Appendix I:
Excerpts from Halliburton NUS study

HAZWRAP

HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM

MAKUA MILITARY RESERVATION
SOIL AND GROUNDWATER ANALYSIS REPORT

PART I - TECHNICAL EVALUATIONS

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1. SUMMARY AND CONCLUSIONS

A baseline soil and groundwater sampling study was conducted at the Makua Military Reservation (MMR), Oahu, Hawaii, pursuant to the Resource Conservation and Recovery Act (RCRA) Subpart X Permit Application for the open burning/open detonation (OB/OD) unit The focus of the MMR environmental sampling program has been to characterize potential impacts associated with OB/OD operations to support the RCRA Subpart X permitting process A complete characterization of environmental conditions within the entire installation for evaluating potential impacts associated with other past and present military activities is beyond the scope of the current study

Part I of this report presents the technical approach and data evaluation results for the MMR environmental sampling program Part II contains the supporting data validation documentation and laboratory analytical data

1.1 BACKGROUND INFORMATION

The MMR is located in a relatively isolated area at the west end of the Island of Oahu, encircled by part of the Waianae Mountains on the north, east, and south and by the Pacific Ocean to the west The U S Army Support Command, Hawaii (USASCH) operates MMR, which is used by the Military Services The two primary functions of the MMR installation are military training and the thermal treatment of waste explosive ordnance by OB/OD The installation was established in 1943 as a military training area and an impact area for high explosive ordnance, and it serves in those roles today As a result of these missions, unexploded ordnance (UXO) is a concern at this site

Preliminary field activities were conducted at MMR during July 1–3, 1993, to prepare for the environmental sampling phase The objectives of these preliminary activities were to identify candidate environmental sampling locations as well as to survey and mark the boundaries of the active portion (approximately 4 acres) of the 18-acre OB/OD unit Based on the results of this preliminary field survey, it was concluded that UXO and fire hazard concerns as well as local geological conditions have the potential to limit environmental sampling opportunities at MMR

The MMR Environmental Sampling Plan (Revision 1, September 1993) was developed considering the results of the preliminary field survey including the UXO hazards and geological conditions at MMR The Sampling Plan served as the protocol [based on U S Environmental Protection Agency (EPA) - Region IX concurrence] for field sampling activities at MMR and for subsequent laboratory analyses

1.2 SAMPLING PROGRAM

The field phase of the Sampling Plan was implemented at MMR during the period November 1–12, 1993. Field activities included:

- unexploded ordnance detection surveys,
- geophysical surveys, and
- soil and groundwater sampling.

UXO detection surveys were conducted to identify safe work zones to support the MMR environmental sampling program. However, the presence of UXO was not a major obstacle for implementing the Sampling Plan (although one borehole at the OB/OD active area had to be abandoned because of the potential for subsurface UXO).

Electromagnetic geophysical techniques were employed as an alternative to drilling deep boreholes to obtain the subsurface information necessary to evaluate potential contaminant-migration pathways. These geophysical data were used in conjunction with (1) U.S. Geological Survey (USGS) hydrogeologic information available from Waianae District, (2) limited test data obtained from earlier USGS borings in the lower Makua Valley, and (3) the soils and groundwater data obtained during the November 1993 sampling program.

Following is a summary of the samples collected at MMR during the period November 1–12, 1993:

- Soil sampling—surface soils (three layers at each location: 0–6 in., 6–12 in., and 12–18 in.)
  - Grab samples at 4 background locations with terrain heights greater than the OB/OD unit. (The 12- to 18-in. interval was not sampled at one location because of shallow bedrock conditions.)
  - Composite samples at four locations within the OB/OD active area
  - Grab samples at two background locations with terrain heights less than the OB/OD unit of the OB/OD unit
- Soil borings—subsurface soils (typically five layers at each location: 0–2 ft, 2–4 ft, 4–6 ft, 6–8 ft, and 8–10 ft)
  - Grab samples at one location upgradient of the OB/OD unit. (The 8- to 10-ft interval was not sampled because of basalt boulder or bedrock conditions.)
  - Grab samples at three locations within the OB/OD active area at 2-ft intervals to depths of 16 to 20 ft
  - Grab samples at one location near the MMR installation boundary in the Makua Stream drainage downslope of the OB/OD units. (The 8- to 10-ft interval was not sampled because of a boulder zone.)
  - Grab samples at two locations at the downgradient boundary of the OB/OD active area. (The 6 to 8-ft interval was not sampled at one location because of basalt boulders at that depth.)

- Groundwater sampling/monitoring well installation
  - OB/OD active area boundary—installation of a monitoring well (dry) at a depth of 50 ft below ground level (bgl)
  - MMR installation boundary—installation of a monitoring well downgradient of the OB/OD unit and the impact (military training) area at a depth of 23 ft bgl
- Sediment sampling (1 layer 0–6 in)
  - Grab sample in the Makua streambed near the west boundary of the installation
  - Grab sample in the unnamed streambed near the west boundary of the installation

The Sampling Plan specified the installation of four groundwater monitoring wells (three in the vicinity of the OB/OD unit plus one at the installation boundary) Based on discussion with Region IX on November 4, 1993, it was decided that a total of two wells would be installed because shallow groundwater was unlikely to be present at the OB/OD unit, judging from MMR soil boring and geophysical data As a result, only one well was installed near the OB/OD unit The location of this well is near the downgradient edge of the OB/OD active area and unit boundary However, groundwater was not encountered at this location, and the well is considered dry

A groundwater monitoring well was successfully installed near the installation's west boundary adjacent to the Makua Stream and relatively close to the coast This location is downgradient of the OB/OD unit as well as the Makua Valley Therefore, sampling results from this well will be indicative of the combined impacts of military training and OB/OD operations at MMR

1.3 ANALYTICAL PROGRAM

The MMR soil and groundwater samples were analyzed commensurate with the Sampling Plan based on standard EPA methods Following is a summary of the target analytical parameters

- semivolatile organics,
- metals,
- cyanide,
- sulfides,
- energetics,
- nitrates/nitrites, and
- nitrites

The nitrates/nitrites and nitrites analyses were conducted by a laboratory on Oahu Other analyses were conducted by a mainland laboratory

A total (including quality control) of 6 aqueous and 84 soil samples were analyzed for the above parameters

In addition, one soil sample from the OB/OD unit was subject to pH and total organic carbon tests Two aqueous samples were tested for specific conductance

1.4 QUALITY ASSURANCE PROGRAM

Quality assurance/quality control (QA/QC) measures were employed during the MMR sampling and analysis program commensurate with the Sampling Plan Elements of the QA/QC program included the following

- daily field log,
- field measurements,
- sample labeling,
- sample container, preservation, and holding time requirements,
- sample collection,
- field QC samples,
- sample chain of custody,
- sample shipment,
- data quality objectives,
- laboratory QC checks,
- data validation requirements, and
- preventive maintenance

The QA/QC measures have been documented and serve to establish the credibility of the MMR sampling program

1.5 HYDROGEOLOGICAL EVALUATION

Geophysical measurements were used to plot terrain conductivity profiles for the OB/OD active area and a portion of the Makua Valley Interpretation of these data supports several important conclusions

Makua Valley can be characterized as an alluvium-filled valley overlying the basalt bedrock The overburden is relatively thin near the coast (50 to 115 ft in the vicinity of the installation boundary) and increases in thickness because of the topographical rise up the valley (to depths of greater than 200 ft at the OB/OD unit) The overburden becomes thinner at the valley walls near the base of the steep bedrock slopes

Geophysical survey results indicated the presence of localized, disturbed soil conditions to a depth of approximately 20 ft in the western portion of the OB/OD active area MMR staff confirmed that this disturbed area corresponds to the location where most OD events occurred Soil boring samples to a depth of 20 ft were subsequently collected from this OD area

Anomalous geophysical results were obtained in a limited area (near the entrance to the military training impact zone) along the Makua Valley fire-break road There is the potential for disturbed subsurface soil conditions and buried metal objects at this location However, this area is not associated with the OB/OD operation This information has been provided for

followup investigation to the U S Army Environmental Hygiene Agency, which is conducting a Preliminary Assessment of MMR for USASCH as part of the Installation Restoration Program

The geological and geophysical investigations of the OB/OD unit indicate that groundwater is not a significant potential migration pathway at MMR The underlying soils at the OB/OD unit are rich in clay and relatively impermeable This clay-rich overburden is at least 200 ft thick, based on the geophysical data In addition, a shallow groundwater aquifer (at depths of 50 ft or less) was not detected at the OB/OD unit based on soil boring results Thus, groundwater is not expected to occur at a depth of less than 200 ft (corresponding to the depth limitations of the geophysical investigation)

The OB/OD soil was sampled and analyzed for pH (8 7, indicative of basic conditions) and total organic carbon (3200 mg/kg) The hydraulic conductivity of the clay overburden at the OB/OD unit is estimated to be less than 10^{-4} cm/s These soil characteristics data indicate a low potential for the leaching and subsurface transport of contaminants The MMR soil data were used as site-specific input for a risk assessment model and to evaluate the migration potential of contaminants

The usually dry, intermittent Makua Stream (within 500 ft north of the OB/OD active area) receives direct runoff from the OB/OD unit during heavy rains This surface runoff in turn can transport sediments from the OB/OD unit and has the potential for recharging the basal lens aquifer in the vicinity of the installation boundary by infiltration Thus, stream sediments and the aquifer near the installation boundary were sampled to evaluate this contaminant migration potential

Several chemical and physical tests were conducted to characterize the aquifer at the monitoring well located near the installation boundary Water samples were slightly to moderately turbid because of fine alluvium clays The salinity tests (both field and laboratory) indicated relatively fresh water with an estimated sodium chloride concentration of 200 to 300 mg/L Water with a salinity of less than 1000 mg/kg is considered fresh, and over 1000 mg/kg brackish to saline The maximum variation in water levels over an 18-h period was 0 05 ft A slight diurnal/semidiurnal fluctuation was measured but attributed to minor barometric and/or evapotranspiration effects rather than to a tidal influence In situ hydraulic conductivity measurements were determined to be in the range of $1\ 08 \times 10^{-1}$ to $3\ 79 \times 10^{-1}$ cm/s Test results also indicate a relatively high transmissivity value of 30,050 ft^2/d These hydraulic conductivity and transmissivity data indicate the potential for a relatively high flow rate for the aquifers near the coast There are no operating withdrawal wells in the near vicinity of MMR In the past, U S Geological Survey (USGS) test wells along the coast at Makua have indicated that fresh water escapes to the sea as underflow

1.6 ANALYTICAL DATA VALIDATION RESULTS

The analytical laboratories provided QC documentation commensurate with EPA Level III requirements specified in the Sampling Plan All sample results and associated Level III data were reviewed (validated) against the EPA QC criteria specified for each analytical method

Positive analytical values for samples associated with blank contamination (false positives) were flagged (qualified), considered as invalid data, and not used to evaluate MMR environmental conditions "Positive" analytical results refers to the detection of the target constituent Some positive results were qualified as "estimated" because they were below the Contract Required Quantification Limit (CRQL) However, estimated data are suitable for use and were used as input for subsequent statistical analysis Alternatively, these data could have been considered as nondetectable results However, these data have been reported for documentation completeness and used to estimate MMR environmental conditions conservatively

A total of 14,356 individual analytical results were obtained including QC samples and positive detection as well as nondetection results for environmental samples considering all target analytical constituents Of this total, 99 3% of the analytical results were classified as valid data (97 5% were considered unconditionally as valid data and 1 8% were qualified as "estimates" but still considered as valid data) Most of the "estimated" results were positive results reported by the laboratory that were below CRQL Therefore, the data quality objective of 90% specified in the Sampling Plan was significantly exceeded Approximately 95% of the analytical results were nondetection data

1.7 DATA EVALUATION RESULTS

Analytical data from the MMR environmental sampling program were statistically evaluated for appropriateness, distribution, and significance based on standard EPA guidance The MMR data set can be considered to be represented by a normal distribution (typical for environmental samples) The data were statistically evaluated to determine if differences between background (at locations with a higher terrain height than the OB/OD unit) and OB/OD analytical data were significant Results classified as statistically significant were summarized by sample location types (i e , background, OB/OD, and installation boundary) as well as by contaminants These results were compared with conservative lifetime exposure health criteria (applicable to the point of compliance at the installation boundary) based on a data base compiled by the Oak Ridge National Laboratory

MMR sampling results confirm that soil and groundwater samples at the installation boundary do not exceed health criteria A limited number of on-site soil samples from the OB/OD unit were higher than these off-site lifetime exposure criteria, however, the health criteria are not applicable to on-site locations because there are no long-term public receptors

Sampling results also indicate that soils at the OB/OD unit are not considered to be hazardous waste based on EPA reactivity and toxic leaching potential criteria

Based on the evaluation of the analytical results from the MMR environmental sampling program, a set of indicator parameters has been identified to characterize OB/OD releases at MMR, 2,4-DNT and 2,6-DNT are good indicators because they were not in the background samples but were at the OB/OD unit Lead is also a candidate indicator because it appeared in the OB/OD samples at levels higher than its respective health criteria

The results of the MMR environmental sampling program were also used as revised input to the exposure/risk assessment model previously used for the permit application Geohydrological data were used as input to define the environmental setting, and analytical results were used as input to define OB/OD contaminant release source terms The following pathways were remodeled

- overland runoff to Makua Stream,
- infiltration to groundwater to the installation boundary,
- infiltration to groundwater to recharging Makua Stream, and
- air concentrations at the MMR installation boundary caused by wind erosion

The revised modeling results indicate that health criteria would not be exceeded at the installation boundary for at least the next millenium Groundwater transport to this point of compliance is predicted to take 2000 to 7000 years, based on the conservative assumption that no closure actions will be taken during this period which could mitigate such a release

1.8 CONCLUSIONS

The MMR sampling program has been successfully completed commensurate with the Sampling Plan and scope modifications concurred in by EPA - Region IX This investigation has provided a credible data set to characterize hydrogeologic conditions as well as baseline soil and groundwater quality associated with OB/OD operations at MMR

The potential for migration of contaminants from the OB/OD unit is low considering the lack of shallow groundwater and the presence of a deep clay overburden which retards infiltration For example, the groundwater transport to the installation boundary is predicted to take thousands of years for the most mobile contaminants (i e , 2,4- and 2,6-DNT) However, groundwater from this aquifer is not used by the military or the public There is a greater near-term migration potential of overland runoff from the OB/OD unit draining into Makua Stream However, Makua Stream is an intermittent stream which is dry 95% of the time, thus minimizing the significance of this potential migration pathway based on both sampling and modeling results which indicate potential exposures below health criteria

MMR sampling results are consistent with the contamination migration potential as determined from site-specific geohydrological conditions and revised modeling assessments Specifically, soil and groundwater sampling results at the installation boundary are significantly lower than the health criteria (including sediment samples from Makua Stream) Contamination levels at the OB/OD unit are relatively low, and contamination migration appears to be minimal A limited set of indicator monitoring parameters (i e , 2,4-DNT, 2,6 DNT, and lead) has been identified associated with potential OB/OD impacts

In summary, groundwater is not a major environmental transport pathway relative to the OB/OD unit at MMR The groundwater at MMR is not used by the military or the public The high evapotranspiration rate at the site plus the deep overburden layer of relatively impermeable clay result in a lack of shallow groundwater at the OB/OD unit The only known shallow groundwater at MMR is the basal freshwater aquifer at the installation

boundary which was sampled via the test well installed at this location However, this shallow aquifer does not have a direct hydrological connection with the OB/OD unit but has the potential for being more directly impacted by on-site military training operations In addition, the soil contamination levels at MMR are low and the OB/OD treatment quantities will be minimal (thus further minimizing the potential for groundwater contamination) Therefore, routine monitoring of groundwater at MMR is not warranted for the OB/OD unit

Results of the sampling program also confirm that OB/OD operations at MMR have ensured the protection of human health and the environment Therefore, the permitting process for the MMR OB/OD unit should continue in order to facilitate the demilitarization needs of the military services in Hawaii

Table 8 5. Summary of soil sampling results for constituents which exceeded health criteria (mg/kg)

Constituent	Depth (bgl)[a]	Background - upslope					OB/OD unit						Background - downslope			Installation boundary			Lifetime exposure health criteria[b]
		SP#					SP#						SP#			SP#			
		1	2	5	6	14A	10	11	11A	12	13	15	16	3	4	7	8	9	
Arsenic	0-6 in	7 6	-	-	-		-	17 9J 16 8D		9 5	- -D			- -D	3 9 -D		- -D	3 6 -D	24
	6 12 in	-	24.6	-	1 1		14 6	8 5		- 7 9D	-			-	7 5				24
	12 18 in		-	-	-		-	9 2J		-	-			-	2 2				24
	2 ft					-		-	- -D	- 7 6D,J		-	-			-			24
	4 ft					-		-	7 4	10		-	-			-			24
	6 ft					-		-	-	8 9		29.9	-			-			24
	8 ft					12 0		-	9 7	-			8 5			-			24
	10 ft							-		8 8		-	-						24
	12 ft							-	0 95	-									24
	14 ft							9 2	-	-									24
	16 ft							-	-	11 5									24
	18 ft							-	15 4										24
	20 ft							-	-										24

Table 8 5 (continued)

Constituent	Depth (bgl)[a]	Background - upslope					OB/OD unit						Background - downslope			Installation boundary			Lifetime exposure health criteria[b]
		SP#					SP#						SP#			SP#			
		1	2	5	6	14A	10	11	11A	12	13	15	16	3	4	7	8	9	
DNT	0-6 in	-	-	-	-		2.7	- 1.6D		-	- -D			- -D	-D		- -D	- -D	1 03
	6-12 in		-	-	-		3.4	-		1.8 -D	-			-	-				1 03
	12-18 in		-	-	-		-	-		5.7	0 44			-	-				1 03
	2 ft					-		33.7	- 0 19D,J	- 3.5D		-	0 53			-			1 03
	4 ft					-		4.6	0 54	23.1		-	-			-			1 03
	6 ft					-		-	0 047J	-		-	-			-			1 03
	8 ft					-		3.7J	4.8J	-			-			-			1 03
	10 ft							-		0 59		-	-						1 03
	12 ft							-	-	-									1 03
	14 ft							-	0 13J	-									1 03
	16 ft							-	4.3J	0 46									1 03
	18 ft							-	66.2										1 03
	20 ft							-	-										1 03

Table 8 5 (continued)

Constituent	Depth (bgl)[a]	Background - upslope					OB/OD unit						Background - downslope			Installation boundary			Lifetime exposure health criteria[b]
		SP#					SP#						SP#			SP#			
		1	2	5	6	14A	10	11	11A	12	13	15	16	3	4	7	8	9	
Lead	0-6 in.	3 1	4 2	3 0	2 7		178	192 580D		101	47 4 36 6D			18 0 19 8D	101 84 3D		4 3 4 0D	13 6 9 3D	500
	6-12 in.	2 6	3 1	3 0	1 8		198	226		164 79 3D	24 4			16 5	89				500
	12-18 in.		2 4	2 5	2 4		133	311		663	34 5			12 2	91 8				500
	2 ft					3 1		29 8	181 203D	168 67 1D		5 1	156			2 0			500
	4 ft					1 6		137	1410	94 6		84 6	7 4			1 6			500
	6 ft					2 1		263	299	110		4 4	16 7			1 5			500
	8 ft					1 4		254	247	70 4			1 9			1 4			500
	10 ft							191		73 9		1 8	2 6						500
	12 ft							254	8 1	101									500
	14 ft							2 7	50	101									500
	16 ft							2 5	19	21 7									500
	18 ft							3 1	43 9										500
	20 ft							2 8	49 4										500

Table 8.5 (continued)

Constituent	Depth (bgl)[a]	Background - upslope SP# 1	2	5	6	14A	OB/OD unit SP# 10	11	11A	12	13	15	Background - downslope SP# 16	3	4	Installation boundary SP# 7	8	9	Lifetime exposure health criteria[b]
PCBs	0-6 in.		-	-	-		-	- -D		-	- 26.15D			- -D	- -D		- -D	- -D	0 0909
	6-12 in.	-	-	-	-		-	-		- -D	-			-	-				0 0909
	12-18 in.		-	-	-		-	-		-	-			-	-				0 0909
	2 ft					-		-	- -D	- -D		-	-			-			0 0909
	4 ft					-		-	-	-		-	-			-			0 0909
	6 ft					-		0.71J	-	-		-	-			-			0 0909
	8 ft					-		-	-	-			-			-			0 0909
	10 ft									-		-	-						0 0909
	12 ft								-	16.53J									0 0909
	14 ft								-	-									0 0909
	16 ft								-	-									0 0909
	18 ft								-										0 0909
	20 ft								-										0 0909

DNT = 2,4 and 2,6 dinitrotoluene
J = Value detected is below the reporting limit or is an estimated concentration
D = Duplicate
A dash indicates constituent analyzed for but not detected at the instrument detection limit, a blank space indicates that a sample was not taken at that depth
Shaded numbers indicate critical values

[a]Below ground level