SECTION 2.0: EXPLANATION OF TASKS COMPLETED

2.1 Unexploded Ordnance Clearance

There was the potential for encountering unexploded ordnance (UXO) throughout the MMR, so precautions were taken during all investigative work to avoid UXO. During the duration of the fieldwork, only limited pieces of ordnance were encountered. This included remnants of fuses and metal shrapnel at the OB/OD area.

2.2 Shallow Soil Samples

This section of the Work Plan describes the overall approach that was used to collect soil samples at Makua Military Reservation (MMR). Detonation of ordnance has the potential to release compounds to the surface soils in the Makua Valley. To evaluate this, eighteen areas of concern in the training areas have been identified (Table 2.1) and shallow soils within those areas were sampled. A total of 102 discrete soil samples were collected from these areas of concern. An additional 22 soil samples were collected outside of the central training areas of MMR. The objective of the soil sampling was to evaluate if concentrations of potential contaminants within the surface soils are present at detectable levels at MMR.

The samples were collected as discrete samples biased toward visual observations. The sampling focused on areas of obvious or suspected contamination and runoff pathways. Field discretion has been used to refine the soil sampling locations and provide for representativeness of the areas of concern being investigated. This method maximizes the potential for compounds to be found by the shallow soil-sampling task.

2.2.1 Soil Sampling Procedure

Soil sampling locations were chosen to be representative of the areas of concern to be investigated. Each surface soil sample was collected as a discrete sample within an area of concern that may have been impacted by military operations. The sample locations were biased toward any visible signs of surficial or point-source contamination, or areas that exhibited either enhanced or retarded vegetation growth. These locations also included the target berms that are

used to stop mostly small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50) or depressions caused by larger projectiles such as 105mm.

Each surface soil sample collected and submitted for analysis was a discrete sample located within a training area that had the potential to be impacted by military operations. This was done to meet the requirement of Region IX U.S. EPA, which does not endorse or permit composite sampling, but rather prefers discrete sampling. Composite sampling is thought to dilute the sample and mask potential detections. Prior to sampling, surface vegetation, rocks, pebbles, leaves, and twigs were cleared from the sampling point to allow collection of a representative material. In the case of an obstacle, the sample point was shifted off the nearest edge of the obstacle and the soil sample collected. For UXO, which during this exercise consisted of metal fragments, the sampling point was shifted to the nearest cleared point. Sampling equipment was decontaminated away from the sampling point. Decontamination procedures include cleaning the sampling device with a non-phosphate surfactant, a distilled water rinse, and finally another distilled water rinse.

Each shallow sampling interval was exposed and the sample taken using a pre-cleaned disposable plastic sampling device or a decontaminated metal sampling scoop. Once the sample was obtained, it was field screened with a GR-110 Exploranium Gamma Ray Scintillometer for gamma radiation. This instrument records gamma radiation. Radioactive contamination from an alpha or a beta source will occur in conjunction with a gamma source, so that measuring for gamma is a very good tool for screening for radioactive contamination. As part of this study, it was necessary to evaluate site-specific background levels of radiation at MMR, and also to perform a separate evaluation of off-site background levels. Measurements obtained in the field were compared to these background levels, as explained in Section 3.6. Background radiation levels were determined by surveying several areas across O`ahu.

The collected shallow soil sample was homogenized in a pre-cleaned stainless steel bowl. The sample was then placed in a certified clean wide-mouth jar and sealed with a Teflon-lined

lid. Twenty-five (25) of the discrete soil samples were analyzed for soil moisture content, grain size analysis and soil salinity. These data provided additional information for estimating erosion of soils and were utilized in the fate and transport analysis (Section 3.9).

2.2.2 Objective Deer

Objective Deer training area, located in the central portion of Makua Valley, consists of 17 target positions in the trench legs (as "pop-up" targets) and eight target positions (berms) in the center of the trench system. Because this large and relatively topographically flat site is one of the more heavily used objectives, randomly selected discrete soil samples were collected with a bias toward visible or point sources of surface impacts, including bare areas or areas of visible distressed vegetation. A total of 15 soil samples were collected at Objective Deer (Figure 2.1). Eight discrete soil samples were collected from the pop-up target positions within the various trench legs, and seven were collected from the target positions in the center of the trench systems (Figure 2.1).

2.2.3 Objective Coyote

This training area consists of 22 target positions (berms) on a topographic high that projects slightly into Makua Valley (Figure 2.2). A total of eight discrete soil samples were collected from the berms located on the east and west sides of the service road (four on the east side and four on the west side of the service road; Figure 2.2) that runs through the site. Mainly small arms projectiles (caliber 223, 5.5 mm, and 7.6 mm) were observed associated with the berms. Samples were biased towards any concentrations of projectiles or associated bare/bald areas.

Figure 2.1 Objective Deer

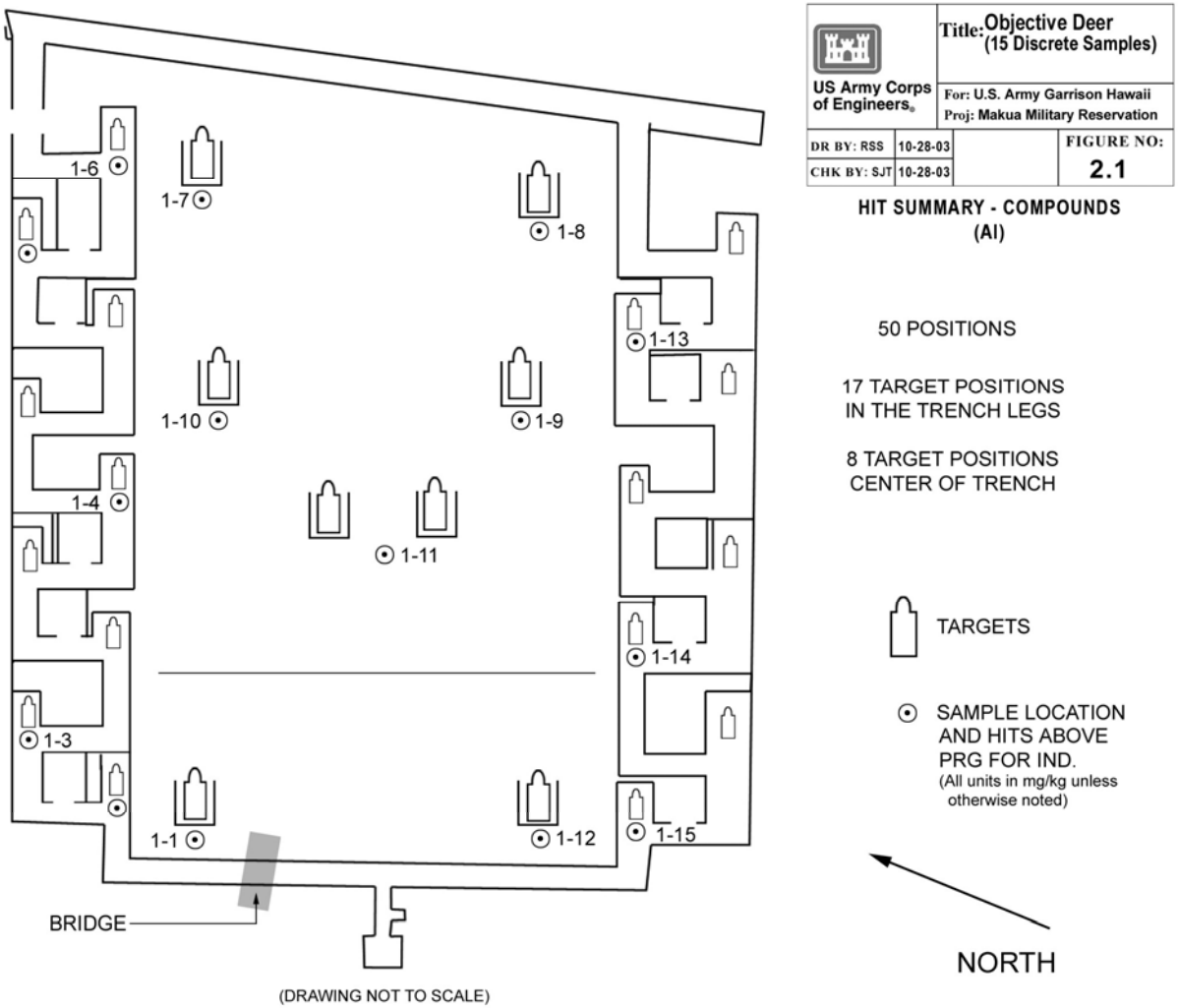


Figure 2.2 Objective Coyote

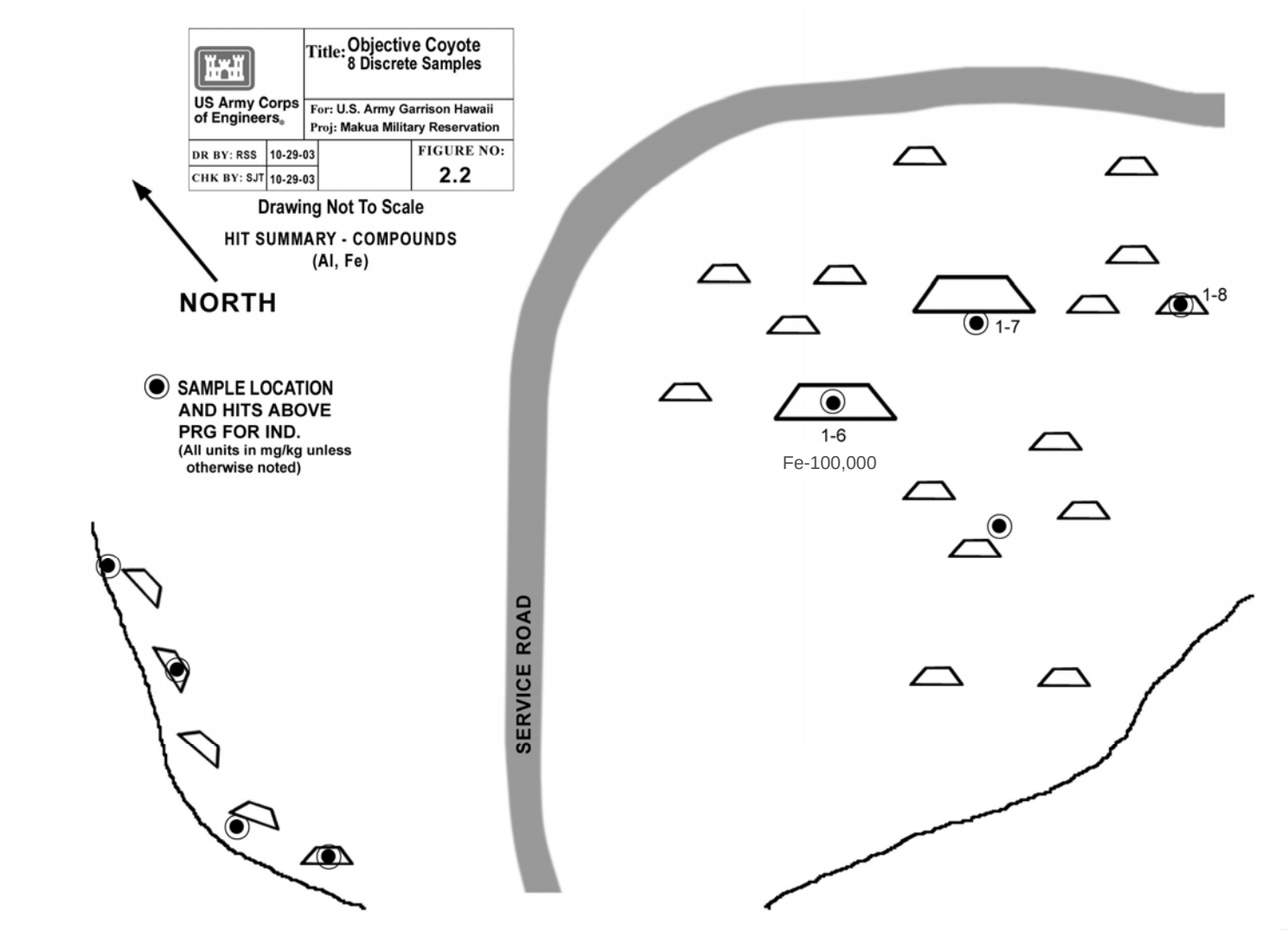


Table 2.1 Summary of Shallow Soil Sampling for Makua Military Reservation

Areas of Concern	Number of Samples to be collected
Objective Deer	15
Objective Coyote	8
Objective Fox	3
Objective Wolf	6
Objective Elk	10
Objective Deeds	3
Objective Badger	10
Objective Buffalo	6
Counter Attack Positions	14

Table 2.1 (Continued)

Summary of Shallow Soil Sampling for Makua Military Reservation

Areas of Concern	**Number of Samples to be collected**
105 Firing Area	2
Proposed Burn Pit	1
Makua Stream Firing Area	3
Weather Station Burn Pan	1
OB/OD Area	5
Demolition Pit (Area)	2
Area G	3
Misc. Training Areas	5
Deer Berms	5
Outlying Areas	22
Background Samples (metals)	10

2.2.4 Objective Fox

This training area consists of 8 target positions (berms) located in the lower elevations and parallel to the axis of Makua Valley. A total of three discrete soil samples were collected from three target positions in Objective Fox (Figure 2.3). A slight number of mostly caliber 223, 5.5 mm and 7.62 mm projectiles were observed in the berms. Soil samples were biased toward areas with a high concentration of projectiles on or within these berms.

2.2.5 Objective Wolf

This Objective consists of 14 target positions (berms) located on a small, low relief topographic "nose." Objective Wolf is the most forward position used for training in MMR. A total of six discrete soil samples were collected adjacent to the berms located northeast of the service road (Figure 2.4). Samples were biased toward bare areas observed within this position.

2.2.6 Objective Elk

This training area consists of 15 target positions (berms) located in the southern portion of Makua Valley. The 15 positions are situated around five large "tire forts" prominently visible on a small topographic nose in the southern areas of MMR. A total of 10 discrete soil samples were collected from four sites within Objective Elk (Figure 2.5). Five of the discrete samples were collected inside each tire fort (along walls or near pop-up targets positioned inside) and five were collected from the target berms located adjacent to the tire forts (Figure 2.5). Samples were biased toward concentrations of small arms projectiles and bald areas associated with the target berms and tire forts.

2.2.7 Objective Deeds

This training area consists of three fixed target positions located east of the service road. A total of three discrete soil samples were collected from three sites within Objective Deeds (Figure 2.6). Because of the rugged location (high relief) of these target positions, the three samples were collected on the front portions of the "berms" with a bias toward areas that had concentrations of small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50) or areas that appeared to have less vegetation than adjacent areas.

Figure 2.3 Objective Fox

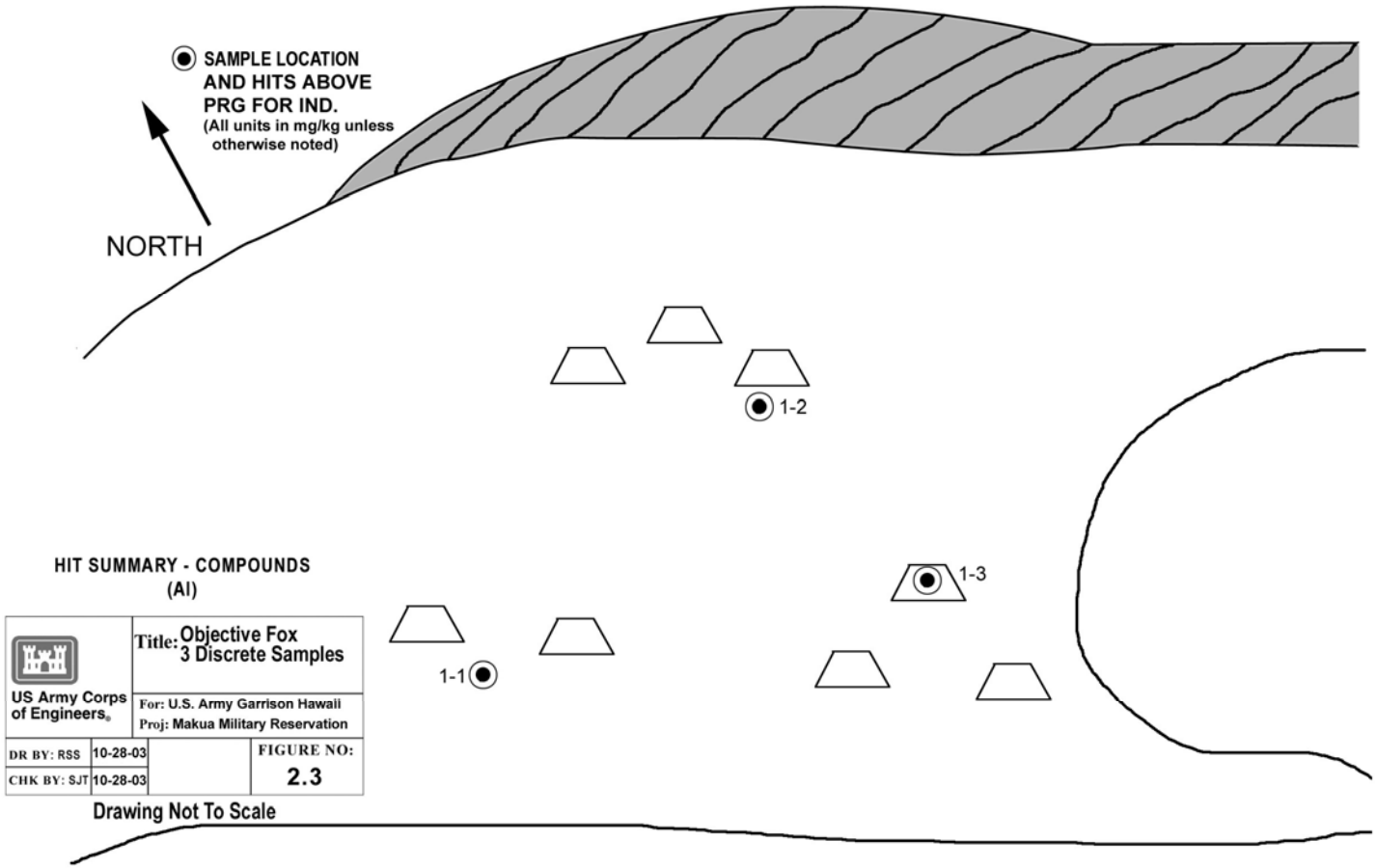


Figure 2.4 Objective Wolf

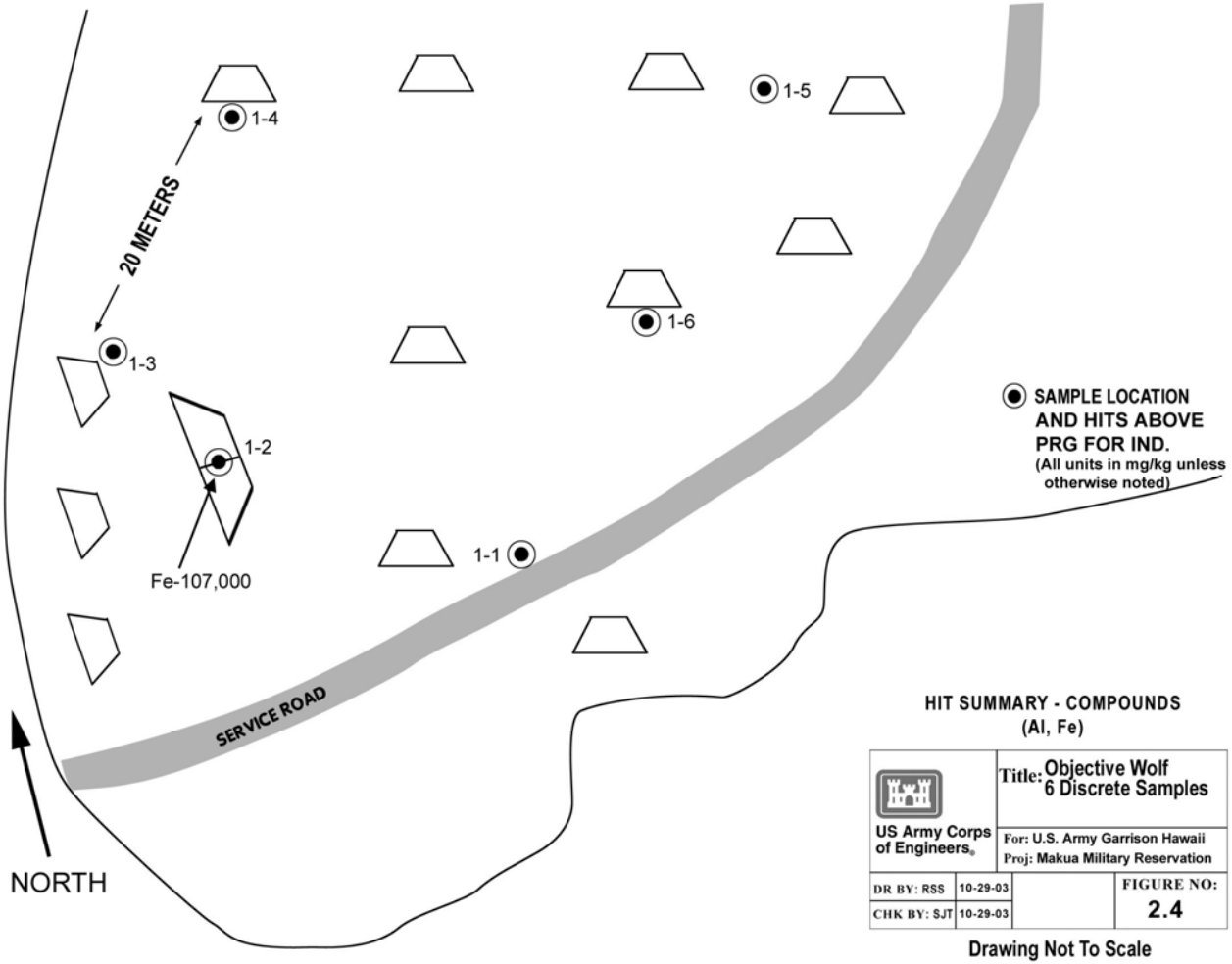


Figure 2.5 Objective Elk

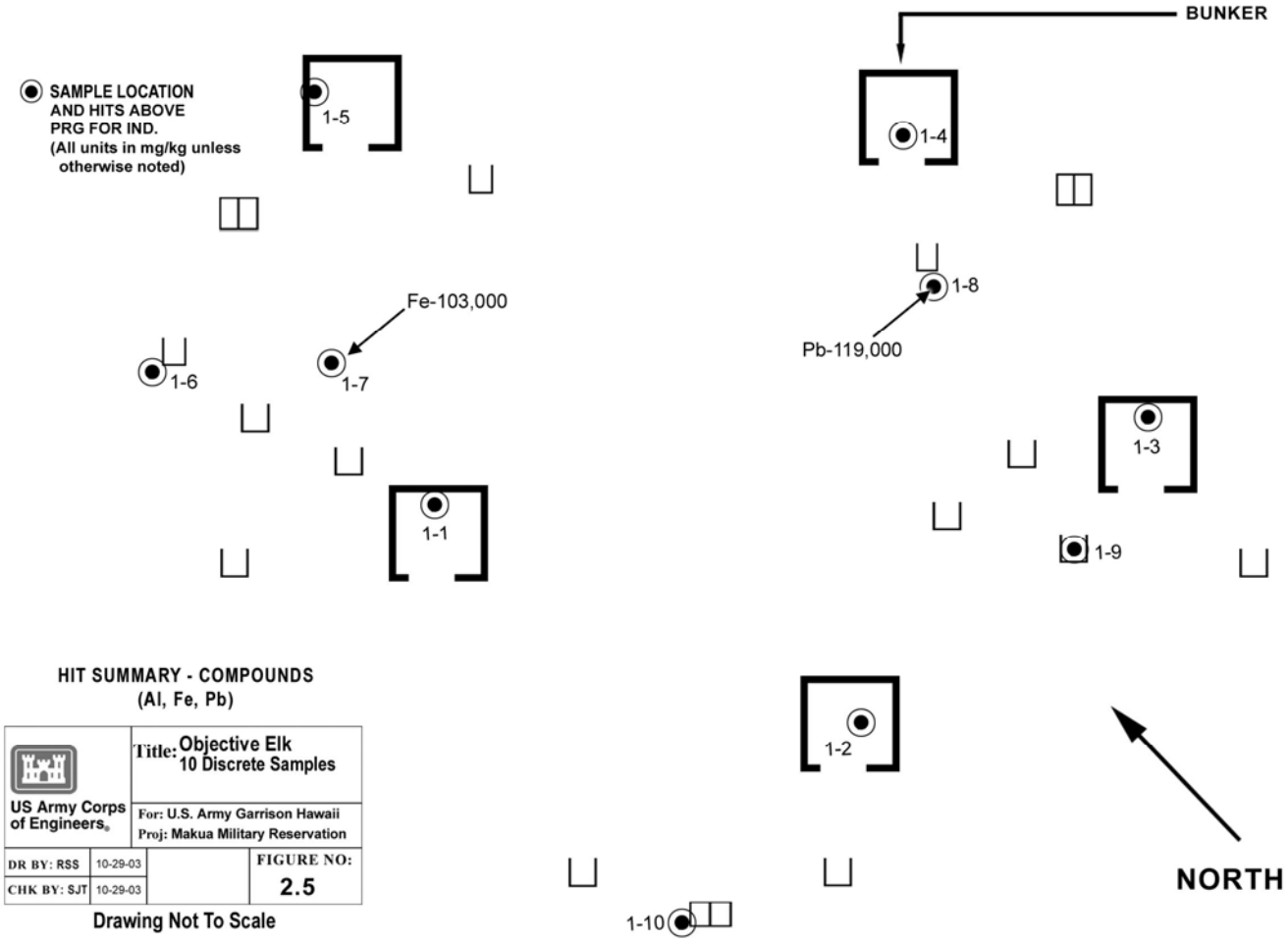
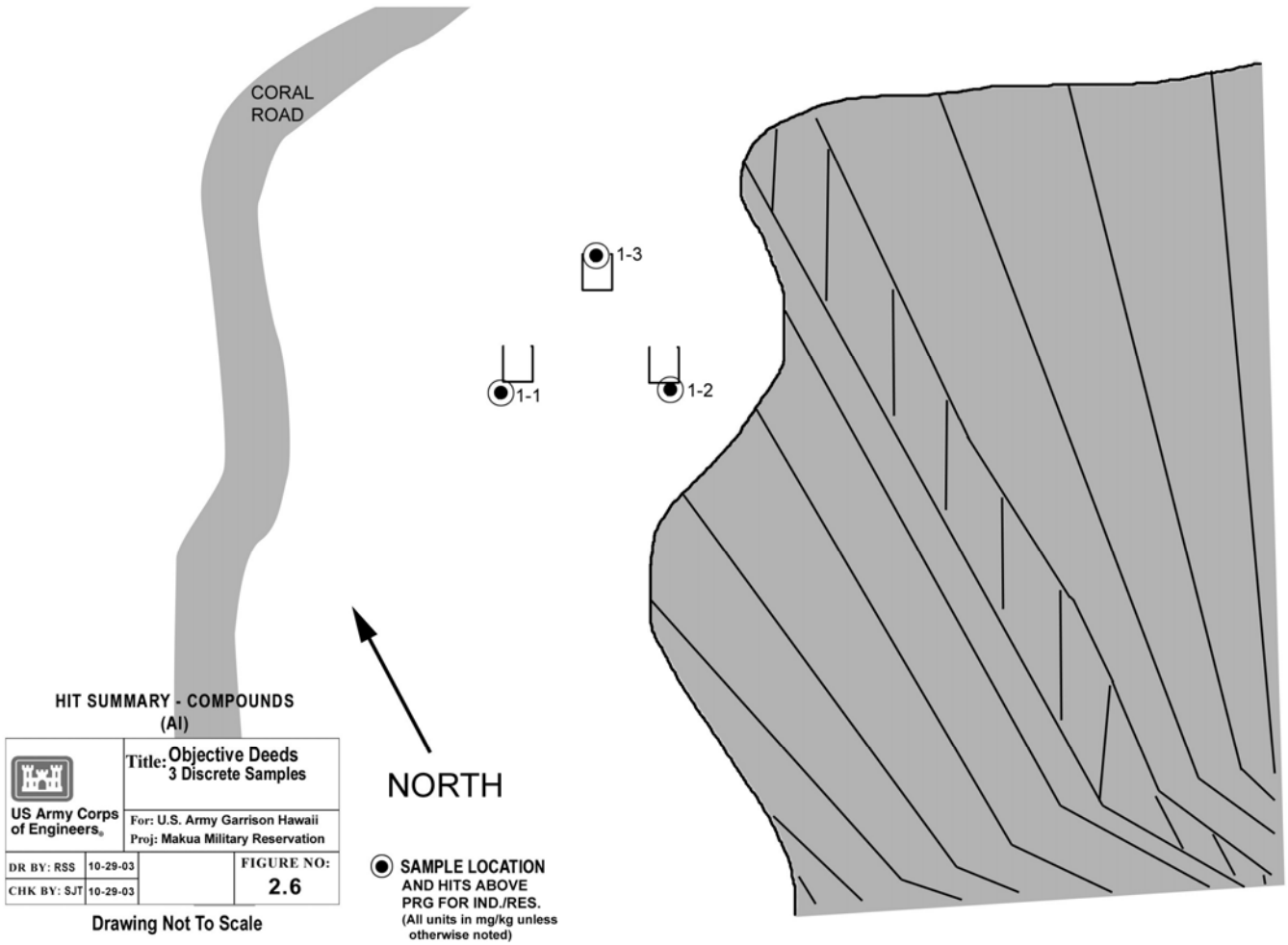


Figure 2.6 Objective Deeds



2.2.8 Objective Badger

This training area consists of five fixed positions reinforced with automobile tires (tire forts). A total of 10 discrete soil samples were collected from the five sites within or adjacent to the tire forts of Objective Badger (Figure 2.7). The five samples within the tire forts were collected along the walls or in areas near the pop-up targets located inside. Additionally, five samples were collected adjacent to the tire forts in areas that appeared to be in the "direct line of fire" during a combined-arms live-fire exercises (CALFEX).

2.2.9 Objective Buffalo

This training area consists of 11 fixed target positions (berms) and a small adjacent trench line just south of the service road. This objective is located on the rocky and rugged portion of an alluvial fan associated with Kaiahi Gulch. Five discrete soil samples were collected from the fixed target berms, and one was collected within the trench line associated with this objective (Figure 2.8). Soil samples collected at Objective Buffalo were biased toward bald areas associated with the target berms or the trench line.

2.2.10 Counter Attack Area

This training area consists of a broad, relatively flat area of 50 fixed target positions (berms). A total of 14 discrete soil samples were collected from the Counter Attack Area (CAA) (Figure 2.9). Because the CAA covers a large area, 14 discrete soil samples were collected in representative areas bare of vegetation, locations that were in the "direct line of fire" during a CALFEX, or concentrated zones of small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50).

2.2.11 One Hundred and Five (105) Firing Area

This area consists of a firing position for 105 mm artillery. This topographically flat area is the position of 105 mm artillery pieces that fire uprange toward the designated objectives during a CALFEX. A total of two discrete soil samples were collected at this location (Figure 2.10).

The two samples were collected in front of the artillery pieces (in slightly bare areas) in line with the 105's muzzle and the general direction of artillery fire (Figure 2.10)

Figure 2.7 Objective Badger

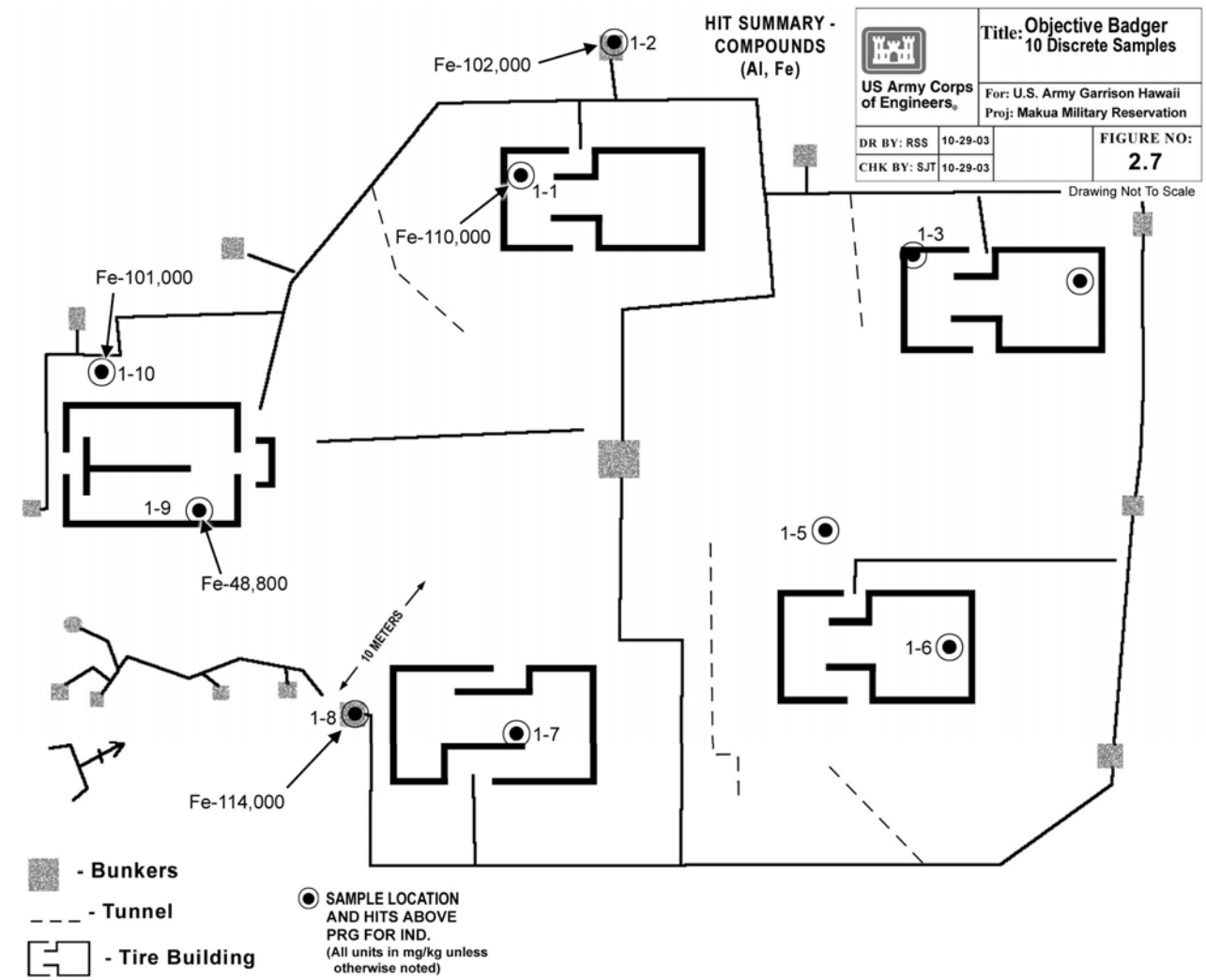


Figure 2.8 Objective Buffalo

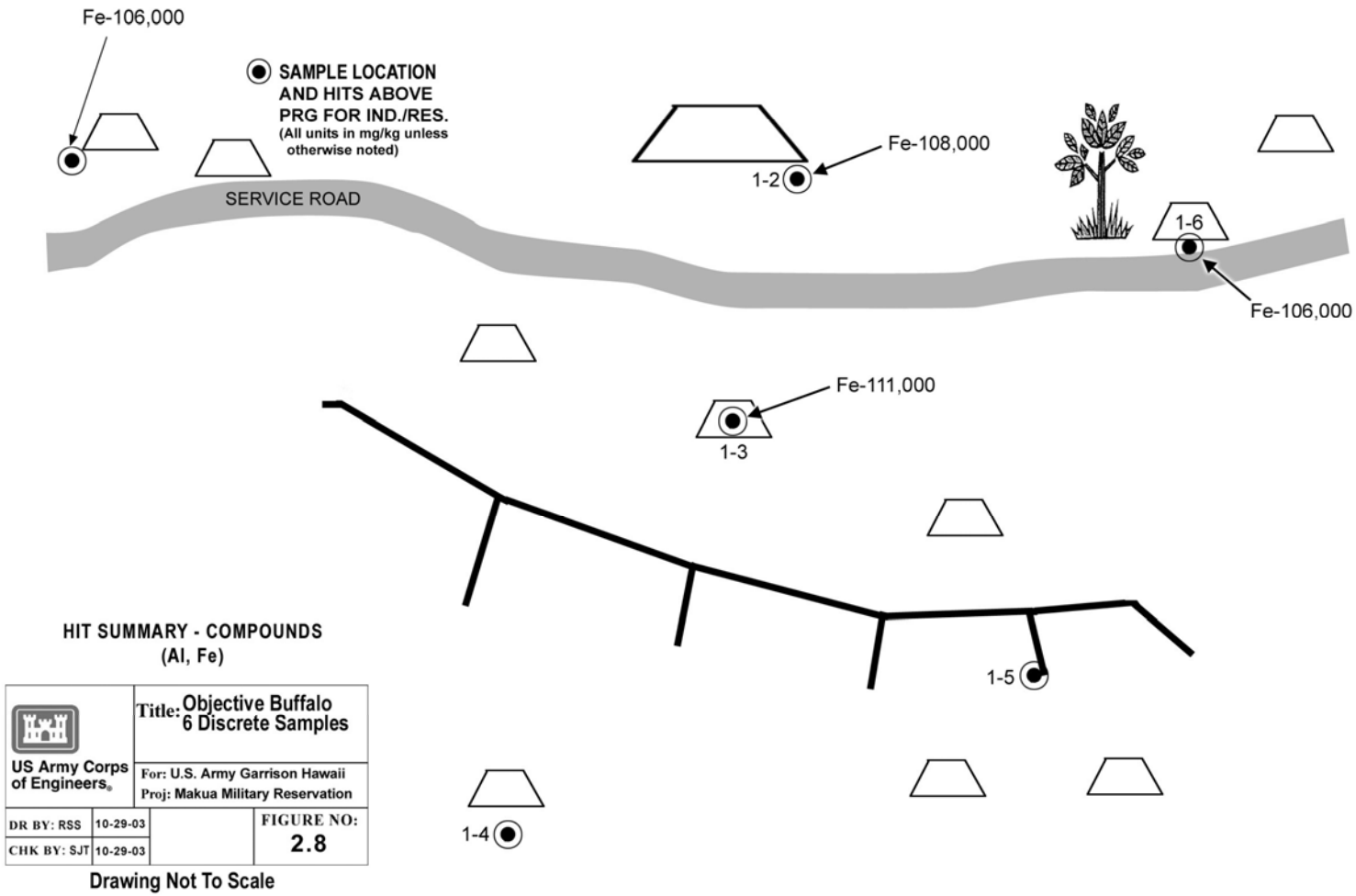


Figure 2.9 Counter Attack Area

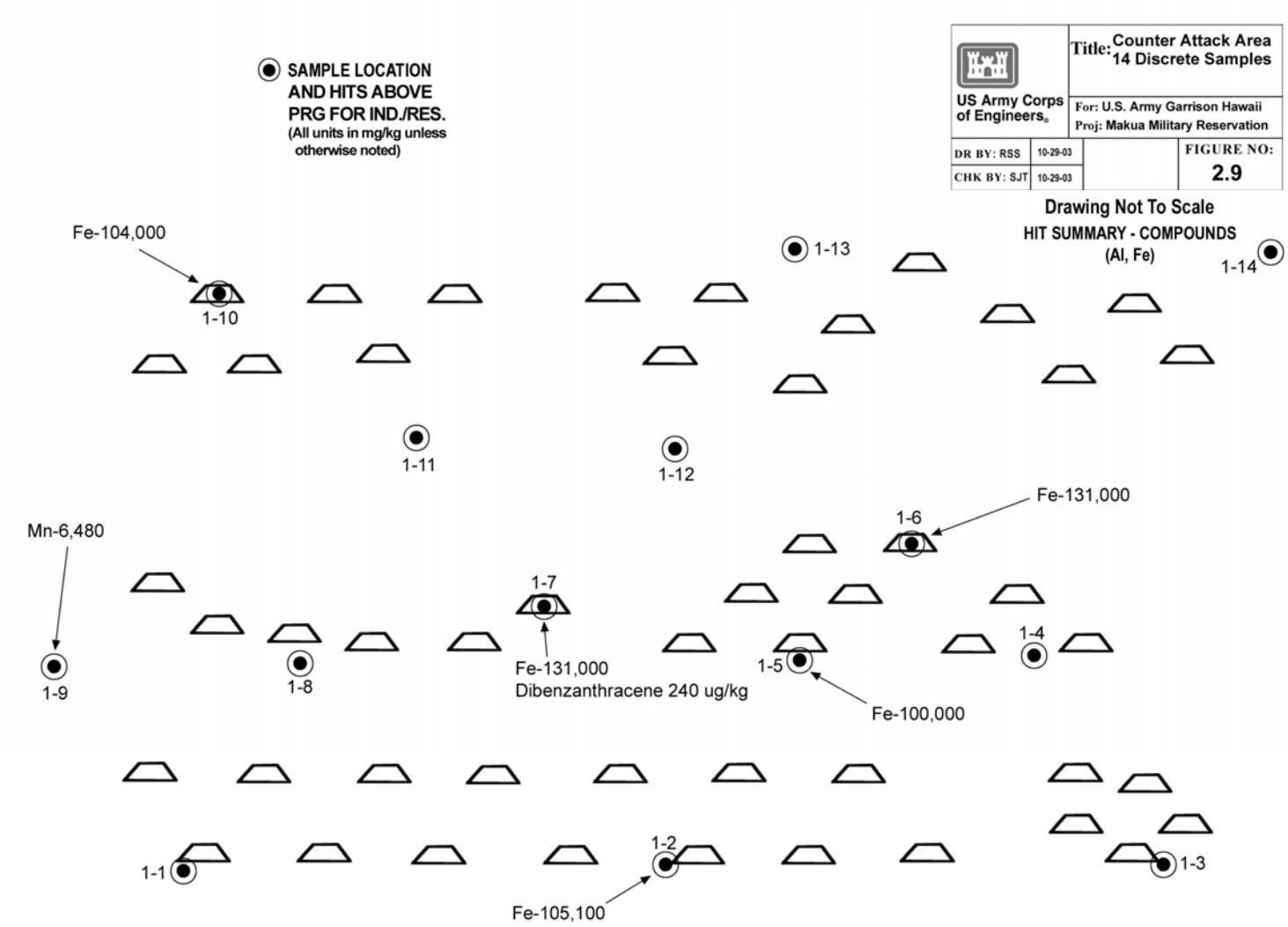


Figure 2.10 Makua Military Reservation Soil Sampling

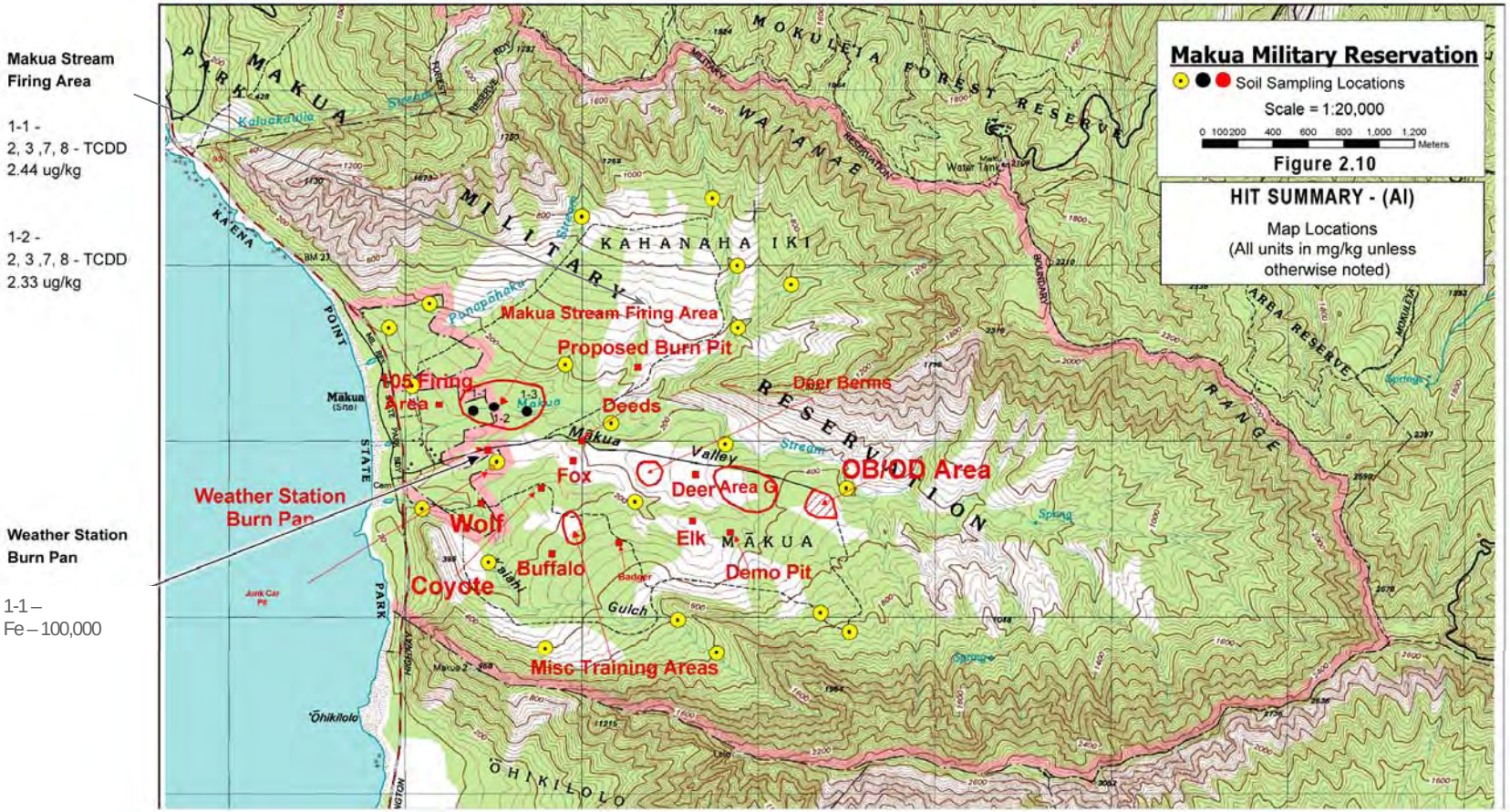


Figure 2.11 Makua Military Reservation Soil Sampling

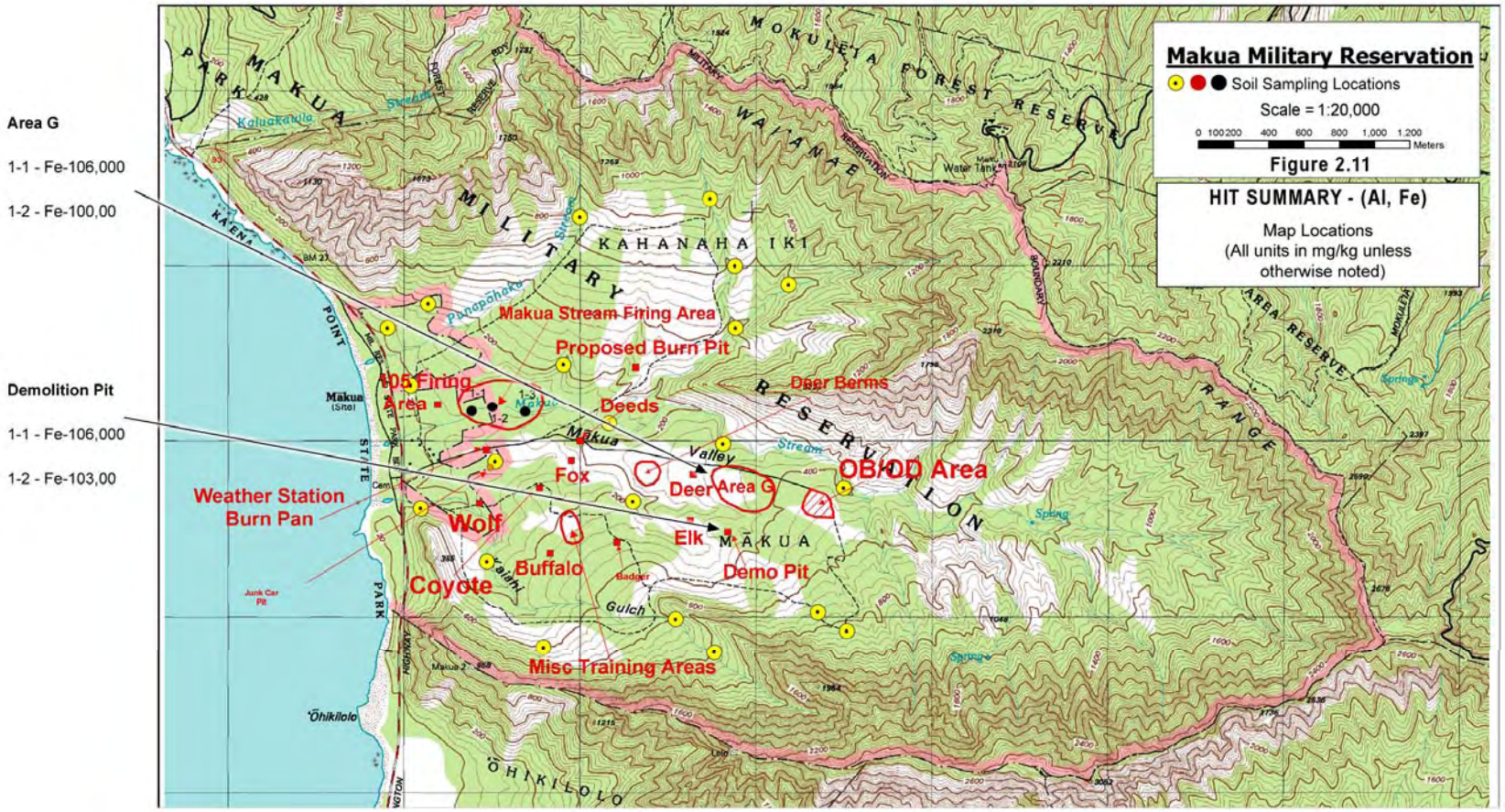


Figure 2.12 Makua Military Reservation Soil Sampling

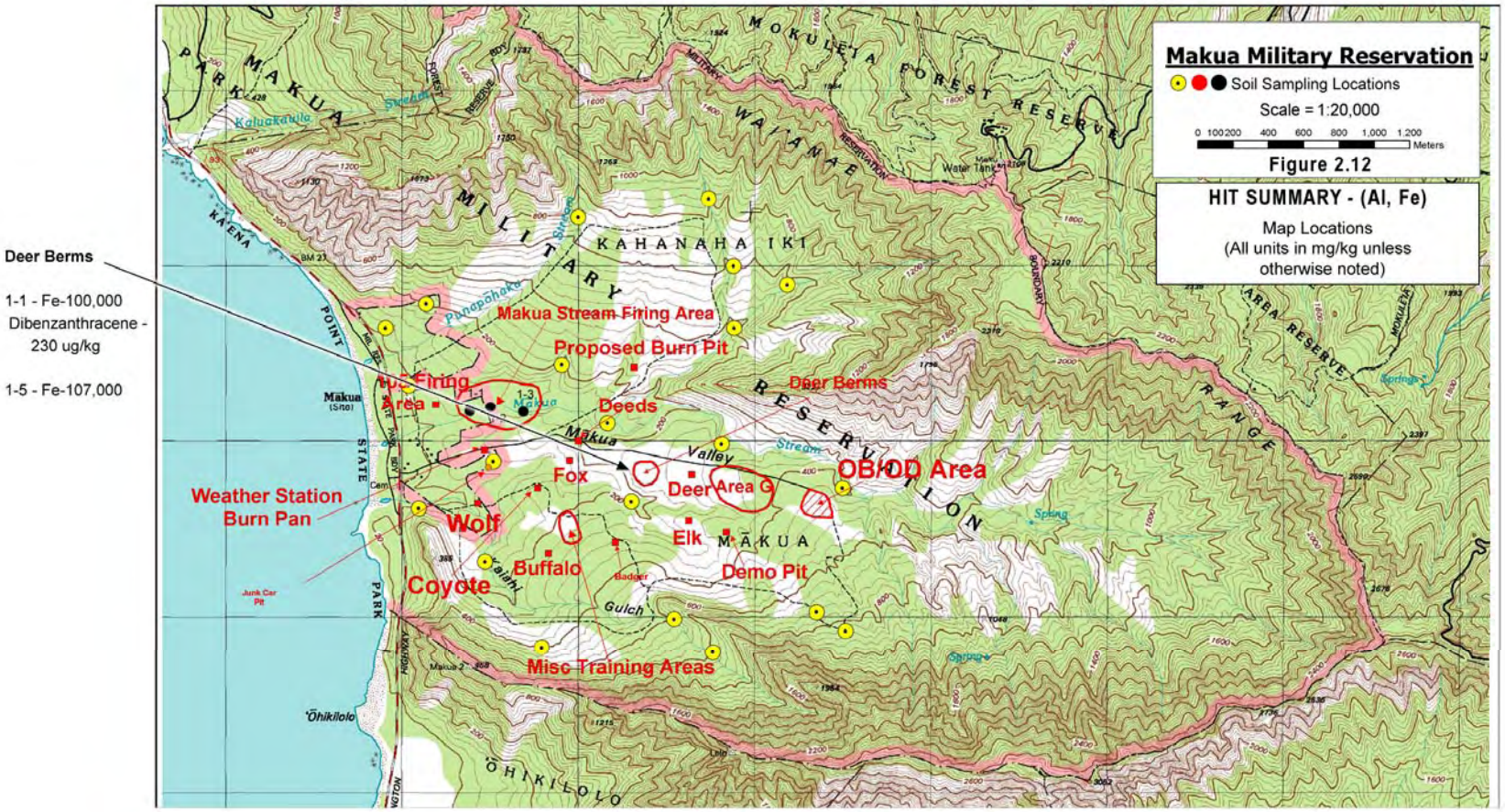
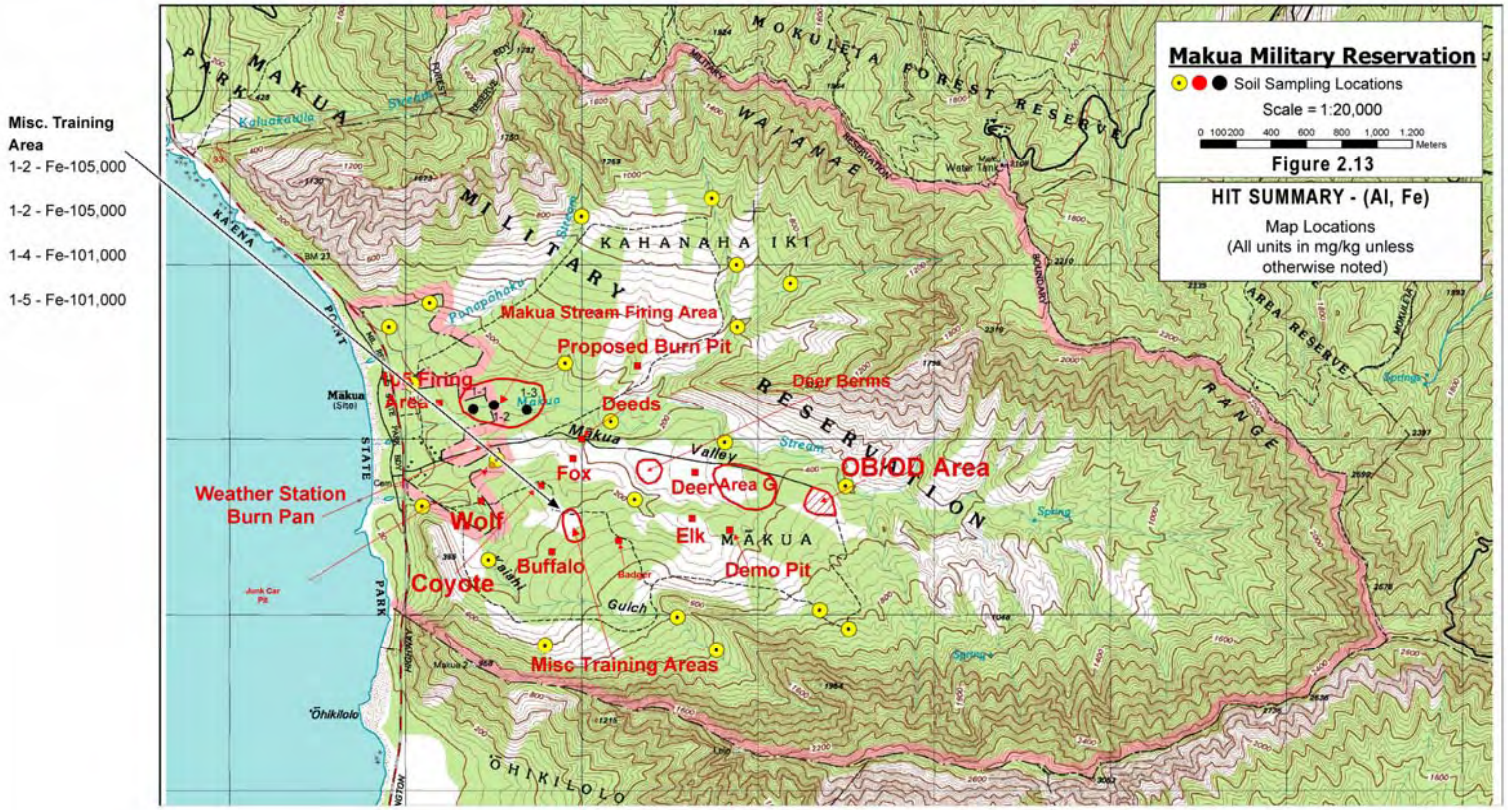


Figure 2.13 Makua Military Reservation Soil Sampling



2.2.12 Proposed Burn Pit

One discrete soil sample was collected at the Proposed Burn Pit (Figure 2.10). The proposed burn pit is located on the north firebreak road on a broad alluvial fan that trends from Kahanakahiki. The Burn Pit was never installed or used as a burn pit, but a discrete sample was collected at this location to verify the site status. The sample was collected in an area where a natural drainage would concentrate any soil contaminants located at the site.

2.2.13 Makua Stream Firing Area

Three discrete soil samples were collected in the Makua Stream Firing Area. This area is within the "firing footprint" of the 105 mm Artillery pieces. The three discrete samples were collected uprange of the 105 firing area in the "drainage area" associated with Makua Stream. The samples were collected in overbank deposits that are in the "line of fire" for the artillery pieces during a CALFEX.

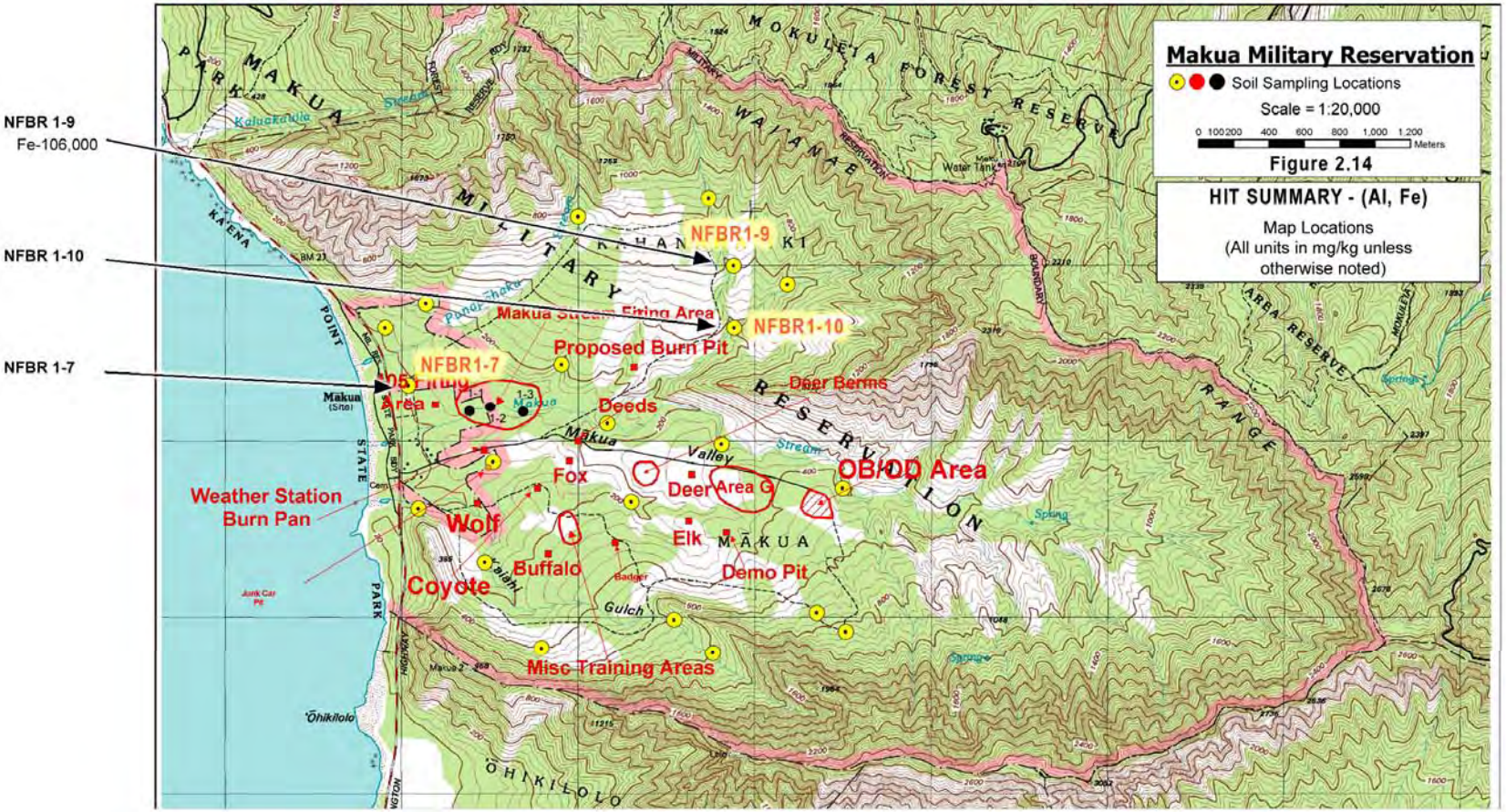
2.2.14 Weather Station Burn Pan

One discrete soil sample was collected from the burn pan at the weather station (Figure 2.10). The area sampled was a discolored area in a small depression that was barren of vegetation.

2.2.15 OB/OD Area

Five shallow soil samples were collected in the Open Burn/Open Detonation Area (Figure 2.15). Because of the presence of UXOs in this area, (and very thick vegetation) clearance was required for the traverses into and out of the sampling area as well as the sampling location itself. The five samples were collected in areas that were either small topographic depressions or slightly less vegetated and/or discolored areas.

Figure 2.14 Outlying Soil Sample Locations



2.2.16 Demolition Pit (Area)

Two discrete soil samples were collected from the Demolition pit (Figure 2.11). These samples were both collected in areas that were barren of vegetation (and slightly discolored) and chosen to be representative of the Demo Pit area.

2.2.17 Area G

Three discrete soil samples were collected from Area G (Figure 2.11). Because Area G is a large and relatively flat area, three samples were collected in areas representative of the whole objective. The sampled areas included zones of slightly less vegetation and discolored patches.

2.2.18 Miscellaneous Training Areas

Five discrete soil samples were collected from the Miscellaneous Training Areas (Figure 2.13). This relatively large area is located on a rocky hillside that is in reality a broad alluvial fan just north of Koiahi Gulch. The area is covered in short grass, making the sampling sites easy to position for representativeness. The five discrete samples were collected in minor depressions or features that had less vegetation than surrounding areas. Because the miscellaneous training areas cover such a large area, samples were collected to be as representative of the area as possible.

2.2.19 Deer Berms

Five discrete soil samples were collected from the Deer Berms (Figure 2.12). This objective includes a number of target berms that are spread over a rather large, relatively flat area. The five soil samples were collected at the fixed target berm positions. The five discrete soil samples were collected at the crown of the target berms or skewed to the side if discoloration or bare vegetation was encountered.

2.2.20 Outlying Soil Samples

An additional 22 soil samples were collected from areas mostly outside of the firebreak roads (North and South Fire Break Roads) that form the boundaries of the training areas.

Figure 2.14 shows the locations of these additional outlying shallow soil samples. The samples were collected from the fine sediments that were deposited in the intermittent streams and washes, from areas selected as being representative of a given site since metals, explosives, or other compounds would most likely collect in the materials in the bottom of the washes. One sample was also collected from the former junk car pit. The remaining 18 samples were positioned to investigate the potential for widespread distribution of contaminants throughout the Makua Valley. These are shown in Figure 2.14, and are labeled NFBR1- and SFBR1- (for North Fire Break Road and South Fire Break Road).

2.3 Boreholes and Lysimeters

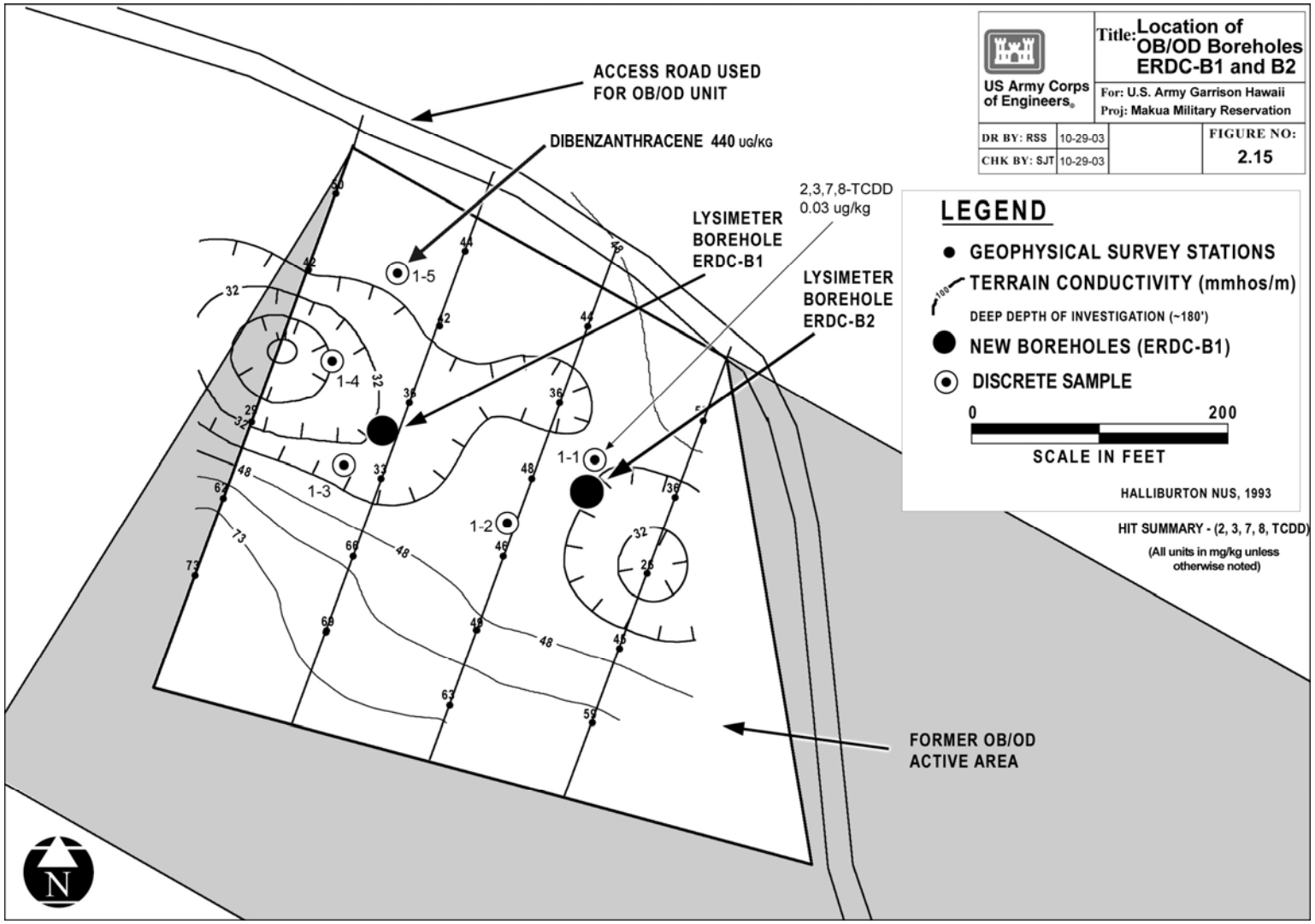
Soil samples were collected from boreholes within the OB/OD area and the former junk car pit to evaluate concentrations of contaminants from burn and disposal operations. These samples were collected to provide additional information on contaminants in the OB/OD area and former junk car pit. Figure 2.15 shows the location of these boreholes within the OB/OD area. Borehole B-1 was drilled down using a hollow stem auger drilling rig to a depth of 45 feet where a large rock was encountered. Samples were collected at intervals of 5 feet to a total depth of 45 feet within borehole B-1. All soil samples were analyzed for metal and explosives, with the sample at a depth of 10 feet analyzed for the complete suite of analytes listed in Table 2.2. The drilling rig was then switched to an air hammer rig, and the remaining 5 feet, to a depth of 50 feet, were drilled into the large boulder. The last split spoon sample at 50 feet depth was not collected, since sampling of a large boulder is not practical. Also, the deepest lysimeter should be placed in the most representative type of formation in the OB/OD area (clay/silt/sand), and not within a boulder.

Borehole B-2 was started drilling using hollow stem auger drilling methods. Again, drilling encountered a large boulder at 25 feet depth, but drilling through the boulder was achieved. At a depth of 44 feet the drilling encountered a gravel layer in which there was no recovery of samples from the split spoon sampler, and auger refusal was met. Since further

drilling in B-1 was futile, the decision was made to end the hole at 44 feet in the top of the gravel layer. Again, the lysimeter required placement in a representative formation (clay/silt/sand) in the OB/OD area. Samples were collected at intervals` of 5 feet, with all soil samples analyzed for metals and explosives, with the samples at depths of 5 and 15 feet analyzed for the complete suite of analytes listed in Table 2.2.

Drilling of the borehole in the junk car pit was difficult. The formation in the area above the junk car pit was clay with large gravel/boulders. Sample recovery using a split spoon sampler was accomplished a depths of 5 and 15 feet, with no sample recovered at depths of 10 and 20 feet due to excessive gravel in the formation. The sample at 5 feet depth was analyzed for the complete suite of analytes listed in Table 2.2, with the sample at 15 feet depth analyzed for metals and explosives. Drilling encountered auger refusal at 20 feet. The decision was made to complete the hole at a depth of 20 feet, since the formation had a high percentage of boulders that cannot be drilled by hollow stem auger methods.

Figure 2.15 Location of OB/OD Boreholes ERDC-B1 and B2



Lysimeters were installed in the boreholes in both the OB/OD area and the junk car pit. Lysimeters were installed at depths of 30 and 45 feet below grade in borehole B-1, and 30 and 42 feet below grade in borehole B-2. One lysimeter was installed in borehole B-3 (junk car pit) at a depth of 19 feet. The lysimeters will be used to collect pore water samples from beneath the OB/OD area and the former junk car pit. The porewater samples will be analyzed for as many of the complete suite of analyses as listed in Table 2.2. The amount of sample from lysimeters may be small (40 ml), so it is likely that results will be obtained only for volatile organic compounds, explosives, and metals. The amount of sample will depend on the soil types, and the ability of these soils to transmit water in the unsaturated zone.

Two rounds of groundwater samples were collected from the lysimeters in early April (April 4 and 5, 2003) and July (July 1 and 7, 2003). The amount of sample collected from the lysimeters is usually 40 to 150 ml, so there is a limit to the number of compounds that can be analyzed by the laboratory. The typical volume of 40 to 150 ml is sufficient for volatile organic analyses and explosives. This water collected from the lysimeters represents soil pore water contained within the unsaturated soil that is drawn into the lysimeter instrument. (A vacuum of 80 to 100 millibars is placed on the lysimeter to draw in the sample.)

For the first round of lysimeter sampling (April 4 and 5), water was collected from SB1A, 1B, and 2B, while SB2A and SB3A were dry. Sample volume was only sufficient enough for volatile organic analyses (40 ml) in SB1B and SB2B. This is quite common in Hawai`i, where the soils dry out and resulting infiltration is stopped, therefore providing no water for the lysimeters to sample. For the second round of groundwater sampling, the sample volume was greater, and additional analyses were run.

2.4 Streambed Soil Samples

Streambed soil sediment samples were collected to assess the impacts of metals, energetics (explosives), and other compounds that might flow with surface water from the OB/OD area as well as from the entire MMR. This surface water could recharge the groundwater

in the lower elevations, and potentially impact the groundwater chemistry. All of the streams in the Makua Valley are intermittent, so they flow only in large rainfall events. Three (3) sets of soil samples were collected from the streambeds at varying depths of 6, 12, and 18 inches below surface in Punapohaku Stream, Makua Stream, and Koiahi Gulch Stream. Soil samples were collected at depths of 6 and 12 inches in Kaluakauila Stream, because the depth of sediment in this stream was shallow (less than 12 inches). Samples were collected by hand digging with trowels. During digging, the site was checked for UXO.

The collected soil samples that were sent to an analytical laboratory to be analyzed for the compounds are listed in Table 2.2. These soil samples were collected on February 27, 2003, and were delivered to the analytical laboratory on February 28, 2003. Results of the streambed soil samples are reported in Section 3.4.

Table 2.2 Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Two (2) sets of OB/OD soil samples	Benzene	8021
	SVOCs	8270C/SIM
	RCRA total metals	6010B
	RCRA TCLP metals	1311/6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	Dioxin/furans	8280
	PCBs	8082
	Perchlorates	314.0
	Nitroglycerine	8332
Four (4) sets of streambed soil samples	Benzene	8021
	SVOCs	8270C/SIM
	RCRA total metals	6010B
	RCRA TCLP metals	1311/6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	Dioxin/furans	8280
	PCBs	8082
	Perchlorates	314.0
	Nitroglycerine	8332
Groundwater sampling - six (6) rounds from 7 monitoring wells	VOCs (including benzene)	8260B
	SVOCs	8270C/8310
	RCRA total metals	6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	PCBs	8082
	Perchlorates	314.0
	Dioxin	8290 (one round)
	Nitroglycerine	8332 (one round)

Table 2.2 (Continued)
Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Background Sampling	Dioxin/Furans	8280
Background Sampling (on-site)	RCRA total metals RCRA TCLP metals	6010B 1311/6010B
Shallow Surface Samples From Training Area (102 site screening samples)	RCRA total metals Energetics (explosives)	6010B 8330
Shallow Surface Samples From Training Area (25 of the 102 samples)	Soil moisture content Soil salinity Grain size analysis	
Shallow Surface Samples From Training Area (21 discrete samples)	Benzene SVOCs RCRA total metals RCRA TCLP metals Cyanide Sulfides Energetics (explosives) Nitrates/nitrites Chlorinated herbicides Pesticides Dioxin/furans PCBs Perchlorates Nitroglycerine	8021 8270C/SIM 6010B 1311/6010B 9010B 376.1 8330 300 8151A 8081A 8280 8082 314.0 8332
Stream Water Samples Four (4) samples from each stream flow event	VOCs (including benzene) SVOCs RCRA total metals Cyanide Sulfides Energetics (explosives) Nitrates/nitrites Chlorinated herbicides Pesticides Dioxin/furans PCBs Perchlorates	8260B 8270C/SIM 6010B 9010B 9030B 8330 300 8151A 8081A 8290 8082 314.0
72 samples from each stream flow event	Total Suspended Solids Grain size analysis	160.1

Table 2.2 (Concluded)
Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Eight (8) sediment and water samples from each stream flow event	RCRA total metals energetics (explosives)	6010B 8330
Lysimeter Pore water Samples*	RCRA Totals Metals Energetics (explosives) VOCs (including benzene)	6010B 8330 8260B

One round of groundwater samples will also include bicarbonate, calcium chloride, and silica. Method detection limits are listed in Sampling And Analysis Plan (Section 7)

*The analytes sampled from the lysimeters are limited due to the small amount of sample available

2.5 Surface Water Evaluation

The sampling and analysis plan called for samples of surface water to be collected in Makua Valley streams from September 1, 2002, through September 1, 2003, for up to three flow events. This period was extended through February 2004 until samples from three stream flow events were collected from all of the four streams of interest. The streams at Makua are intermittent, in that they flow only during larger rainfall events that occur only a few times each year, if at all. Surface water sampling of intermittent stream flow was conducted on Makua Stream during a rainfall event on February 13 and 14, 2003, January 23 and 24, 2004, and February 27 through March 6, 2004. For the first event on February 13 and 14, 2003, it rained approximately 5 inches in the Waianae Range on the margins of MMR and 2 inches in the Makua Valley near the ocean. At approximately 3:00 A.M. on February 14 Makua Stream began to flow, and it flowed until February 14 at 11:00 P.M. The automated sampler began collecting samples at an interval of one 1-liter bottle every 15 minutes for 2 hours, and every 0.5 hour for another 8 hours. The sampler was then reloaded with new bottles, and set to collect one 1-liter bottle every hour for the remainder of the flow event. The maximum flows on Makua Stream occurred from approximately 5:30 A.M. until 8:30 A.M. February 14. Table 2.3 lists the samples collected for the first event. Additional rainfall summary data are presented in Appendix L.

During the flow event at Makua Stream, a total of 40 (1) liter bottles were collected. Nearly all of these bottles were analyzed for total suspended solids, with five of the bottles analyzed for the complete suite of analyses. A listing of the time of bottle collection and the analytes for the samples is included in Table 2.3. These complete suite samples were collected on February 14 at 3:09, 3:48, 4:29, 5:29, 7:45, 20:56. These intervals provided data for surface water chemistry for first flush, peak flow, and the end of the flow event. In addition, dissolved metals samples were collected and analyzed from an additional 13 samples, and total metals were collected from an additional seven bottles. A total of 20 of the bottles were collected and

analyzed for explosives across the entire range that occurred over the 1-day period. These were more samples than was outlined in the Sampling and Analysis Plan because this event may have been the only stream flow event from which we could collect samples for this EIS effort. It was also desirable to make every attempt to quantify compounds in the water across a wide range of flows.

Table 2.3 Stream Water Sampling Intervals – First Event (February 14, 2003)

(Manually Collected Samples)

Sample Number	Round	Time	Date	Analytes
Koiahi Gulch				
MMRKSSW-R1	1	7:30	2/14/03	Full Suite (see Table 2.2)
MMRKSSW-R2	2	9:10	2/14/03	Metals, Explosives
MMRKSSW-R3	3	10:58	2/14/03	Metals, Explosives
MMRKSSW-R4	4	12:20	2/14/03	Metals, Explosives
Makua Stream				
MMRMSSW-R1	1	7:45	2/14/03	Full Suite (see Table 2.2)
MMRMSSW-R2	2	9:30	2/14/03	Metals, Explosives
MMRMSSW-R3	3	11:05	2/14/03	Metals, Explosives
MMRMSSW-R4	4	12:26	2/14/03	Metals, Explosives
MMRMSSW-R5	5	14:55	2/14/03	Metals, Explosives
Punapohaku Stream				
MMRPSSW-R1	1	7:58	2/14/03	Full Suite (see Table 2.2)
MMRPSSW-R2	2	9:35	2/14/03	Metals, Explosives
MMRPSSW-R3	3	11:15	2/14/03	Metals, Explosives
MMRPSSW-R4	4	12:33	2/14/03	Metals, Explosives
MMRPSSW-R5	5	15:10	2/14/03	Metals, Explosives
MMRPSSW-R6	6	16:00	2/15/03	Metals, Explosives
Kaluakauila Stream				
MMRKASSW-R1	1	7:58	2/14/03	Full Suite (see Table 2.2)
MMRKASSW-R1	2	9:35	2/14/03	Metals, Explosives
MMRKASSW-R1	3	11:15	2/14/03	Metals, Explosives
MMRKASSW-R1	4	12:33	2/14/03	Metals, Explosives
MMRKASSW-R1	5	15:10	2/14/03	Metals, Explosives
MMRKASSW-R1	6	16:15	2/15/03	Metals, Explosives

Table 2.3 Stream Water Sampling Intervals – First Event (February 14, 2003)
(Automated Sampler, Makua Stream)

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03, 2:55	1	x	x					x	Makua
2/14/03, 3:09	2			x	x	x	x	x	Makua
2/14/03, 3:15	3	x	x					x	Makua
2/14/03, 3:18	4	x	x					x	Makua
2/14/03, 3:33	5	x		x				x	Makua
2/14/03, 3:48	6	x	x	x	x	x	x	x	Makua
2/14/03, 3:55	7	x		x				x	Makua
2/14/03, 3:58	8	x	x					x	Makua
2/14/03, 3:59	9	x	x					x	Makua
2/14/03, 4:29	10	x	x	x	x	x	x	x	Makua
2/14/03, 4:59	11	x	x	x					Makua
2/14/03, 5:29	12	x	x	x	x	x	x	x	Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03, 5:59	13	x	x	x					Makua
2/14/03, 6:29	14	x	x						Makua
2/14/03, 6:59	15	x	x	x					Makua
2/14/03, 7:29	16	x	x						Makua
2/14/03, 7:59	17	x	x						Makua
2/14/03, 8:29	18	x	x	x					Makua
2/14/03, 8:59	19	x	x	x					Makua
2/14/03, 9:29	20	x	x						Makua
2/14/03, 9:59	21	x	x	x					Makua
2/14/03, 10:29	22	x	x						Makua
2/14/03, 10:59	23	x	x						Makua
2/14/03, 11:29	24	x	x						Makua
2/14/03, 11:50	25	x	x	x					Makua
2/14/03, 12:45	26	x	x	x					Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03,12:48	27	x	x						Makua
2/14/03, 13:35	28	x	x						Makua
2/14/03, 13:38	29	x	x						Makua
2/14/03, 14:38	30	x	x						Makua
2/14/03, 14:55	31	x	x	x					Makua
2/14/03, 14:58	32	x	x	x					Makua
2/14/03, 14:59	33	x	x						Makua
2/14/03, 15:41	34	x	x						Makua
2/14/03, 16:46	35	x	x						Makua
2/14/03, 17:46	36	x	x	x					Makua
2/14/03, 18:49	37	x	x						Makua
2/14/03, 19:49	38	x	x	x					Makua
2/14/03, 20:56	39	x		x	x	x	x	x	Makua
2/14/03, 21:56	40	x	x						Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream

Key

TSS = Total Suspended Solids

Metals and Explosives = Metals by methods 6010B (dissolved and total) and Explosives by Methods 8330

VOCs = Volatile Organic Compounds by Method 8260B

SVOCs = Semivolatile Organic Compounds by Methods 8270C and 8310

Perchlorates = Perchlorated by Method 314.0

Nitroglycerine = Nitroglycerine by Method 8332

Other = Composite samples of bottles 1 through 10 analyzed for: Cyanide by Method 9010B, sulfides by Method 376.1

Nitrate/nitrites by Method 300, Chlorinated Herbicides by Method 8151A, Pesticides by Method 8081A, and PCBs by Method 8082

Table 2.4 Stream Water Sampling Intervals – Second Event (January 23, 2004)
(Manually Collect Samples)

Stream	Round	Time	Date	Analytes
Koiahi Gulch				
MMRKGSR2-1	1	10:10	1/23/04	Full Suite (see Table 2.2)
MMRKGSR2-2	2	13:05	1/23/04	Metals, Explosives
MMRKGSR2-3	3	14:50	1/23/04	Metals, Explosives
MMRKGSR2-4	4	17:34	1/23/04	Metals, Explosives
MMRKGSR2-5	5	19:05	1/23/04	Metals, Explosives
Punapohaku Stream				
MMRPSR2-1	1	12:12	1/23/04	Full Suite (see Table 2.2)
Makua Stream				
MMRMSR2-1	1	11:10	1/23/04	Full Suite (see Table 2.2)
Kaluakauila Stream				
MMRKASR2-1	1	13:55	1/23/04	Full Suite (see Table 2.2)
MMRKASR2-2	2	18:25	1/23/04	Metals, Explosives

Table 2.4 Stream Water Sampling Intervals – Second Event (January 23, 2004) (Automated Samples from Makua Stream)

Date, Time	Bottle Number MMR-SW-E4-	TSS	Metals	Explosives	Stream
1/22/04 22:41	B01	x		x	Makua
1/23/04 1:12	B02	x	x		Makua
1/23/04 1:45	B03	x		x	Makua
1/23/04 2:18	B04	x	x		Makua
1/23/04 2:48	B05	x		x	Makua
1/23/04 3:31	B06	x	x		Makua
1/23/04 3:38	B07	x			Makua
1/23/04 4:23	B08	x			Makua
1/23/04 5:24	B09	x			Makua
1/23/04 6:24	B10	x			Makua
1/23/04 7:24	B11	x	x		Makua
1/23/04 8:24	B12	x		x	Makua
1/23/04 9:24	B13	x			Makua
1/23/04 10:24	B14	x			Makua
1/23/04 11:24	B15	x			Makua
1/23/04 12:24	B16	x			Makua
1/23/04 13:24	B17	x			Makua
1/23/04 14:24	B18	x			Makua
1/23/04 15:24	B19	x			Makua
1/23/04 16:24	B20	x			Makua
1/23/04 17:17	B21	x			Makua
1/23/04 18:17	B22	x			Makua
1/23/04 19:17	B23	x			Makua

Date, Time	Bottle Number MMR-SW-E4-	TSS	Metals	Explosives	Stream
1/23/04 20:17	B24	x	x		Makua
1/23/04 21:17	B25	x		x	Makua
1/23/04 22:17	B26	x			Makua
1/23/04 23:17	B27	x			Makua
1/24/04 0:17	B28	x			Makua
1/24/04 1:17	B29	x			Makua
1/24/04 2:17	B30	x			Makua
1/24/04 3:17	B31	x			Makua
1/24/04 4:17	B32	x			Makua
1/24/04 5:17	B33	x			Makua
1/24/04 6:17	B34	x			Makua
1/24/04 7:17	B35	x			Makua
1/24/04 8:17	B36	x			Makua
1/24/04 9:17	B37	x			Makua
1/24/04 10:17	B38	x			Makua
1/24/04 11:17	B39	x			Makua
1/24/04 13:17	B40	x			Makua
1/24/04 14:17	B41	x			Makua
1/24/04 15:17	B42	x			Makua
1/24/04 16:17	B43	x			Makua
1/24/04 17:17	B44	x			Makua

Key

TSS = Total Suspended Solids

Metals by Method 6010B, Explosives by Method 8330

Table 2.5 Stream Water Sampling Intervals – Third Event (February 27, 2004)

(Manually Collected Samples)

Stream	Round	Time	Date	Analytes
Koiahi Gulch				
MMR-KGS-R3-1	1	11:00	2/27/04	Full Suite (see Table 2.2)
MMR-KGS-R3-2	2	12:40	2/27/04	Metals, Explosives
MMR-KGS-R3-3	3	16:00	2/28/04	Metals, Explosives
MMR-KGS-R3-4	4	10:00	2/29/04	Metals, Explosives
MMR-KGS-R3-5	5	16:15	3/05/04	Metals, Explosives
Makua Stream				
MMR-MS-R3-1	1	11:15	2/27/04	Full Suite (see Table 2.2)
MMR-MS-R3-2	2	12:50	2/27/04	Metals, Explosives
MMR-MS-R3-3	3	13:10	3/04/04	Metals, Explosives
Punapohaku Stream				
MMR-PS-R3-1	1	12:25	2/27/04	Full Suite (see Table 2.2)
MMR-PS-R3-2	2	13:15	2/27/04	Metals, Explosives
Kaluakauila Stream				
MMR-KAS-R3-1	1	11:55	2/27/04	Full Suite (see Table 2.2)
MMR-KAS-R3-2	2	13:05	2/27/04	Metals, Explosives

Table 2.5 Stream Water Sampling Intervals – Third Event (February 27, 2004)
(Automatically Samples from Makua Stream)

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/27/04, 11:10	B01-1	x			Makua
2/27/04, 11:40	B02-1				Makua
2/27/04, 12:10	B03-1	x			Makua
2/27/04, 12:40	B04-1	x			Makua
2/27/04, 13:10	B05-1	x			Makua
2/27/04, 13:40	B06-1	x			Makua
2/27/04, 14:10	B07-1	x			Makua
2/27/04, 14:40	B08-1	x			Makua
2/27/04, 15:40	B09-1	x			Makua
2/27/04, 16:40	B10-1	x		x	Makua
2/27/04, 17:40	B11-1	x	x		Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/27/04, 18:40	B12-1	x			Makua
2/27/04, 19:40	B13-1	x			Makua
2/27/04, 20:40	B14-1	x			Makua
2/27/04, 21:40	B15-1	x			Makua
2/27/04, 22:40	B16-1	x			Makua
2/27/04, 23:40	B17-1	x			Makua
2/28/04, 0:40	B18-1	x			Makua
2/28/04, 1:40	B19-1	x			Makua
2/28/04, 2:40	B20-1	x			Makua
2/28/04, 3:40	B21-1	x			Makua
2/28/04, 4:40	B22-1	x			Makua
2/28/04, 5:40	B23-1	x			Makua
2/28/04, 6:40	B24-1	x			Makua
2/28/04, 11:00	B01-2	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/28/04, 11:30	B02-2	x			Makua
2/28/04, 12:00	B03-2	x			Makua
2/28/04, 12:30	B04-2	x			Makua
2/28/04, 13:00	B05-2	x			Makua
2/29/04, 9:50	B06-2	x			Makua
2/29/04, 10:50	B07-2	x			Makua
2/29/04, 11:50	B01-3	x			Makua
2/29/04, 12:50	B02-3	x			Makua
2/29/04, 13:50	B03-3	x			Makua
2/29/04, 14:50	B04-3	x			Makua
2/29/04, 15:50	B05-3	x			Makua
2/29/04, 16:50	B06-3	x			Makua
2/29/04, 17:50	B07-3	x			Makua
3/4/04, 15:01	B01-4	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
3/4/04, 16:01	B02-4	x			Makua
3/4/04, 17:01	B03-4	x			Makua
3/4/04, 18:01	B04-4	x			Makua
3/4/04, 19:01	B05-4	x			Makua
3/4/04, 20:01	B06-4	x			Makua
3/4/04, 21:01	B07-4	x			Makua
3/4/04, 22:01	B08-4	x			Makua
3/4/04, 23:01	B09-4	x			Makua
3/5/04, 0:01	B10-4	x			Makua
3/5/04, 15:38	B01-5	x			Makua
3/5/04, 16:38	B02-5	x			Makua
3/5/04, 17:38	B03-5	x			Makua
3/5/04, 18:38	B04-5	x			Makua
3/5/04, 19:38	B05-5	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
3/5/04, 20:38	B06-5	x			Makua
3/5/04, 21:38	B07-5	x			Makua
3/5/04, 22:38	B08-5	x			Makua
3/5/04, 23:38	B09-5	x			Makua
3/6/04, 0:38	B10-5	x			Makua
3/6/04, 7:38	B11-5	x			Makua
3/6/04, 15:38	B12-5	x			Makua
Key					
TSS = Total Suspended Solids					
Metals = Metals by Methods 6010B (dissolved and total)					
Explosives = Explosives by Methods 8330					

In addition to the bottles collected by the automated samples, six rounds of grab samples were collected in Koiahi Gulch Stream, Makua Stream, Punapohaku Stream, and Kaluakahila Stream. These were collected at intervals as listed below in Table 2.3. Complete suite samples were collected from 7:30 to 7:58 for the four streams on February 14, 2003. The results of the chemical analyses for the surface water sampling are discussed in Section 3.5.

For the second event (January 23 and 24, 2004) samples were collected as listed in Table 2.4. Both manually collected samples and samples collected by the ISCO automated sampler were sent to the analytical laboratory. More samples were collected from Koiahi Gulch Stream and Makua Stream than Punapohaku Stream and Kaluakahila Stream since these two streams drain the main portions of Makua Military Reservation.

For the third event (February 27 through March 6, 2004) samples were collected as listed in Table 2.5. Both manually collected samples and samples collected by the automated sampler were sent to the analytical laboratory. This stream flow event lasted much longer than other events with the stream flowing for 8 days. A very large log flowed down the stream and damaged the automated sampler and caused a memory failure for the unit (the memory failure may have also been caused by lightening). However, the required number of samples was still removed from the damaged sampler.

Two smaller surface water flow events occurred on April 6 and 7, 2003, and January 1 and 2, 2004. These rainfall events and surface water flows were smaller than the three main events. The smaller events occurred on a Sunday or holiday, and the project staff was unaware that the flow had occurred, as we remotely checked the weather stations and estimated incorrectly that a flow would not have occurred based upon the size of the rainfall event. As a result, the samples from the ISCO automated sampler were not removed from the sampler until after the event, and past the required holding times. The water collected from the automated sampler exceeded laboratory holding times; however, the decision was made to send these samples to the laboratory for metals, explosives, and total suspended solids analyses. Appendix E lists the

sampling interval for the samples collected during the April 6 and 7, 2003, and January 1 and 2, 2004, runoff events. Additional rainfall data are contained in Appendix L.

2.6 Rehabilitation of Monitoring Well SP-7

During 1993 one monitoring well was constructed at Makua Military Reservation (Halliburton NUS, 1994). This monitoring well was installed along Makua Stream as shown in Figure 2.15. This well had not been sampled in over 9 years and without some rehabilitation, groundwater sample results could be inaccurate. The rehabilitation involved bailing the well with a small drilling rig to remove solids for approximately 2 days. The well was also lightly surged with a surge block. A total of approximately 140 gallons were bailed from well SP-7 over the 2-day period. Parameters such as conductivity, pH, oxidation/reduction potential, turbidity, dissolved oxygen, and temperature were collected. Bailing was completed only after these parameters had stabilized. This well was sampled for groundwater chemistry as outlined in Section 3.7.

2.7 Groundwater Monitoring Wells in Dry Streambeds

Surface runoff of compounds from the Makua Military Reservation constitutes a second pathway of potential importance. It is a concern that surface water flows during large rainfall events in the intermittent streams might infiltrate (recharge) the alluvial material and impact the groundwater chemistry.

Two additional shallow wells (ERDC-MW-1 and ERDC-MW-2) were installed on Makua Military Reservation as shown in Figure 2.16. These wells were installed to evaluate surface water infiltration from the Koiahi Gulch Stream and Punapohaku Stream that may be impacting the groundwater chemistry. These are the two intermittent streams north and south of Makua Stream, so these wells are north and south of the existing well SP-7. Well MW-1 was drilled to a depth of 36 feet, with a shallow water level measured at a depth of 7.5 feet from land surface. Drilling was accomplished using the hollow stem auger method. The specification called for monitoring wells to have screens above the water table so that floating compounds that

might be in groundwater would enter the well. Therefore, 30 feet of PVC screen was placed in the hole, with 6 feet of PVC blank to land surface. Elevation of the top of the wellhead is approximately 9 feet. Table 2.6 summarizes the well construction for the wells at Makua Military Reservation. Well MW-1 was developed for 2 days to allow for accurate sampling. Well MW-1 was sampled as outlined in the groundwater sampling chemistry sections of this Appendix.

Well MW-2 was drilled along Punapohaku Steam to sample groundwater along the southern portions of Makua Valley. Well MW-2 was drilled to a depth of 36 feet, with a measured water level of 8.6 feet below grade. This well was installed with 30 feet of PVC screen below land surface and 6 feet of blank casing. This shallow well will allow for floating compounds to enter the well. The well was completed and developed for 2 days to allow for proper samples to be collected. An approximate total of 1800 gallons was removed from this well during development over the 2-day period. Well MW-2 was sampled as outlined in the groundwater sampling chemistry sections of this Appendix.

2.8 Deep Monitoring Wells

Two sets of nested triple sets (two locations, three wells at each location) of monitoring wells and one upgradient well were installed to provide information of groundwater chemistry deeper below land surface. A total of seven deeper monitoring wells were drilled and installed for this task. The locations of the monitoring wells are shown in Figure 2.16. These additional groundwater wells were used to evaluate the potential for contamination from the MMR to impact the groundwater discharging to the ocean. A review of data from these wells will be used to evaluate the potential impacts on groundwater of metals or explosives resulting from ordnance throughout the Makua Valley, not just the OB/OD area. These wells (ERDC-MW-3A, 3B, 3C, ERDC-MW-4A, 4B, 4C, and ERDC-MW-5) were installed downgradient of potential sources such as the OB/OD area.

Figure 2.16 Monitoring Well Locations

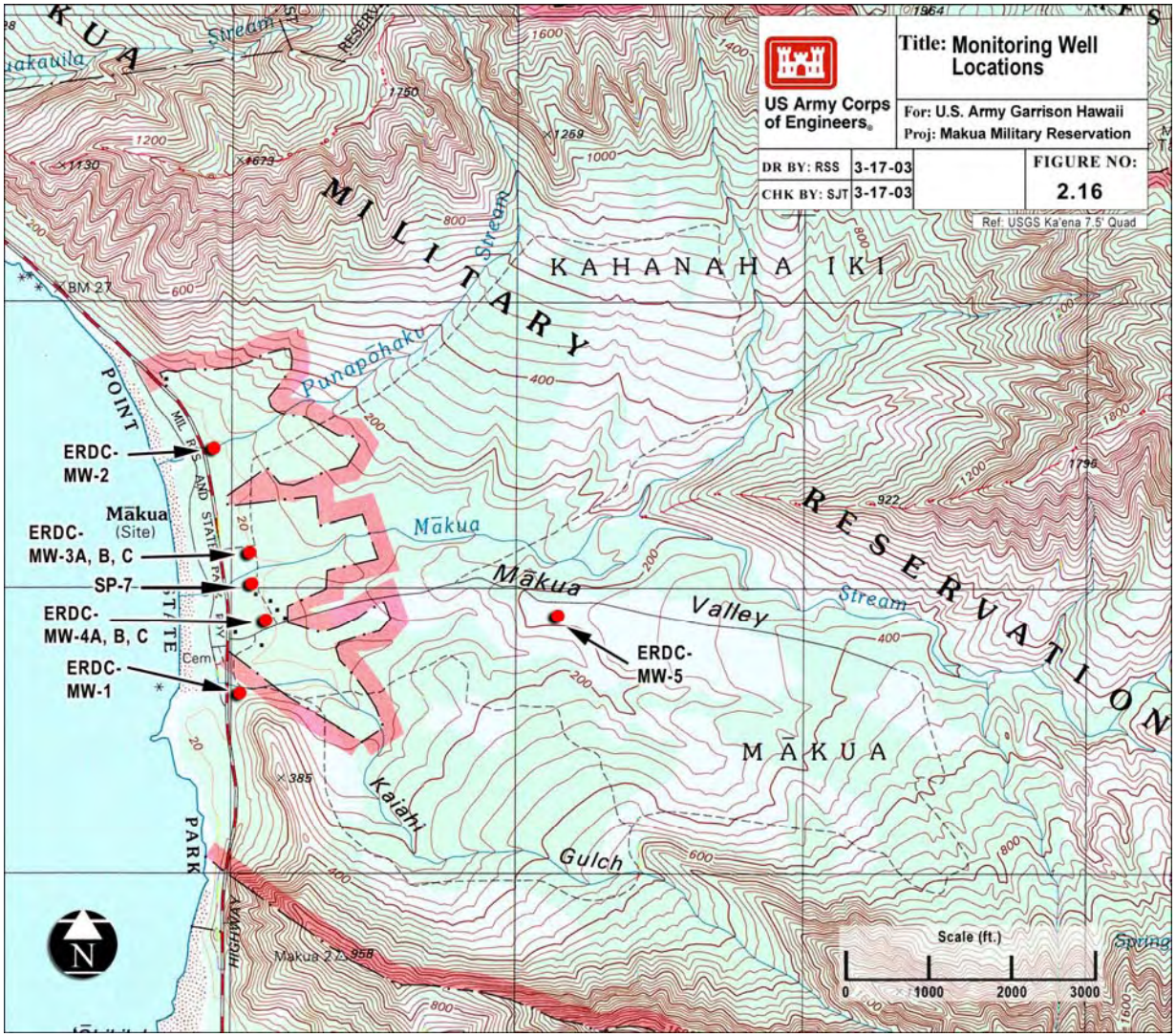
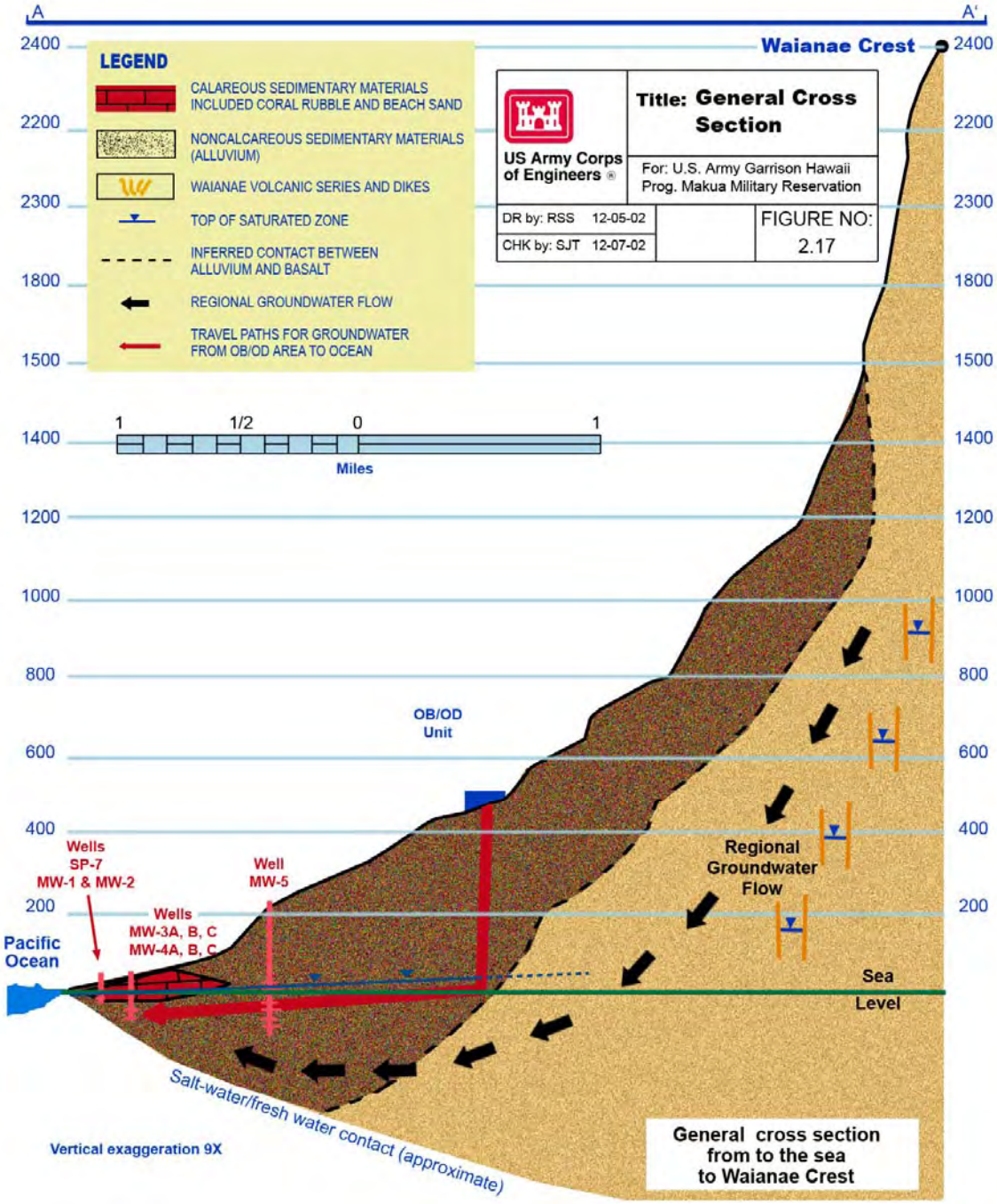


Table 2.6 Monitoring Wells at Makua Military Reservation

Well No.	Wellhead Elevation (feet MSL)	Depth from Land Surface (feet)	Elevation of Screen Interval (feet MSL)
ERDC-MW-1	10	36	+ 4 to –26
ERDC-MW-2	10.8	36	+ 5 to –25
ERDC-MW-3A	19.1	45	+4 to –26
ERDC-MW-3B	18.3	69	-26 to –51
ERDC-MW-3C	18.6	100	-51 to –81
ERDC-MW-4A	19.3	45	+ 4 to –26
ERDC-MW-4B	19.3	70	-26 to –51
ERDC-MW-4C	19.7	100	-50 to –80
ERDC-MW-5	235.4	320	20 to -85

Figure 2.17 General Cross Section



This will allow sampling of groundwater prior to it reaching receptors (the ocean). The sets of wells ERDC-MW-3A, B, C and ERDC-MW-4A, B, C were tiered to sample groundwater at different elevations. This will provide a more accurate assessment of the potential for contamination to reach the ocean by sampling different levels within the freshwater lens.

Figure 2.17 shows a cross section of the Makua Military Reservation running from the ocean (makai) to the top of the Waianae Range (mauka). There are generally two components of groundwater flow to the ocean: the regional groundwater flow in the Waianae volcanic rocks (black arrows in Figure 2.17) and potentially the groundwater flow in perched layers in the alluvium (red arrows in Figure 2.17). Groundwater percolating through the soils below the OB/OD area might travel either of these two paths shown in black or red in Figure 2.17. Figure 2.17 shows that the seven additional monitoring wells (ERDC-MW-3A, 3B, 3C, 4A, 4B, 4C, and MW-5) are designed to sample groundwater in these two paths.

Wells ERDC-MW-3A and 4A were designed to sample groundwater flowing within the alluvium, and potentially discharging at the ocean. The screened interval for ERDC-MW-3A and 4A are in the alluvial formation layers containing groundwater, sampling a somewhat deeper portion of the freshwater lens than wells SP-7, ERDC-MW-1 and ERDC-MW-2. Wells ERDC-MW-3A and 4A were installed with hollow stem auger drilling methods. They were installed to a total depth of 45 feet, with a screen length of 30 feet extending from +4 to -26 feet MSL. This screen extends above the top of the water table to allow potentially floating compounds to flow into the well.

Wells ERDC-MW-3B, 3C and 4B, 4C sample groundwater in regional groundwater flow that might flow below the existing shallow monitoring well (SP 7) or the shallower monitoring wells. The screened intervals for these wells are listed in Table 2.6. The bottom of the screened interval for ERDC-MW-3B and 4B was placed at an elevation of approximately –50 feet, with a 25feet screen extending from an elevation of about -26 to -51 feet MSL. The bottom of wells ERDC-MW-3C and 4C was placed approximately near the top of the freshwater/saltwater

interface, with a 30-feet-long screened interval at an elevation of -52 to -82 MSL. Wells ERDC-MW-3B and 4B were drilled with hollow stem auger drilling method, while the two deeper wells ERDC-MW-3C and 4C were drilled using air rotary drilling methods. The drill cuttings were also screened for gamma radiation in all of the wells.

Well ERDC-MW-5 was installed between the OB/OD area and the ocean. This well is also located between the impact area and the ocean. This well was installed at an approximate elevation of 235 feet above MSL. This well will act as an "early warning well" to measure the potential for contamination from upland areas, such as the OB/OD area or impact area, to discharge into the ocean. This well encountered a thick layer of silt and clay extending to a depth of approximately 290 feet below land surface. No water was encountered during drilling of this thick silt/clay unit from land surface to a depth of 290 feet, even though the well was allowed to sit overnight. It was evaluated that this formation would make a poor well, so drilling was continued to a total depth of 340 feet, where a higher permeability gravel layer was encountered from a depth of 290 to 340 feet. Based on a review of the drilling data with the field geologist, the project manager, and the project's technical advisor, the well was installed with 105 feet of screen from a depth of 215 to 320 feet. The screen extends from 20 feet above the water table to a depth that is 30 feet within the first formation that transmits water. Therefore, the well samples trace levels of contamination that might flow in the silt/clay layer, as well as within the gravel layer beneath. Additional explanation of the geologic information is listed in the Geologic Information Section, 3.8.3.

2.9 Background Soil Sampling Programs

The background soil-sampling program included off-site samples for dioxin and furans, as well as samples collected from Makua Valley to evaluate background metals concentrations. These samples were collected during February and September 2003 after the land access agreements were negotiated. In the case for all six background dioxin locations, samples were collected from State of Hawai`i owned or managed lands.

An additional survey of radiation levels was taken of the Island of O`ahu for comparison to the levels measured in Makua Valley. Measured radiation readings are summarized in Section 3.6. The radiation readings were taken with a GR-110 Exploranium Gamma Ray Scintillometer. On December 26, 2003, a survey trip was taken around the entire Island of O`ahu, and scintillometer readings were collected. These readings are outlined in Section 3.0 of this report.

The Background soil-sampling program included off-site samples analyzed by the laboratory for dioxin and furans, as well as samples collected from Makua Valley to evaluate background metals concentrations. Samples for dioxins and furans were collected from the boreholes in the burn area and from the streambeds. Dioxin samples were also collected during one round for all 10 groundwater wells. Locations of the off-site background soil samples are shown in Figure 2.18 and listed in Table 2.7.

It is necessary to evaluate background dioxin and furan levels in soils, since dioxin and furans are often found in soil samples, and may be unrelated to military operations at a site. Dioxin compounds are created during the burning of wood, and can be created by the brush fires that occur frequently along the Waianae Coast.

Since dioxin and furans could be created by conditions other than military operations at Makua, background samples locations were selected in other areas along the Waianae Coast. Written permission was obtained from the State of Hawai`i, as all of the locations selected were on lands owned by the State of Hawai`i. Listed below is an explanation of the samples.

Samples from the three mauka (mountain side) locations were used to evaluate background dioxin/furan levels in alluvial soil materials. Samples from stream bottoms were used to evaluate background dioxin/furan levels in streambed soil samples. The sample locations have been selected in areas that can be accessed easily. These final locations did vary somewhat from those shown in the Sampling and Analysis Plan, as the locations were moved to State of Hawai`i owned lands for access (Figures 2.19 through 2.23).

The background soil samples ERDC-BK2, 4, and 6 set were collected on February 28, 2003, and ERDC-BK1, 3, and 5 were collected on September 9, 2003. Sample results are contained in Section 3.6 of this report.

Figure 2.18 Background Sampling Locations

Table 2.7 Off-Site Background Sample Locations

Number	Depth	Media Sampled	Figure Number
ERDC-BK1A,B	6 and 12 inches	Alluvium north of Makua Valley	2.19
ERDC-BK2A,B	6 and 12 inches	Alluvium in Makaha Valley	2.20
ERDC-BK3A,B	6 and 12 inches	Alluvium in Waianae Valley	2.21
ERDC-BK4A,B	6 and 12 inches	Streambed in Keaau area	2.22
ERDC-BK5A,B	6 and 12 inches	Streambed in Makaha Valley	2.23
RDC-BK6A,B	6 and 12 inches	Streambed in Waianae Valley	2.21

2.10 Groundwater Sampling

For this project a total of six (6) rounds of groundwater samples were collected from each monitoring well, including the previously installed well (SP-7), and the nine new wells (ERDC-MW-1, 2, 3A, 3B, 3C, 4A, 4B, 4C, 5). All six rounds have been collected. The first round of groundwater samples was collected from December 15 through December 24, 2002. The second round of groundwater samples was collected from January 16 through February 13, 2003. For this second round, all the wells were sampled from January 16 2003, through January 23, 2003, except for well ERDC-MW-5, which was sampled on February 13, 2003. Sampling of this well (MW-5) was delayed due to a CALFAX occurring at Makua, as sampling cannot take place during live fire exercises. Sampling was also delayed due to pump equipment problems. The third round was collected April 1 through 7, the fourth round was collected April 21 through 28, and the fifth round was collected September 29 through October 3, 2003. The sixth round was collected in December 2003 through January 2004. This allowed for 1 full year of groundwater conditions to be sampled. The results of the groundwater sampling are listed in Section 3.7.

Figure 2.19 Detailed Background Sampling Locations ERDC-BK-1

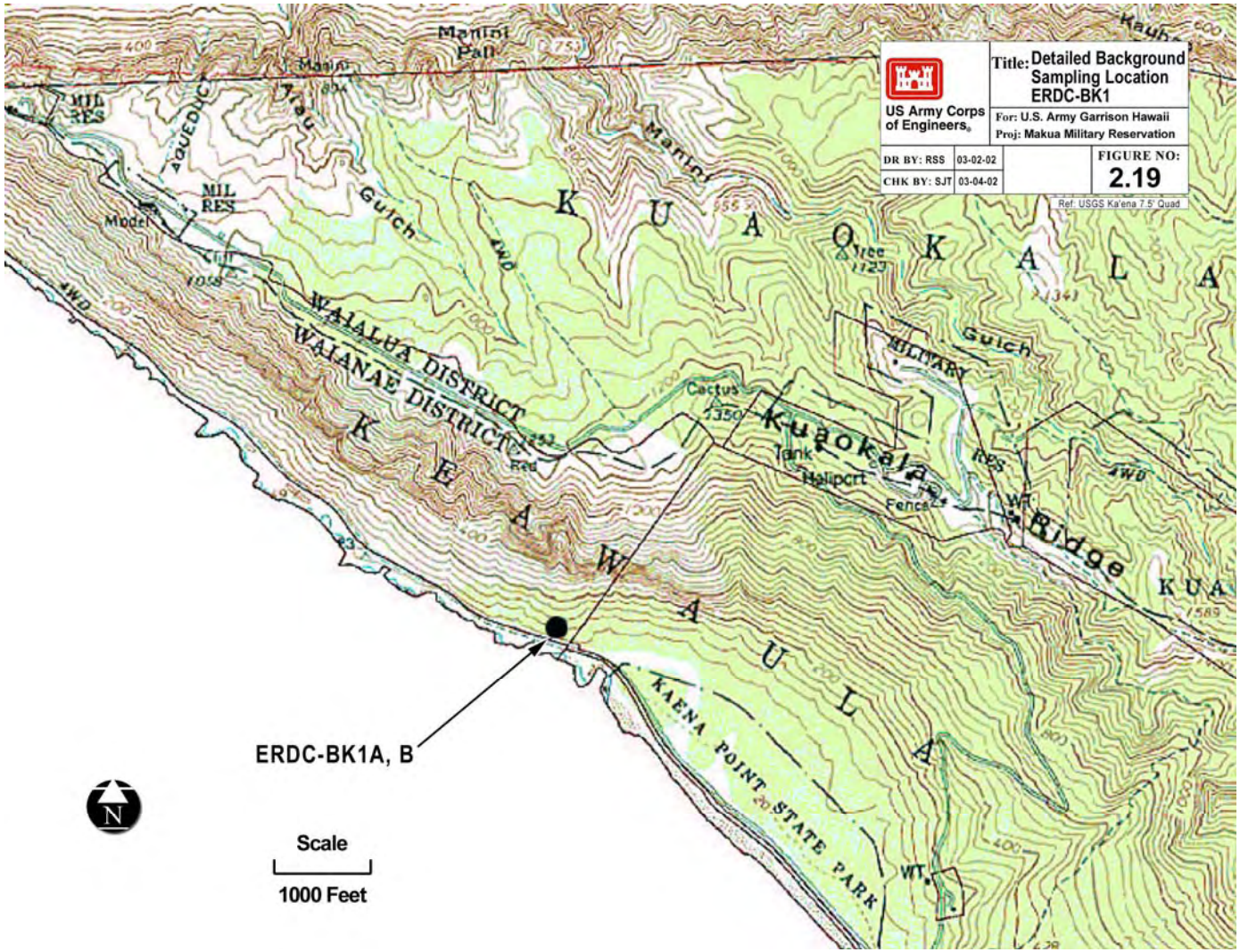


Figure 2.20 Detailed Background Sampling Locations ERDC-BK-2

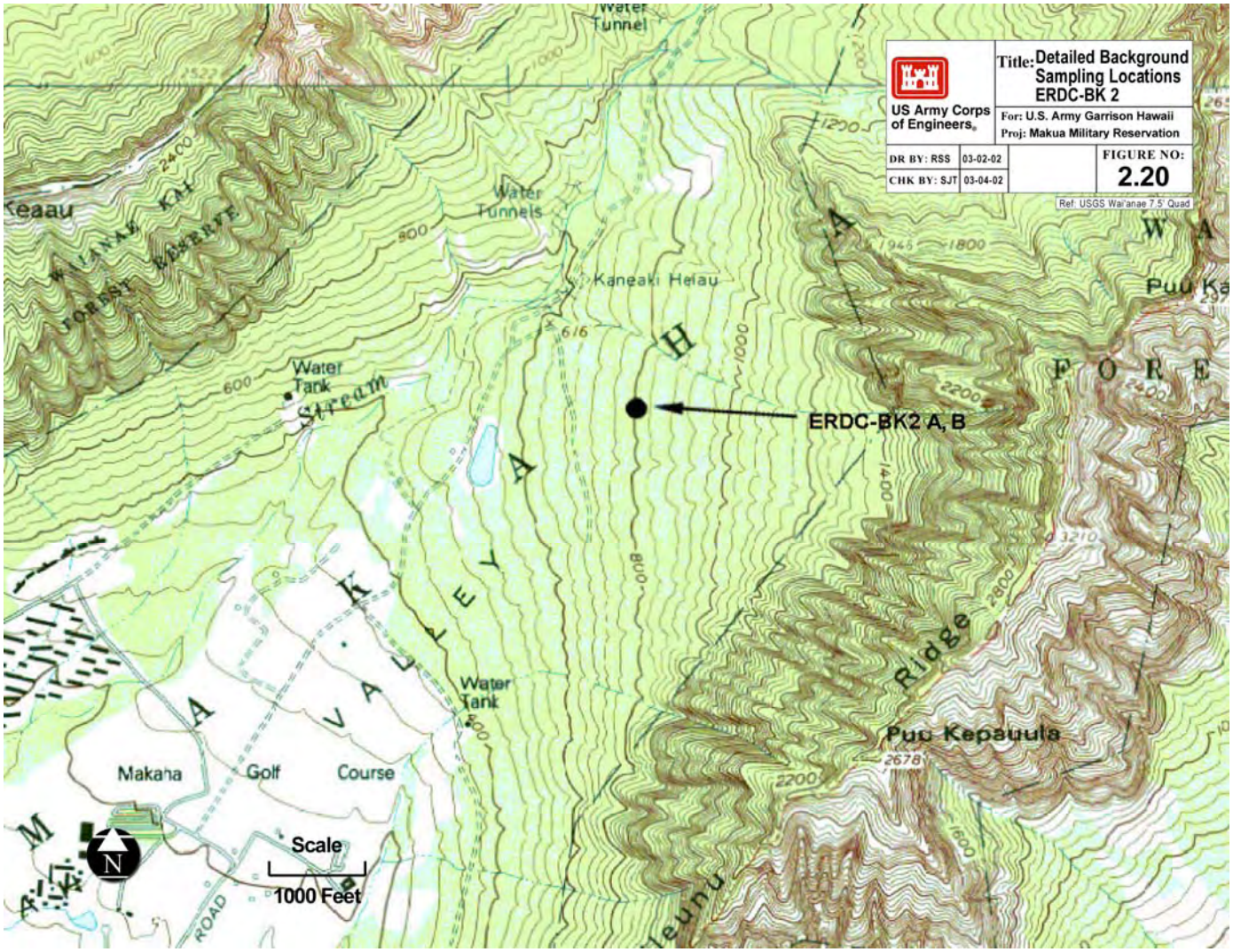


Figure 2.21 Detailed Background Sampling Locations ERDC-BK-3, 6

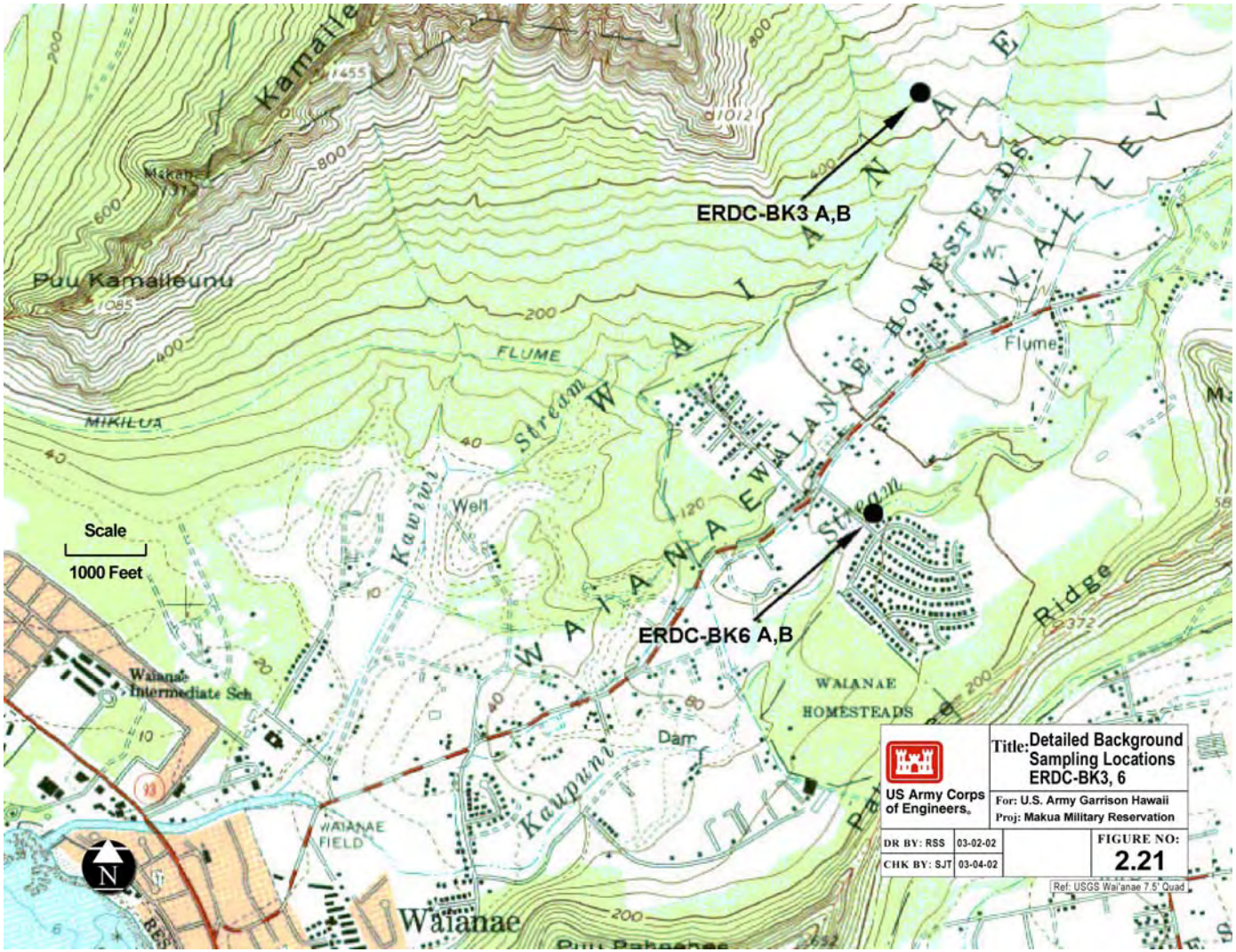


Figure 2.22 Detailed Background Sampling Locations ERDC-BK-4

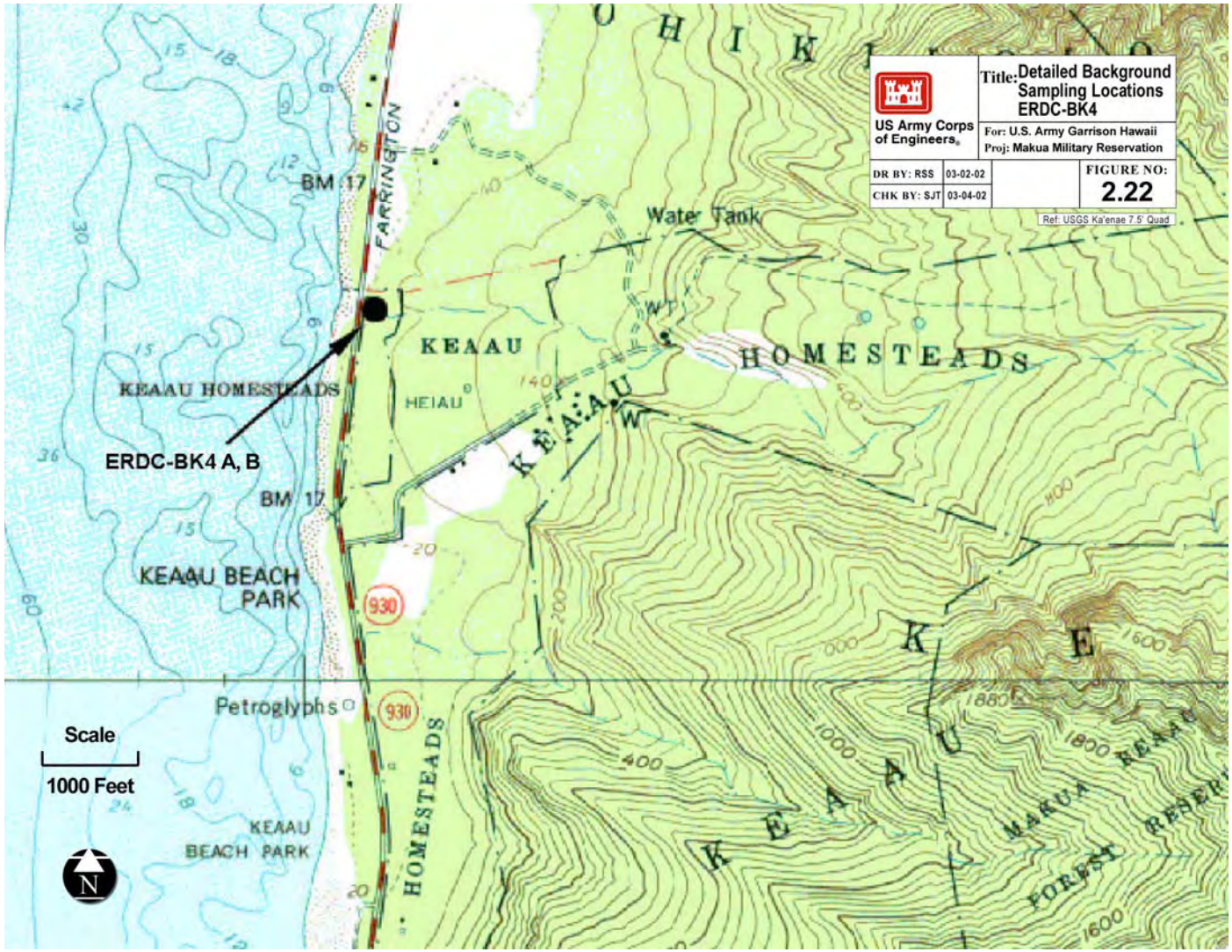
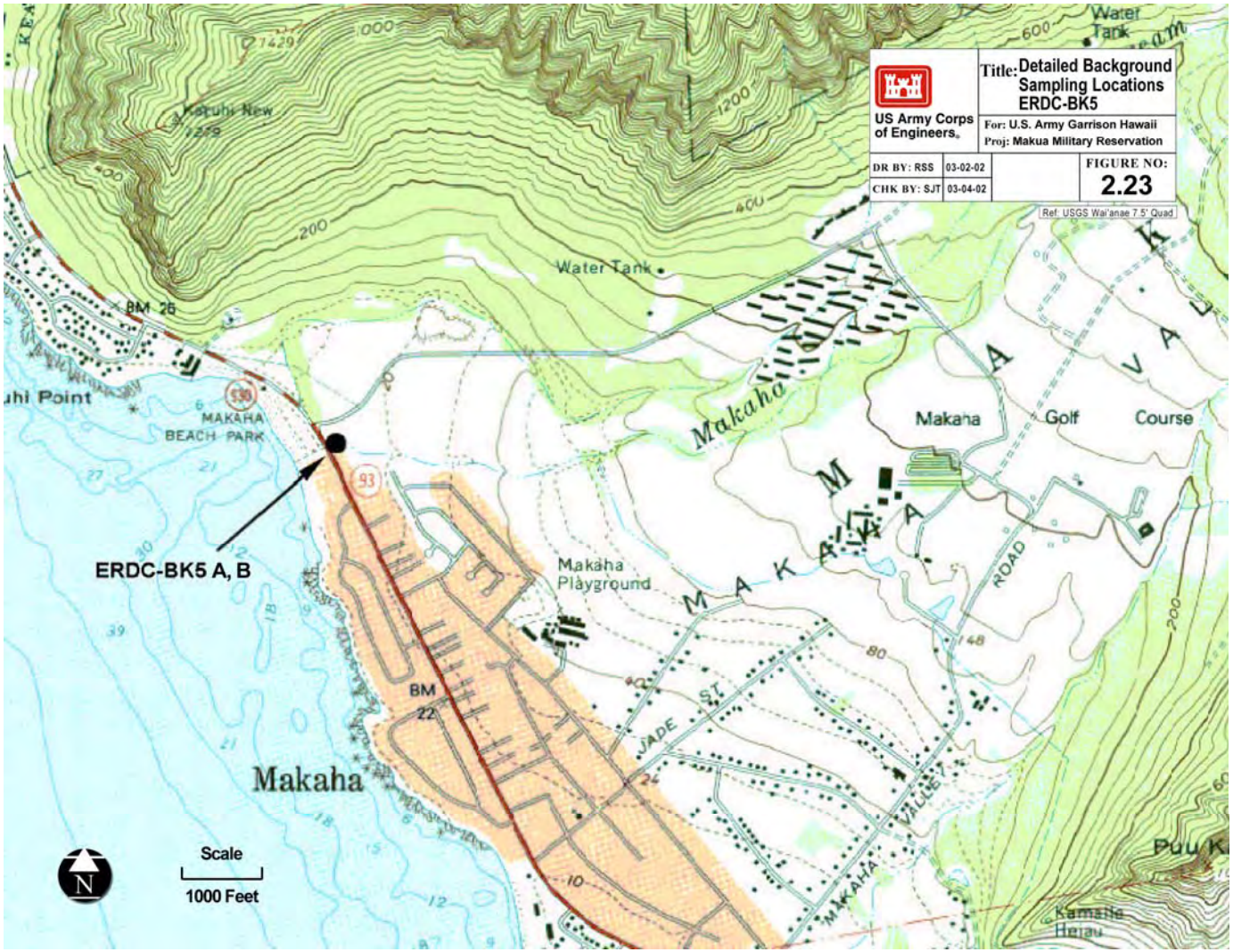


Figure 2.23 Detailed Background Sampling Locations ERDC-BK-5



2.11 Hydrogeological Characterization

Upon completion of well installations at Makua Military Reservation, measurements were collected to characterize the hydrogeologic conditions of the water bearing formations. These measurements established the configuration of the water table and its fluctuations, and provided approximations of hydraulic conductivity. Water levels were collected from the 10 monitoring wells prior to sampling the well. One complete set of water levels was collected at high tide and low tide in a period of less than 1 hour to allow for comparison between the wells. A transducer was placed in well SP-7 for several days to investigate the tidal influences on water levels. Results of the water level survey are outlined in Section 3.8 of this document.

Both falling head and rising head slug tests were conducted in each of the monitoring wells (SP-7 and ERDC-MW-1, 2, 3A, 3B, 4A, 4B, 5). These slug tests allowed for estimation of permeability in the formations in the Makua Valley. This involved the use of a solid slug that was placed in and out of the well, while the response of the well was measured with transducers and computer equipment. Results of the slug testing are outlined in Section 3.8 of this document.

2.12 Fate and Transport Modeling

Fate and transport analyses are conducted using the data collected as part of this study to estimate the potential for compounds introduced as part of military training to be transported off-site. To evaluate this, a site conceptual model is also developed that explains processes that result in groundwater flowing through Makua Valley. The two primary pathways for both MMR and the OB/OD area are considered to be: (1) contaminant release into surface soils, percolation of contaminant from the surface into the groundwater and subsequent groundwater migration off-site to the ocean or near-shore area; and (2) transport of soil particles containing contaminants that move with large rainfall events into streams discharging into the near-shore area, Muliwai ponds, or ocean. To evaluate the potential travel times for compounds discharging to the ocean, both surface water and groundwater modeling were performed. In addition, other studies

performed on-site and off-site that may provide estimates of impacts of off-site receptors are summarized.

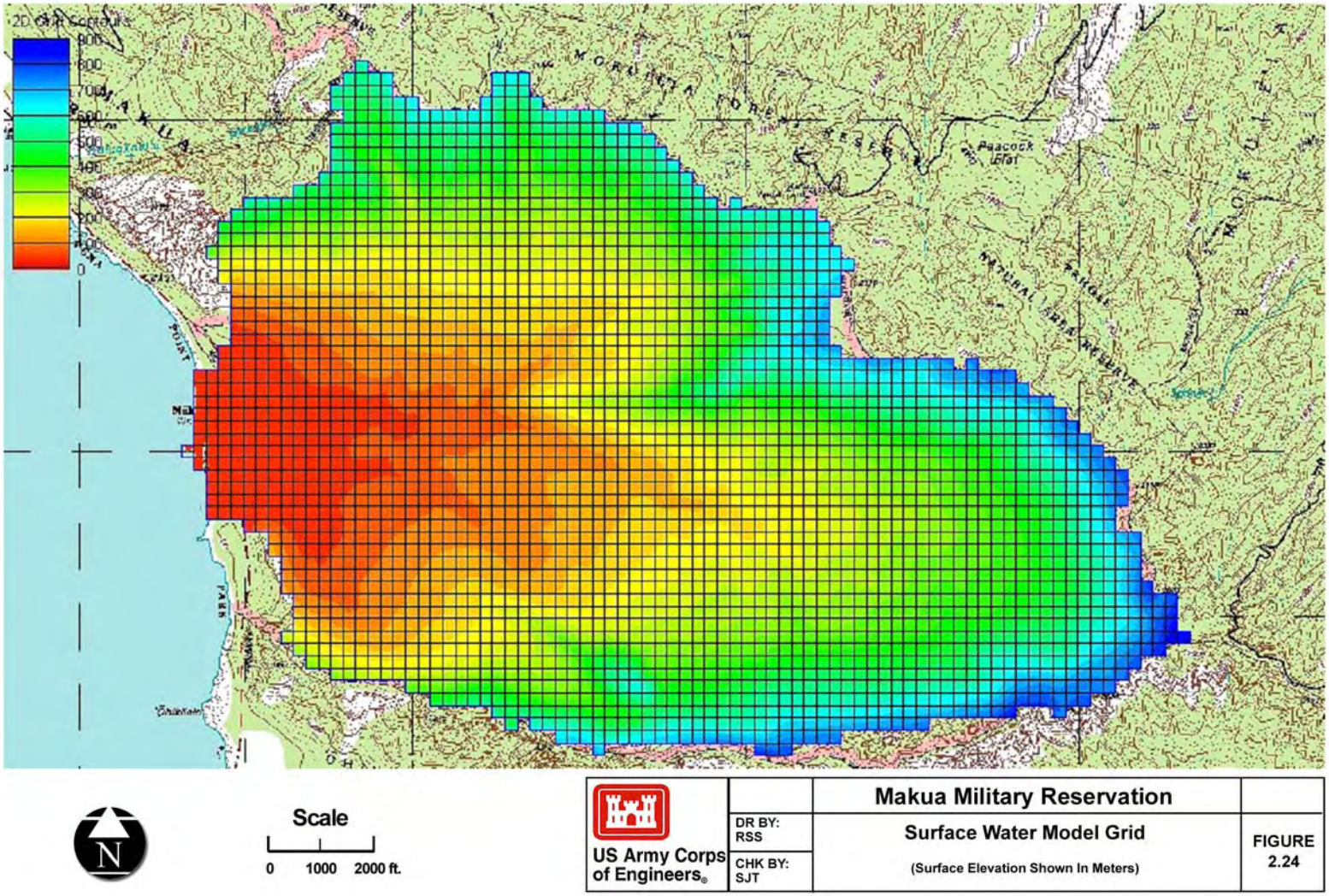
2.12.1 Surface Water Modeling

The surface water modeling portion of this study was performed and to provide estimates of groundwater recharge, and provide estimates of flow and sediment transport due to large rainfall events. The model also provides estimates of flooding inundation. The two-dimensional surface water model is designed to calculate the volume of flow at the outlet of the three streams in Makua: Punapohaku Steam, Koiahi Gulch Stream, and Makua Stream. The surface water modeling grid extends throughout Makua Valley from the top of the Waianae Mountains to the ocean as shown in Figure 2.24.

As part of preparation of this surface water model, precipitation data were collected from the existing MMR weather stations, the rain gage at the stream sampling station, and eight additional rain gages placed at the top of the Waianae Range. The rain gages were in place during February 14, 2003, January 23, 2004, and February 27, 2004, surface water flow in the Makua Valley. A map showing rainfall gage locations is shown in Appendix L.

The modeling was performed using the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model (Downer and Ogden, 2002) along with the Watershed Modeling System (WMS) (Nelson, 2001) preprocessor and postprocessor. GSSHA is a physically based, distributed-parameter model that simulates physical processes occurring in the watershed that produce stream flow and sediment movement. The model is able to explicitly account for the spatial distribution of land use, soil textures, vegetation and contaminant loadings in a much more rigorous way than lumped parameter models such as Hydrological Simulation Program Fortran (HSPF) (Donigian et al., 1984). The GSSHA model, developed with U.S. Army funds, was designed in part to assess the problem of soil erosion and contaminant flow due to overland flow from Department of Defense firing ranges. It has the capability to simulate multiple runoff mechanisms and is therefore applicable to a much wider range of problems than its predecessor, CASC2D (Ogden

Figure 2.24 Surface Water Modeling Grid



and Julien, 2002, Downer et al., 2002). For this modeling effort, the model was designed to incorporate overland flow due to rainfall to stream channels, and infiltration of rainfall into the land surface.

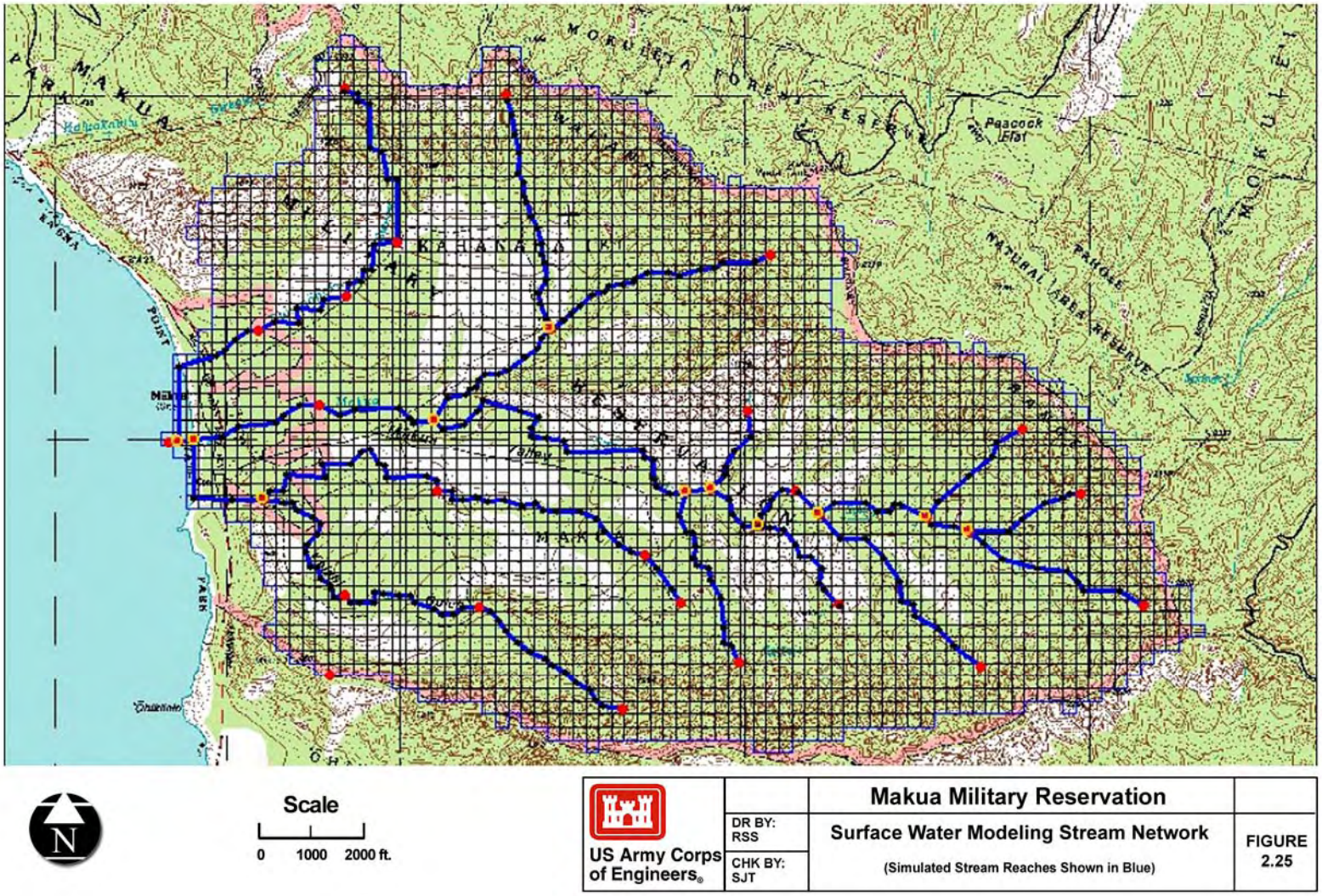
The GSSHA surface water model input data included parameters such as soil moisture content, vegetation type, soil type, and precipitation data. Soil moisture data were collected from soil samples taken throughout Makua Valley as part of this study as outlined in Section 3.4.2. Soil moisture content and grain size analyses were collected and used as input for the model. Precipitation data were collected from the three existing MMR weather stations and eight rain gages placed throughout the Makua Valley. These 11 rainfall data points provided a detailed distribution of rainfall throughout the Valley during the simulated rainfall events.

Stream flow measurements were collected as outlined in Section 3.5. Measurements or estimates of stream flow were made for Punapohaku Stream, Koiahi Gulch Stream, and Makua Stream for the February 14 2003, January 23, 2004, and February 27, 2004, flow events. Distributed parameters in the model were based on land use and soil textural classification taken from a GIS database prepared by the Range Control Division of Schofield Barracks for Makua. Stream bottom shape and slope were collected at 10 locations throughout the valley to provide input into the computer model.

The preparation of the model involved incorporating digital topography (DEM, or digital elevation model) collected on a 5-meter grid throughout Makua Valley. This is extremely detailed topography, as most other sites simulated typically have only a 10- or 30-meter digital topographic map. The stream network was then added to the model as shown in Figure 2.25. Punapohaku Stream, Koiahi Gulch Stream and Makua Stream were detailed and simulated as 1-D channels, with each stream having an outlet point for calculating the stream hydrograph.

The model grid was composed of 86 grid blocks in the east/west direction and 57 grid blocks in the north-south direction with each square having a size of 75 meters (Figure 2.24). The model was run using a time step of 30 seconds. Infiltration was calculated using the Green ..

Figure 2.25 Surface Water Modeling Stream Network



and Ampt infiltration method. Due the short simulation period, evapo-transpiration was negligible and was not simulated. An initial moisture content of 20% was used for the model runs The streambeds were simulated as trapezoidal erodible channels. Soil erosion factors include crop management of 0.005 and conservation practices of 1.0. Both of these parameters are generally used for undeveloped land this is largely vegetated by grass or trees (Downer and Ogden, 2003).

Additional model input parameters include the distributed overland flow roughness coefficient for the model area. This roughness value is analogous to a Manning's n value, and original values are estimated from standard literature sources that relate land use to overland flow roughness (Downer and Ogden, 2002). Figure 2.26 shows the overland roughness values that were used for the modeling. The different zones in Figure 2.26 represent different vegetation types, with values for roughness varying from 0.192 to 0.30.

Soil hydraulic properties that control infiltration values for different soil types throughout the Makua Valley are input parameters required for the model. Values for shallow vertical hydraulic conductivity (K_s) varied from 0.10 to 2.85 cm hr^{-1} (Figure 2.27). The values of hydraulic conductivity represent the ability of the shallow geologic material to transmit water, as part of Darcy's Law V=KI, where the variables are V, K, and I, for velocity, hydraulic conductivity, and hydraulic gradient, respectively. In Darcy's Law, for a given velocity V, the hydraulic conductivity K and the vertical gradient I are inversely related. Most of the project area has the somewhat higher hydraulic conductivity values of 2.85 cm hr^{-1}, with the streambeds and central areas having lower `values of hydraulic conductivity. During simulations, the amount of infiltration is highly dependent on K_s, as well as the slope of the land surface (higher slopes have less infiltration and more runoff), capillary head (soil suction), and the soil porosity.

The parameters used in the model were calibrated using the February 14, 2003, January 23, 2004, and February 27, 2004, flow events. The model incorporated overland flow, channel flow, and infiltration losses. The model was run for 1.7 days beginning at 0930 February 13,

2003. The model were simulated for all three events to cover the period from the beginning of rainfall until the flow of water measured at the stream outlets (measured) and the model runs (simulated) has ceased. For the February 14, 2003 flow event, the model was run for 1.7 days beginning 0930 on February 13, 2003. For the January 23, 2004 event the model was run for 1.7 days beginning at 18:00 on January 22, 2004. For the February 27, 2004 event the model simulation was run longer for 11 days, as during this stream flow event two large storms dropped rainfall on the valley. Output from the simulations utilized in this modeling exercise included stream hydrographs, infiltration to groundwater, and suspended sediment transport. Additional outputs include sand load (bed load), which was not included in this evaluation. Like all surface water models, this model's calculations for bed load are made with empirical equations. Measuring bed load in the field is not required to provide the parameters to design the model. The modeling effort focused on suspended sediment and flooding, which are more critical parameters to evaluate for impacts. For this study the bed load (or sand load) was not measured, as the Makua beach environment has abundant sand already, so more sand is not considered a significant impact. The surface water modeling effort is calibrated to the February 14, 2003, January 23, 2004, and February 27, 2004, flow events. Since there are almost no detectable levels of potential contamination in the surface water, the output of the surface water modeling has been limited to evaluating flooding and sediment transport and not the impacts of chemical constituents to off-site receptors. Since limited evaluations are made with the model, the usefulness of the surface water modeling is somewhat diminished. Additional results of the calibration and predictive runs are explained in Section 3.9.1.

Figure 2.26 Overland Flow Roughness Values (n)

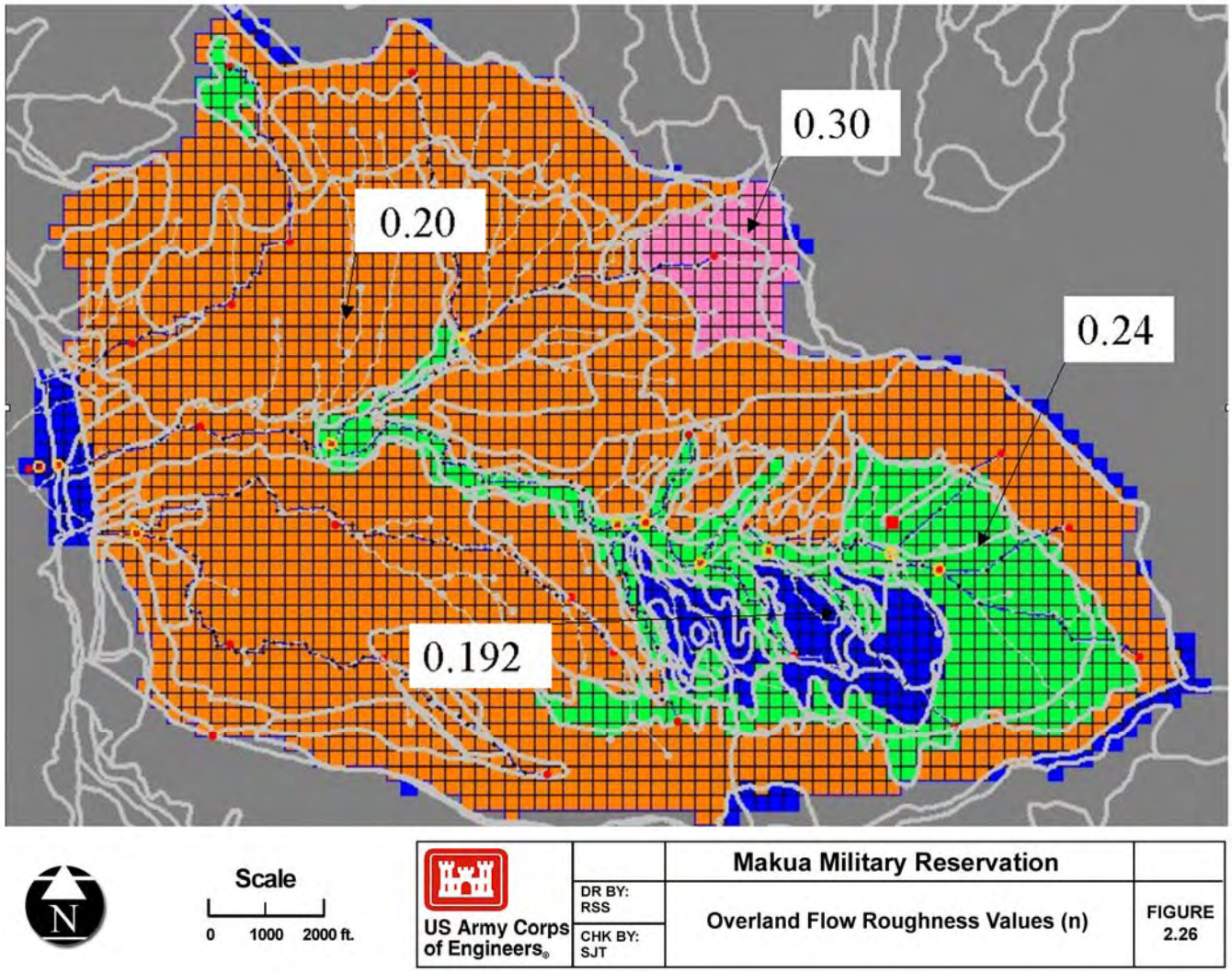
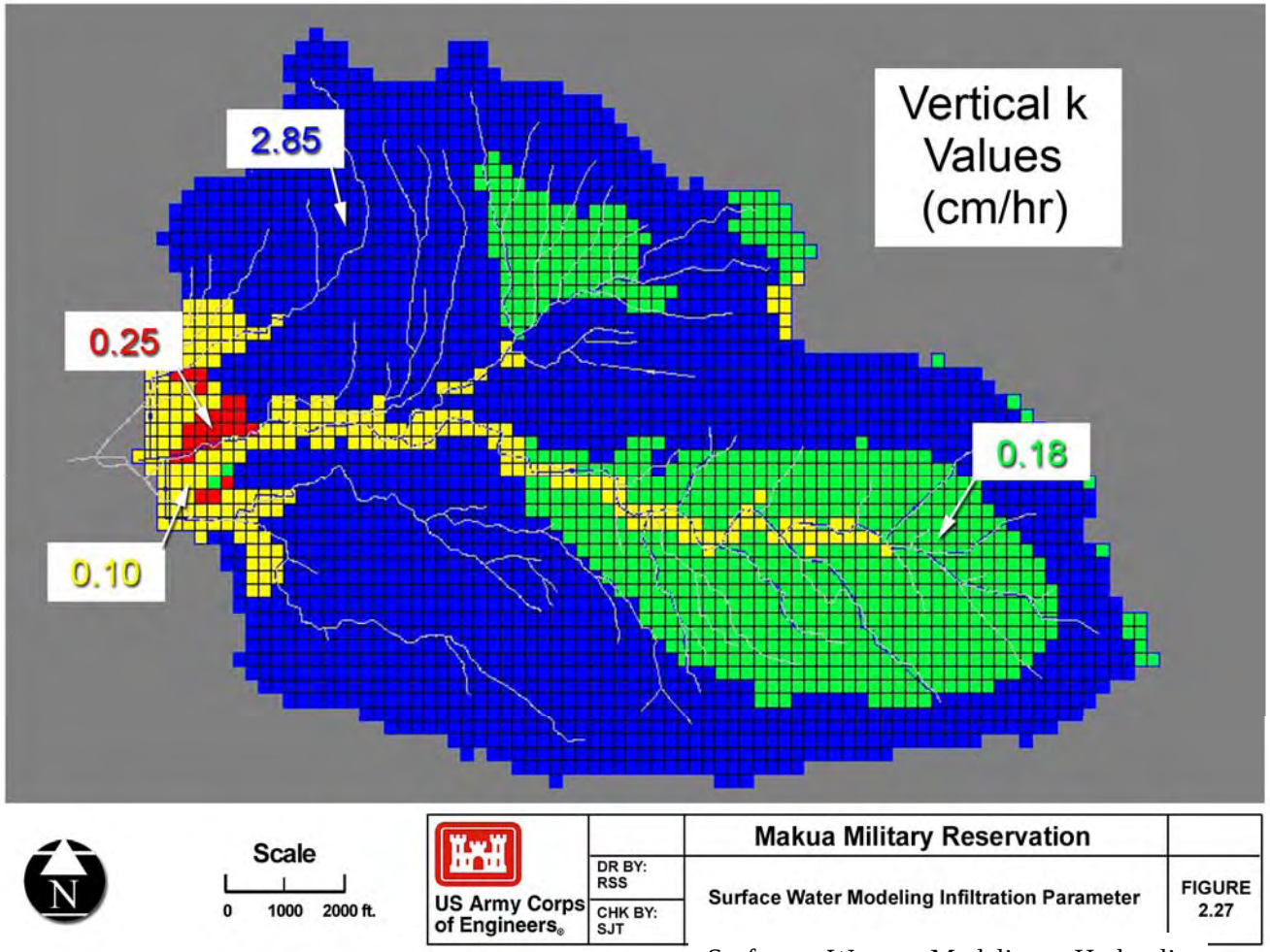


Figure 2.27 Surface Water Modeling Hydraulic Conductivity (K) Parameters



Surface Water Modeling Hydraulic Conductivity (K) Parameters

2.12.2 Groundwater Modeling

A three-dimensional flow and solute transport model was developed to provide an additional tool for evaluating the potential for off-site transport of compounds related to military operation. The model domain extends from the boundary of MMR at the top of the Waianae Range to the ocean. The models used were the U.S. Geological Survey's Modflow flow model (McDonald and Harbaugh, 1988) and the MT3D solute transport model (Zheng, 1990). The U.S. Geological Survey's MODPATH (Pollack, 1994) model was also used to estimate groundwater flow paths and travel times within the Makua Valley as outlined in Appendix H-1. Model runs were also conducted using the U.S. Geological Survey's SEAWAT model in response to reviewers comments on the Draft EIS. The SEAWAT model was designed to simulate variable-density groundwater flow and solute transport by combining a modified version of the flow model MODFLOW-2000 and the transport model MT3DMS into a single model. Additional runs using this SEAWAT model are outlined in Appendix H-2.

Complete descriptions of the site conceptual model and the use of the groundwater model are contained in Appendix H of this report. The models were created with the Department of Defense's Groundwater Modeling System (GMS) pre- and post-processing software for the MODFLOW, MT3D, MODPATH, and FEMWATER codes. The SEAWAT model was created with the Visual MODFLOW v. 4.1 pre- and post-processor. The MODFLOW model included transport within the saturated portions of the aquifer. Transport of compounds potentially in the unsaturated zone was estimated for input into the groundwater flow and solute transport models using a FEMWATER (Ogden and Julien, 2002) finite element vadose zone model, as outlined in Appendix I.

The MODFLOW, MT3D, SEAWAT, and FEMWATER model combination was used to estimate travel times for groundwater to flow from the recharge areas in the Waianae mountain range to the ocean. Travel paths of groundwater from the training areas of concern (such as the OB/OD area) to potential off-site receptors are also estimated. Input from the entire sampling

program, including the installation of monitoring wells, groundwater sampling, and slug testing, was included in the building of the groundwater models (Appendix H).

2.13 Risk Based Screening Levels for Data Comparison

For this hydrogeologic assessment of the Makua Military Reservation, results of the soil and water sampling performed by the analytical laboratory were compared to a number of lists of risked based screening levels. For this project these lists included the following:

a. Groundwater and Surface Water Risk Based Screening Levels

- Federal Maximum Contaminant Levels (MCLs), or Federal drinking water standards.
- USEPA U.S. Environmental Protection Agency (EPA) Region IX (Region IX includes Hawai`i) Preliminary Remediation Goals (PRGs) for Tap Water published October 2002.
- Hawai`i State Department of Health Hawai`i Administrative Rules Title 11 (Hawai`i Title 11-281 Tier I Action Levels for Rainfall Less than 200 cm/yr drinking water source not threatened, and 11-54-4 Basic Water Quality Criteria Applicable to All Waters**).
- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Surface Water.
- Federal Ambient Water Quality Criteria (AWQC) for Freshwater** (Also called National Recommended Water Quality Criteria – 2002).

**(The "Federal Ambient Water Quality Criteria (AWQC) for Freshwater" and "11-54-4 Basic Water Quality Criteria Applicable to All Waters" are the same lists).

b. Soil and Sediment Risk Based Screening Levels

- USEPA U.S. EPA Generic Soil Screening Levels (SSLs) for Ingestion, Inhalation, and Migration to Groundwater published October 2004.
- USEPA U.S. EPA Region IX Preliminary Remediation Goals (PRGs) for Industrial Land Use Published October 2002.
- Hawai`i State Department of Health Hawai`i Administrative Rules Title 11 (Hawai`i Title 11-281 Tier I Action Levels for Rainfall Less than 200 cm/yr drinking water source not threatened).
- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Soil (applicable to surface soil samples only).

- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Sediment (applicable to surface soil samples only).

2.13.1 Laboratory Detection Limit Comparison

A comparison was made between the laboratory detection limits and the Region IX Preliminary Remediation Goals (PRGs), U.S. EPA Maximum Contaminant Levels (MCLs), and State of Hawai`i Conservative Risk-Based Screening Levels. Based on these values, a number of the detection limits were lowered for certain analytes for this project. These include semivolatile organics, some metals, and dioxin compounds. For semivolatile organic compound analyses in soils, U.S. EPA method 8720CSIM will be used, and for water samples, U.S. EPA method 8310 will be used. For metals analyses, method 6010Blow will be used to obtain lower detection limits for arsenic, lead, and selenium. For dioxin analyses in water, U.S. EPA method 8290 will be used to obtain lower detection limits for water samples.

2.13.2 Explanation of Risk Based Screening Levels for Data Comparison

For this hydrogeologic assessment of the Makua Military Reservation, results of the soil and water sampling performed by the analytical laboratory were compared to the industrial Preliminary Remediation Goals published by Region IX, U.S. Environmental Protection Agency (EPA). PRGs are risk-based concentrations, derived from standardized equations, combining exposure information assumptions with U.S. EPA toxicity data. PRG values are considered by U.S. EPA to be protective for humans (including sensitive groups), over a lifetime. Region IX PRGs do not address non-human health receptors such as ecological impacts. In general, under the Superfund program, no further action at a site is required for concentration levels below Region IX PRGs. These PRGs are often applied to sites for consideration in programs other than Superfund, including Environmental Impact Statements (EIS). Region IX Industrial PRGs are used for comparison of soil laboratory data, with the residential PRGs listed for informational purposes. Region IX Industrial PRG values are used to compare the laboratory analytical data to evaluate if a potential concern exists, since no soldiers or persons live at Makua, but only spend

part of their working day at the site. Chemical concentrations above the PRG levels would not automatically designate a site as "dirty," or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by potential site contaminations is appropriate. Further evaluation may include additional sampling, but also may include considering ambient (or background) levels in the environment (EPA, 2004). Region IX PRGs published in October 2002 are used, as these were the PRG values applied to the project during the field investigation and approval of the Sampling and Analysis Plan.

Results of the soil sampling performed by the analytical laboratory were also compared to U.S. EPA Generic Soil Screening Levels (SSLs) for Ingestion, Inhalation, and Migration to Groundwater. Consideration of these U.S. EPA Generic SSLs for Ingestion and Inhalation are included and used in developing the Region IX PRGs, so no separate comparison to these values are necessary (EPA, 2004).

A comparison of the Generic SSLs for the protection of groundwater has been included for 100 most common contaminants at Superfund sites. The SSLs were developed using a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface such as dilution, chemical decay, and biodegradation. The geologic conditions at Makua are conducive to these processes due to the long travel paths for groundwater, and the long distances from the impact area and OB/OD to off-site receptors. Therefore, the SSLs with a DAF of 20 are used for comparison. In general, if an SSL is not exceeded for the migration to groundwater pathway, the user may eliminate this pathway from further investigation (EPA, 2004).

Soil and water samples are also compared to Hawai`i Title 11-281 Tier 1 Action Levels for Groundwater (rainfall $\leq$ 200 cm/year, drinking water source not threatened). These regulations essentially are for underground storage tanks containing products such as gasoline and diesel fuel. While there are no records of underground tanks in the Makua area, these Tier 1 values are used for comparison as a guideline if remediation of the soil would be necessary.

To evaluate the potential for ecological impacts, a comparison of soil and water samples is made to the U.S. EPA Region 5 Ecological Data Quality Levels (or Ecological Screening Levels) for soil and sediment. Ecological values similar to PRGs are not published for Region IX, so in this vacuum the Region 5 Ecological Screening Levels (ESLs) are used to provide an indication of potential impacts. The Region 5 ESLs have been used outside of Region 5 (such as the Blackbird Mine in Idaho), and the Tri-Service (Army, Navy, Air Force) Remedial Project Manager's Handbook for Ecological Risk Assessment also listed these as a source for comparison of soil values for ecological risk. The acute (short term exposure) standards are more applicable than chronic (long term exposure) standards for Makua since the streams only flow a few times each year, and the biota would be exposed to the surface water flows for only a short period of time (maybe a few days each year). They are used to provide a general indication if additional work is necessary to evaluate ecological impacts. Comparisons for soil and water (to the Region IX Industrial PRGs and MCLs) are contained in the main text o the EIS.

Comparisons to the Hawai`i State Department of Health Hawai`i Administrative Rules, Title 11-54-4 Basic Water Quality Criteria Applicable to All Waters, U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs), Federal Ambient Water Quality Criteria (AWQC) for Freshwater, U.S. EPA Generic Soil Screening Levels (SSLs) for Migration to Groundwater, and Hawai`i Title 11-281 Tier I Action Levels are contained in Appendix K.