Inspection Guidelines - Crest

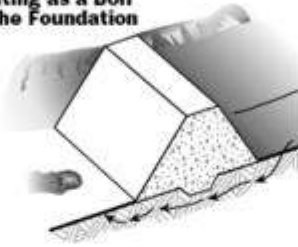
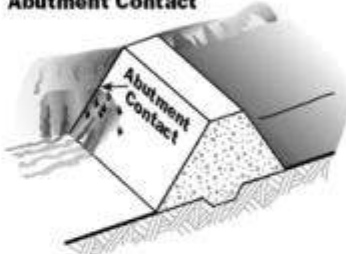
Problem	Probable Cause and Possible Consequences	Recommended Actions
<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <p><b>Puddling on Crest— Poor Drainage</b></p>  </div> <div style="text-align: center;"> <p><b>Drying Cracks</b></p>  </div> </div>		
Puddling on Crest – Poor Drainage	<ol style="list-style-type: none"> <li>1. Poor grading and improper drainage of crest.</li> <li>2. Localized consolidation or settlement on crest allows puddles to develop.</li> <li>1. Causes localized saturation of the crest.</li> <li>2. Inhibits access to all parts of the dam and crest.</li> <li>3. Becomes progressively worse if not corrected.</li> </ol>	<ol style="list-style-type: none"> <li>1. Drain standing water from puddles.</li> <li>2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope.</li> <li>3. Provide gravel or road base material to accommodate traffic.</li> <li>4. Periodically maintain and regrade to prevent low areas reforming.</li> </ol>
Drying Cracks	<p>Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and numerous. Point of entry for surface runoff and surface moisture, causing saturation of adjacent embankment areas. This saturation, and later drying of the dam, could cause further cracking.</p>	<ol style="list-style-type: none"> <li>1. Seal surface cracks with a tight, impervious material.</li> <li>2. Routinely grade crest to proper drainage and fill cracks.</li> <li>3. Cover crest with non-plastic material (not clay) to prevent large variations in moisture content.</li> </ol>

Inspection Guidelines - Crest

Inspection Guidelines – Embankment Seepage Areas

Problem	Probable Cause and Possible Consequences	Recommended Actions
	<p><b>Excessive Quantity and/or Muddy Water Exiting From a Point</b></p> 	<p><b>Stream of Water Exiting Through Cracks Near the Crest</b></p> 
<p><b>Excessive Quantity and/or Muddy Water Exiting From a Point</b></p>	<ol style="list-style-type: none"> <li>1. Water has created an open pathway, channel or pipe through the dam. The water is eroding and carrying embankment material.</li> <li>2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water.</li> <li>3. Poor construction has allowed water to create an open pathway or pipe through the embankment.</li> </ol> <ol style="list-style-type: none"> <li>1. Continued flows can saturate parts of the embankment and lead to slides in the area.</li> <li>2. Continued flows can further erode embankment materials and lead to failure of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same or clearing up.</li> <li>2. If quantity of flow is increasing, water level in reservoir should be lowered until flow stabilizes or stops.</li> <li>3. Search for opening on upstream side and plug if possible.</li> <li>4. A qualified engineer should inspect the condition and recommend further actions to be taken.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Embankment Seepage Areas

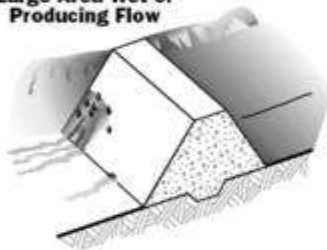
Problem	Probable Cause and Possible Consequences	Recommended Actions
Stream of Water Exiting Through Cracks Near the Crest	<ol style="list-style-type: none"> <li>1. Severe drying has caused shrinkage of embankment material.</li> <li>2. Settlement in the embankment or foundation is causing the transverse cracks. Flow through the crack can cause failure of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>1. Plug upstream side of crack to stop flow.</li> <li>2. Lower water level in the reservoir should be lowered until below level of cracks.</li> <li>3. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p><b>Seepage Water Exiting as a Boil in the Foundation</b></p>  </div> <div style="text-align: center;"> <p><b>Seepage Exiting at Abutment Contact</b></p>  </div> </div>		
Seepage Water Exiting as a Boil in the Foundation	<p>Some part of the foundation material is supplying a flow path. This could be caused by a sand or gravel layer in the foundation. Increased flows can lead to erosion of the foundation and failure of the dam.</p>	<ol style="list-style-type: none"> <li>1. Examine the boil for transportation of foundation materials.</li> <li>2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressures created by the water level with the dike may control flow velocities and temporarily prevent further erosion.</li> <li>3. If erosion is becoming greater, the reservoir level should be lowered.</li> <li>4. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Embankment Seepage Areas

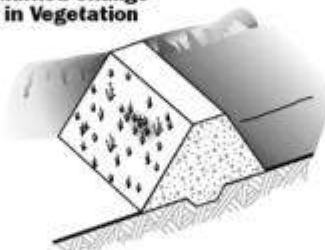
Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Seepage Exiting at Abutment Contact</b>	<ol style="list-style-type: none"> <li>1. Water flowing through pathways in the abutment.</li> <li>2. Water flowing through the embankment. Can lead to erosion of embankment materials and failure of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>1. Study leakage area to determine quantity of flow and extent of saturation.</li> <li>2. Inspect daily for developing slides.</li> <li>3. Water level in reservoir may need to be lowered to assure the safety of the embankment.</li> <li>4. A qualified engineer should inspect the condition and recommend further actions.</li> </ol>

DLNR NOTIFICATION REQUIRED

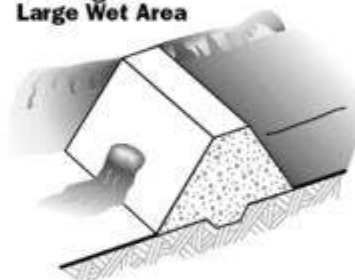
**Large Area Wet or Producing Flow**



**Marked Change in Vegetation**



**Bulge in Large Wet Area**



**Large Area Wet or Producing Flow**

A seepage path has developed through the abutment or embankment materials and failure of the dam can occur.

1. Increased flows could lead to erosion of embankment material and failure of the dam.
2. Saturation of the embankment can lead to local slides which could cause failure of the dam.

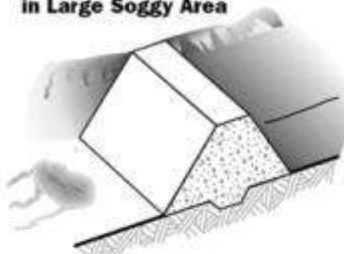
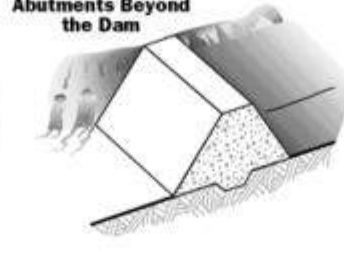
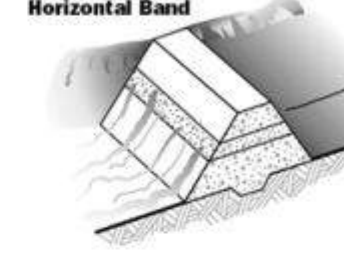
1. Stake out the saturated area and monitor for growth or shrinking.
2. Measure any outflows as accurately as possible.
3. Reservoir level may need to be lowered if saturated areas grow at a fixed storage level or if flow increases.
4. A qualified engineer should inspect the condition and recommend further actions.

DLNR NOTIFICATION REQUIRED

#### Inspection Guidelines - Embankment Seepage Areas


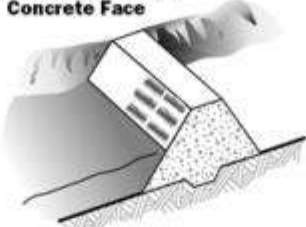
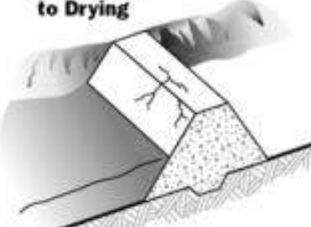
Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Marked Change in Vegetation</b>	<ol style="list-style-type: none"> <li>1. Embankment materials are supplying flow paths.</li> <li>2. Natural seeding by wind.</li> <li>3. Change in seed type during early post-construction seeding. Can show a saturated area.</li> </ol>	<ol style="list-style-type: none"> <li>1. Use probe and shovel to establish if the materials in this area are wetter than surrounding areas.</li> <li>2. If area shows wetness, when surrounding areas are dry or drier, a qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p align="center">DLNR NOTIFICATION REQUIRED</p>
<b>Bulge in Large Wet Area</b>	Downstream embankment materials have begun to move. Failure of the embankment resulting from massive sliding can follow these early movements.	<ol style="list-style-type: none"> <li>1. Compare embankment cross-section to the end of construction condition to see if observed condition may reflect end of construction.</li> <li>2. Stake out affected area and accurately measure outflow.</li> <li>3. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p align="center">DLNR NOTIFICATION REQUIRED</p>

**Inspection Guidelines - Embankment Seepage Areas**

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Trampoline Effect in Large Soggy Area</b> 	<b>Leakage From Abutments Beyond the Dam</b> 	<b>Wet Area in Horizontal Band</b> 
<b>Trampoline Effect (bouncy when jumped on) in Large Soggy Area</b>	<p>Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system. Condition shows excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation materials could result in failure of the dam.</p>	<ol style="list-style-type: none"> <li>1. Carefully inspect the area for outflow quantity and any transported material.</li> <li>2. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Leakage From Abutments Beyond the Dam</b>	<p>Water moving through cracks and fissures in the abutment materials. Can lead to rapid erosion of abutment and evacuation of the reservoir. Can lead to massive slides near or downstream from the dam.</p>	<ol style="list-style-type: none"> <li>1. Carefully inspect the area to determine quantity of flow and amount of transported material.</li> <li>2. A qualified engineer or geologist should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Wet Area in Horizontal Band</b>	<p>Frost layer or layer of sandy material in original construction.</p> <ol style="list-style-type: none"> <li>1. Wetting of areas below the area of excessive seepage can lead to localized instability of the embankment, resulting in slides.</li> <li>2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>1. Determine as closely as possible the flow being produced.</li> <li>2. If flow increases, reservoir level should be reduced until flow stabilizes or stops.</li> <li>3. Stake out the exact area involved.</li> <li>4. Using hand tools, try to identify the material allowing the flow.</li> <li>5. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

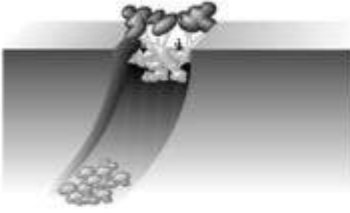


Inspection Guidelines - Embankment Seepage Areas

Inspection Guidelines – Concrete Upstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p><b>Large Increase in Flow or Sediment in Drain Outfall</b></p> 	<p><b>Cracked Deteriorated Concrete Face</b></p> 	<p><b>Cracks Due to Drying</b></p> 
<p><b>Large Increase in Flow or Sediment in Drain Outfall</b></p>	<p>Shortened seepage path or increased storage levels.</p> <ol style="list-style-type: none"> <li>1. Higher velocity flows can cause erosion of drain, then embankment materials.</li> <li>2. Can lead to piping failure.</li> </ol>	<ol style="list-style-type: none"> <li>1. Accurately measure outflow quantity and determine amount of increase over previous flow.</li> <li>2. Collect jar samples to compare turbidity.</li> <li>3. If either quantity or turbidity has increased by 25%, a qualified engineer should evaluate the condition and recommend further actions.</li> </ol> <p><b>DLNR NOTIFICATION REQUIRED</b></p>
<p><b>Cracked Deteriorated Concrete Face</b></p>	<p>Concrete deteriorated from weathering. Joint filler deteriorated or displaced. Soil is eroded behind the face and caverns can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.</p>	<ol style="list-style-type: none"> <li>1. Determine cause. Either patch with grout or contact engineer for permanent repair method.</li> <li>2. If damage is extensive, a qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p><b>DLNR NOTIFICATION REQUIRED</b></p>
<p><b>Cracks Due to Drying</b></p>	<p>Soil loses its moisture and shrinks, causing cracks. <i>Note:</i> Usually limited to crest and downstream slope. Heavy rains can fill cracks and cause small parts of embankment to move along internal slip surface.</p>	<ol style="list-style-type: none"> <li>1. Monitor cracks for increases in width, depth, or length.</li> <li>2. A qualified engineer should inspect condition and recommend further actions.</li> </ol> <p><b>DLNR NOTIFICATION REQUIRED</b></p>

Inspection Guidelines - Concrete Upstream Slope


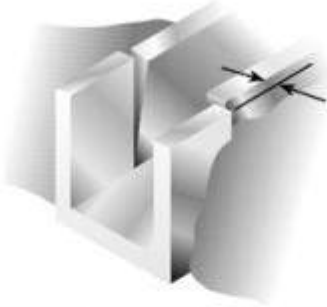

Inspection Guidelines – Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Excessive Vegetation or Debris in Channel</b> 	<b>Erosion Channels</b> 	<b>Excessive Erosion in Earth-Slide Causes Concentrated Flows</b> 
<b>Excessive Vegetation or Debris in Channel</b>	<p>Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel.</p> <p>Reduced discharge capacity; overflow of spillway, overcropping of dam. Prolonged overtopping can cause failure of the dam.</p>	<p>Clean out debris periodically; control vegetative growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.</p>
<b>Erosion Channels</b>	<p>Surface runoff from intense rainstorms or flow from spillway carries surface material down the slope, resulting in continuous troughs. Livestock traffic creates gullies where flow concentrates varies.</p> <p>Unabated erosion can lead to slides, slumps or slips which can result in reduced spillway capacity. Inadequate spillway capacity can lead to embankment overtopping and result in dam failure.</p>	<p>Photograph condition. Repair damaged areas by replacing eroded material with compacted fill. Protect areas against future erosion by installing suitable rock riprap. Re-vegetate area if appropriate. Bring condition to the attention of the engineer during next inspection.</p>

Inspection Guidelines - Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Excessive Erosion in Earth-Slide Causes Concentrated Flows</b>	<p>Discharge velocity too high; bottom and slope material loose or deteriorated; channel and bank slopes too steep; bare soil unprotected; poor construction protective surface failed.</p> <p>Disturbed flow pattern; loss of material, increased sediment load downstream, collapse of banks; failure of spillway; can lead to rapid evacuation of the reservoir through the severely eroded spillway.</p>	<p>Minimize flow velocity by proper design. Use sound material. Keep channel and bank slopes mild. Encourage growth of grass on soil surface. Construct smooth and well-compacted surfaces. Protect surface with riprap, asphalt or concrete. Repair eroded portion using sound construction practices.</p>

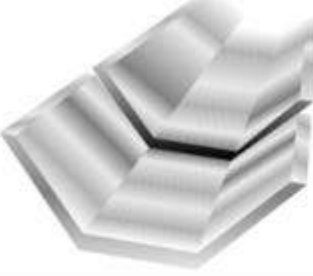

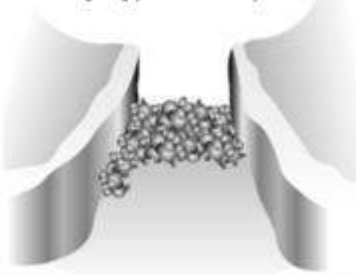
Inspection Guidelines - Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p><b>End of Spillway Chute Undercut</b></p> 	<p><b>Wall Displacement</b></p> 	<p><b>Large Cracks</b></p> 
<b>End of Spillway Chute Undercut</b>	<p>Poor configuration of stilling basin area. Highly erodible materials. Absence of cut-off wall at end of chute.</p> <p>Structural damage to spillway structure; collapse of slab and wall lead to costly repair.</p>	<p>Dewater affected area; clean out eroded area and properly backfill. Improve stream channel below chute; provide properly sized riprap in stilling basin area. Install cutoff wall.</p>
<b>Wall Displacement</b>	<p>Poor workmanship; uneven settlement of foundation; excessive earth and water pressure; insufficient steel bar reinforcement of concrete.</p> <p>Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Major displacement will cause severe cracks and eventual failure of the structure.</p>	<p>Reconstruction should be done according to sound engineering practices. Foundation should be carefully prepared. Adequate weep holes should be installed to relieve water pressure behind wall. Use enough reinforcement in the concrete. Anchor walls to prevent further displacement. Install struts between spillway walls. Clean out and back flush drains to assure proper operations. Consult an engineer before actions are taken.</p> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
Large Cracks	Construction defect; local concentrate distress; local material deterioration; foundation failure, excessive backfill pressure. Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure.	Large cracks without large displacement should be repaired by patching.  Surrounding areas should be cleaned or cut out before patching material is applied. Installation of weep holes or other actions may be needed.

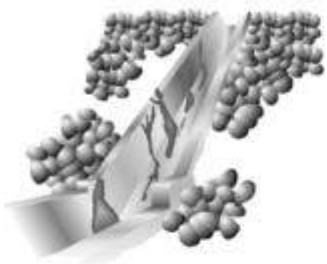
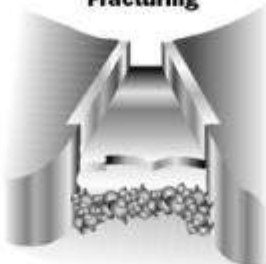

Inspection Guidelines - Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p><b>Open or Displaced Joints</b></p> 	<p><b>Breakdown and Loss of Riprap</b></p> 	<p><b>Material Deterioration—Spalling and Disintegration of Riprap, Concrete, Etc.</b></p> 
<p><b>Open or Displaced Joints</b></p>	<p>Excessive and uneven settlement of foundation; sliding of concrete slab; construction joint too wide and left unsealed. Sealant deteriorated and washed away.</p> <p>Erosion of foundation material may weaken support and cause further cracks; pressure induced by water flowing over displaced joints may wash away wall or slab, or cause extensive undermining.</p>	<p>Construction joint should be no wider than 1/2". All joints should be sealed with asphalt or other flexible materials. Water stops should be used where feasible. Clean the joint, replace eroded materials, and seal the joint. Foundations should be properly drained and prepared. Underside of chute slabs should have ribs of enough depth to prevent sliding. Avoid steep chute slope.</p> <p>DLNR NOTIFICATION REQUIRED</p>
<p><b>Breakdown and Loss of Riprap</b></p>	<p>Slope too steep; material poorly graded; failure of subgrade; flow velocity too high; improper placement of material; bedding material or foundation washed away.</p> <p>Erosion of channel bottom and banks; failure of spillway.</p>	<p>Design a stable slope for channel bottom and banks. Riprap material should be well-graded (the material should contain small, medium and large particles). Subgrade should be properly prepared before placement of riprap. Install filter fabric if necessary. Control flow velocity in the spillway by proper design. Riprap should be placed according to specification.</p> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<b>Material Deterioration – Spalling and Disintegration of Riprap, Concrete, Etc.</b>	Use of unsound or defective materials; structures subject to freeze-thaw cycles; improper maintenance practices; harmful chemicals. Structure life will be shortened; premature failure.	Avoid using shale or sandstone for riprap. Add air-entraining agent when mixing concrete. Use only clean, good quality aggregates in the concrete. Steel bars should have at least 1" of concrete cover. Concrete should be kept damp and protected from freezing during curing.



**Inspection Guidelines - Spillways**

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p><b>Poor Surface Drainage</b></p> 	<p><b>Concrete Erosion, Abrasion, and Fracturing</b></p> 	<p><b>Leakage in or Around Spillway</b></p> 
<b>Poor Surface Drainage</b>	<p>No weep holes; no drainage facility; plugged drains.</p> <p>Wet foundation has lower supporting capacity; uplift pressure resulting from seepage water may damage spillway chute; accumulation of water may also increase total pressure on spillway walls and cause damage.</p>	<p>Install weep holes on spillway walls. Inner end of hole should be surrounded and packed with graded filtering material. Install drain system under spillway near downstream end. Clean out existing weep holes. Back flush and rehabilitate drain system under the supervision of an engineer.</p> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Concrete Erosion, Abrasion, and Fracturing</b>	<p>Flow velocity too high (usually occurs at lower end of chute in high dams); rolling of gravel and rocks down the chutes; cavity behind or below concrete slab.</p> <p>Pockmarks and spalling of concrete surface may progressively worsen; small hole may cause undermining of foundation, leading to failure of structure.</p>	<p>Remove rocks and gravels from spillway chute before flood season. Raise water level in stilling basin. Use good quality concrete. Assure concrete surface is smooth.</p> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Spillways




Problem	Probable Cause and Possible Consequences	Recommended Actions
Leakage in or Around Spillway	<ol style="list-style-type: none"> <li>Cracks and joints in geologic formation at spillway are permitting seepage.</li> <li>Gravel or sand layers at spillway are permitting seepage.</li> </ol> <ol style="list-style-type: none"> <li>Could lead to excessive loss of stored water.</li> <li>Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials.</li> </ol>	<ol style="list-style-type: none"> <li>Examine exit area to see if type of material can explain leakage.</li> <li>Measure flow quantity and check for erosion of natural materials.</li> <li>If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops.</li> <li>A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Spillways

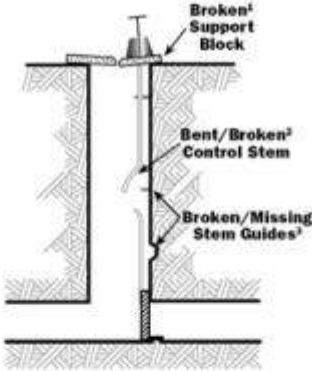
Problem	Probable Cause and Possible Consequences	Recommended Actions
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p><b>Too Much Leakage From Spillway Under Drains</b></p>  </div> <div style="text-align: center;"> <p><b>Seepage From a Construction Joint or Crack in Concrete Structure</b></p>  </div> </div>		
<b>Too Much Leakage From Spillway Under Drains</b>	<p>Drain or cutoff may have failed.</p> <ol style="list-style-type: none"> <li>Excessive flows under the spillway could lead to erosion of foundation material and collapse of parts of the spillway.</li> <li>Uncontrolled flows could lead to loss of stored water.</li> </ol>	<ol style="list-style-type: none"> <li>Examine exit area to see if type of material can explain leakage.</li> <li>Measure flow and check for erosion of natural materials.</li> <li>If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops.</li> <li>A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>
<b>Seepage From a Construction Joint or Crack in Concrete Structure</b>	<p>Water is collecting behind structure because of insufficient drainage or clogged weep holes.</p> <ol style="list-style-type: none"> <li>Can cause walls to tip in and over. Flows through concrete can lead to rapid deterioration from weathering.</li> <li>If spillway is located within embankment, rapid erosion can lead to failure of the dam.</li> </ol>	<ol style="list-style-type: none"> <li>Check area behind wall for puddling of surface water.</li> <li>Check and clean as needed; drain outfalls, flush lines and weep holes.</li> <li>If condition persists, a qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Spillways

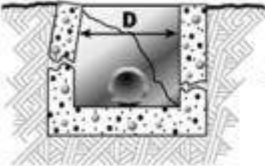

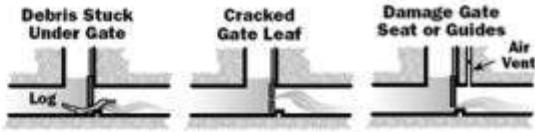
Inspection Guidelines – Inlets, Outlets, and Drains

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p style="text-align: center;"><b>Outlet Pipe Damage</b></p> <div style="display: flex; justify-content: space-around; align-items: flex-end;"> <div style="text-align: center;"> <p><b>Crack</b></p>  </div> <div style="text-align: center;"> <p><b>Hole</b></p>  </div> <div style="text-align: center;"> <p><b>Joint Offset</b></p>  </div> </div>		
<b>Outlet Pipe Damage: Crack</b>	Settlement; impact. Excessive seepage, possible internal erosion.	Check for evidence of water either entering or exiting pipe at crack, hole, etc.
<b>Outlet Pipe Damage: Hole</b>	Rust (steel pipe); erosion (concrete pipe); cavitation.	Tap pipe in vicinity of damaged area, listening for hollow sound which indicates a void has formed along the outside of the conduit.
<b>Outlet Pipe Damage: Joint Offset</b>	Settlement or poor construction practice. Provides passageway for water or exit or enter pipe, resulting in erosion of internal materials of the dam.	If a progressive failure is suspected, request engineering advice.


Inspection Guidelines - Inlets, Outlets, and Drains

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p style="text-align: center;"><b>Control Works</b></p> 		
Damage to Control Works	<ol style="list-style-type: none"> <li><b>BROKEN SUPPORT BLOCK</b> Concrete deterioration. Excessive force exerted on control stem by trying to open gate when it was jammed.  Causes control support block to tilt; control stem may bind. Control head works may settle. Gate may not open all the way. Support block may fail completely, leaving outlet inoperable.</li> <li><b>BENT/BROKEN CONTROL STEM</b> Rust. Excess force used to open or close gate. Inadequate or broken stem guides.  Outlet is inoperable.</li> <li><b>BROKEN/MISSING STEM GUIDES</b> Rust. Inadequate lubrication. Excess force used to open or close gate when jammed.  Loss of support for control stem. Stem may buckle and break under normal use (as in this example).</li> </ol>	<p>Any of these conditions can mean the control is either inoperable or, at best, partly operable. Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made. Engineering help is recommended.</p>

Inspection Guidelines - Inlets, Outlets, and Drains

Problem	Probable Cause and Possible Consequences		Recommended Actions
<b>Failure of Concrete Outfall Structure</b> 	<b>Outlet Releases Eroding Toe of Dam</b> 	<b>Valve Leakage</b> 	
<b>Failure of Concrete Structure</b>	<b>Outfall</b> Excessive side pressures on non reinforced concrete structure. Poor concrete quality.  Loss of outfall structure exposes embankment to erosion by outlet releases.		1. Check for progressive failure by monitoring typical dimension, such as "D" shown in figure.  2. Repair by patching cracks and supplying drainage around concrete structure. Outfall structure may need total replacement.
<b>Outlet Releases Eroding Toe of Dam</b>	Outlet pipe too short. Lack of energy-dissipating pool or structure at downstream end of conduit.  Erosion of toe over steepens downstream slope, causing progressive sloughing.		1. Extend pipe beyond toe (use pipe of same size and material, and form watertight connection to existing conduit).  2. Protect embankment with riprap over suitable bedding.
<b>Valve Leakage: Debris Stuck Under Gate</b>	Trashrack missing or damaged.  Gate will not close. Gate or stem may be damaged in effort to close gate.		Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trashrack.
<b>Valve Leakage: Cracked Gate Leaf</b>	Rust, affect vibration, or stress resulting from forcing gate closed when it is jammed.  Gate-leaf main fail completely, evacuating reservoir.		Use valve only in fully open or closed position. Minimize use of valve until leaf can be repaired or replaced.
<b>Valve Leakage: Damaged Gate Seat or Guides</b>	Rust, erosion, cavitation, vibration or wear.  Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.		Minimize use of valve until guides or seats can be repaired. If cavitation is the cause, check to see if air vent pipe exists, and is unobstructed.

Inspection Guidelines - Inlets, Outlets, and Drains

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p><b>Seepage Water Exiting From a Point Adjacent to the Outlet</b></p> 		
<p><b>Seepage Water Exiting From a Point Adjacent to the Outlet</b></p>	<ol style="list-style-type: none"> <li>1. A break in the outlet pipe.</li> <li>2. A path for flow has developed along the outside of the outlet pipe.</li> </ol> <p>Continued flows can lead to erosion of the embankment materials and failure of the dam.</p>	<ol style="list-style-type: none"> <li>1. Thoroughly investigate the area by probing and/or shoveling to try to determine cause.</li> <li>2. Determine if leakage water is carrying soil particles.</li> <li>3. Determine quantity of flow.</li> <li>4. If flow increases or is carrying embankment materials, reservoir level should be lowered until leakage stops.</li> <li>5. A qualified engineer should inspect the condition and recommend further actions.</li> </ol> <p>DLNR NOTIFICATION REQUIRED</p>

Inspection Guidelines - Inlets, Outlets, and Drains

## 2. Hyperlink to Internet Quicklinks (DOC)

<http://dlnreng.hawaii.gov/dam/forms/emergency-action-plan/>

### February 2016 – Links to Information for the Hawaiian Islands

#### Weather – NOAA Satellites (6 Hour Loops)

<http://www.ssd.noaa.gov/goes/west/hi/flash-rb.html> (Hawaiian Islands)

<http://www.ssd.noaa.gov/goes/west/tpac/flash-rb.html> (Tropical Pacific)

<http://www.ssd.noaa.gov/goes/west/nepac/flash-rb.html> (Northeast Pacific)

<http://weather.hawaii.edu/satellite/satanim.cgi?res=4km&chnl=ir&domain=hus&size=large&period=2880&incr=30&rr=900&satplat=goeswest&overlay=off&animtype=flash> (Northeast Pacific – 48 Hours)

#### TV Weather

<http://khon2.com/weather/radar/>

<http://www.kitv.com/weather>

<http://www.hawaiinewsnow.com/category/202017/weather>

#### Central Pacific Hurricane Center

<http://www.prh.noaa.gov/hnl/cphc/?gtwo>

#### Hawaii Flash Flood Response Tool

<http://hawaii-pacioos-application-1672159924.us-east-1.elb.amazonaws.com/>

#### USGS Data for Hawaii

[http://waterdata.usgs.gov/hi/nwis/current/?type=lake&group\\_key=county\\_cd](http://waterdata.usgs.gov/hi/nwis/current/?type=lake&group_key=county_cd) (Reservoir Levels)

[http://waterdata.usgs.gov/hi/nwis/current/?type=all&group\\_key=county\\_cd](http://waterdata.usgs.gov/hi/nwis/current/?type=all&group_key=county_cd) (All Real Time Gages)

<http://hvo.wr.usgs.gov/seismic/volcweb/earthquakes/> (Earthquakes)

<http://waterwatch.usgs.gov/?m=real&r=hi&w=map> (Stream Flow & Reservoir Level Data Map)

#### State of Hawaii Dam Inventory User Login

<http://132.160.239.52/daminventory/login.aspx>

#### Pacific Disaster Center Home Page

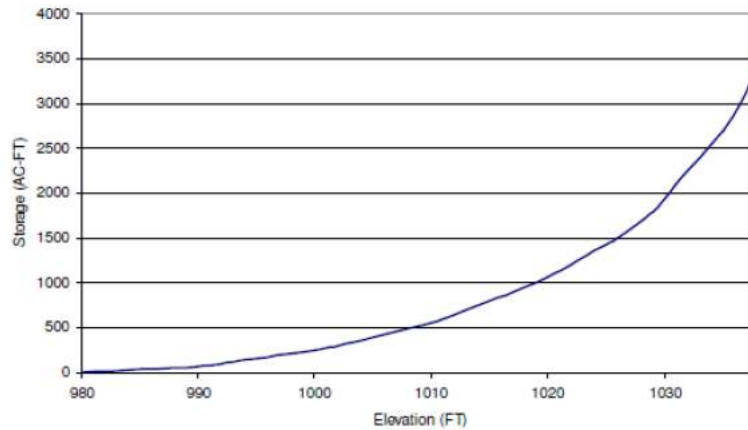
<http://www.pdc.org/>

#### Hawaii State Civil Defense (Hawaii Emergency Management Agency) Home Page

<http://www.scd.hawaii.gov/>

**XV. Appendix D – Dam Owner Additional Information**

**1. Nu'uanu Reservoir No. 4 Storage Capacity Curve**



**Figure 4-4. Elevation-storage curve for Nu'uanu Reservoir No. 4**

Oceanit, 2008. *Dam Break Analysis For Nu'uanu Reservoir (H1001)*. Prepared for Army Corps of Engineers.

**XVI. Appendix E - Terms & Conditions**

**Disclaimers:**

The Department of Land and Natural Resources, Engineering Division (DLNR) has developed this DLNR Emergency Action Plan (EAP) template based on guidance from FEMA Publication 64. These guidelines help dam owners and emergency management agencies effectively develop, prepare and implement emergency actions should there be an incident at a dam facility. The use of this DLNR EAP template is highly recommended, however not mandatory.

Dam Owners are responsible for the Production, Distribution, Updating/Maintenance, and Testing of their facility EAPs, per HAR 13-190.1. Each owner shall ensure that content entered into the plan is specific for each facility. The successful use of this plan relies on the inspection and notification event triggers in the plan.

There are many factors and scenarios for a dam failure, and several assumptions were made in order to run the models. DLNR assisted with development of dam break modeling and potential inundation mapping using a sunny day dam break scenario. Dam failure evacuation maps were then developed by the Counties. Dam Owner's may provide alternative dam break models to the County Emergency Management / Civil Defense Agencies to update the dam failure evacuation maps. Upon developing revisions or modifications to the evacuation maps, dam owners shall submit a digital copy to DLNR for inclusion on this EAP site.

The use of this template is provided as a guidance to initiate an EAP. DLNR is not responsible for errors, deficiency or omissions within the plan. Any use, disclosure, or distribution by unintended recipients is prohibited. Should an error be found, please notify DLNR as soon as possible for a change to be posted.