Headquarters Marine Corps

FINAL

Range Environmental Vulnerability Assessment
Marine Corps Air Ground Combat Center
Twentynine Palms

November 2008
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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

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Range Environmental Vulnerability Assessment

Marine Corps Air Ground Combat Center Twentynine Palms

November 2008

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Acronym List

^oF	Degrees Fahrenheit
µg/L	Micrograms per Liter
amsl	Above Mean Sea Level
ASR	Archive Search Report
bgs	Below Ground Surface
BLM	Bureau of Land Management
BZO	Battle Sight Zero
cal	Caliber
CAMA	California-Arizona Maneuver Area
CAMOUT	Combined Arms Military Operations in Urban Terrain
CAX	Combined Arms Exercise
C.C.	Convoy Combat
CSM	Conceptual Site Model
DESFIREX	Desert Fire Exercise
DoD	Department of Defense
DoDIC	Department of Defense Identification Code
DTC	Desert Training Center
EOD	Explosive Ordnance Disposal
FAA	Federal Aviation Administration
FMD	Facilities Management Division
FOB	Forward Operating Base
G3	Range Operations and Control
GIS	Geographic Information System
HEAT	High Explosive Anti-Tank
HMX	Cyclotetramethylene tetranitramine
HQMC	Headquarters Marine Corps
HMX	Cyclotetramethylene tetranitramine
INRMP	Integrated Natural Resources Management Plan
IRP	Installation Restoration Program
kg/m^2	Kilograms per Square Meter
LAV	Light-Armor Vehicles
LAW	Light Anti-Tank Weapon
LTA	Laser Target Area
m	Meters
m^2	Square Meters
MC	Munitions Constituents

MCAGCC	Marine Corps Air Ground Combat Center
MCTC	Marine Corps Training Center
MFTL	Mojave Fringe-Toed Lizard
mg/kg/d	Milligrams per Kilogram per Day
mg/L	Milligrams per Liter
MIDAS	Munitions Items Disposition Action System
mm	Millimeters
MOUT	Military Operations in Urban Terrain
MSR	Main Supply Route
MTU	Marksmanship Training Unit
n/a	Not Applicable
NAAS	Naval Auxiliary Air Station
NRCS	Natural Resources Conservation Service
NREA	Natural Resources and Environmental Affairs
PRA	Preliminary Range Assessment
RDX	Cyclotrimethylene trinitramine
REVA	Range Environmental Vulnerability Assessment
RDX	Cyclotrimethylene trinitramine
RRPS	Range Recycling Processing Section
RTA	Range Training Area
RTAMS	Range / Training Areas Management Section
RUSLE	Revised Universal Soil Loss Equation
SAR	Small Arms Range
SDZ	Surface Danger Zone
TBD	To Be Determined
TDS	Total Dissolved Solids
TNT	Trinitrotoluene
U.S.	United States
USACE	United States Army Corps of Engineers
USACHPPM	United States Army Center for Health Promotion and Preventive Medicine
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UXO	Unexploded Ordnance
WWII	World War II

Executive Summary

The United States Marine Corps (Marine Corps) Range Environmental Vulnerability Assessment (REVA) program meets the requirements of the current Department of Defense (DoD) Directive 4715.11 *Environmental and Explosives Safety Management on Operational Ranges within the United States* and DoD Instruction 4715.14 *Operational Range Assessments*.

The purpose of the REVA program is to identify whether there is a release or substantial threat of a release of munitions constituents (MC) from the operational range or range complex areas to off-range areas. This is accomplished through a baseline assessment of operational range areas and, where applicable, the use of fate and transport modeling / analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas. Indicator MC selected for the REVA program include trinitrotoluene (TNT), cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), and perchlorate.

This report presents the assessment results for the operational ranges and training areas at Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, California. This report is the first comprehensive report on MC associated with the operational ranges at MCAGCC Twentynine Palms and serves as the baseline of environmental conditions and potential vulnerabilities of the operational ranges. Subsequent vulnerability assessments will be conducted on operational ranges at MCAGCC Twentynine Palms on a five-year cycle or when significant changes are made to existing ranges that potentially affect the determinations made during this baseline assessment, as described in the *REVA Reference Manual* (HQMC, 2006).

Military Munitions Training and Operations

MCAGCC Twentynine Palms is the Marine Corps' largest live-fire training facility, encompassing nearly 600,000 acres across the Mojave Desert in San Bernardino County, California. The primary mission of MCAGCC Twentynine Palms is to develop, administer, conduct, support, and evaluate the Marine Corps' training exercises and operations, while supporting the tenant commands of the Marine Expeditionary Force and the Marine Corps Communications and Electronics School. The installation conducts a full spectrum of warfighter training, from multiweapon system, multiservice field maneuvering exercises to individual small arms proficiency training by individual Marines.

The installation was first established as a full-time Marine Corps base in 1953 as the Marine Corps Training Center Twentynine Palms, although live-fire training has been conducted intermittently at the installation since 1942. Live-fire training increased greatly in the mid-1970s, following the establishment of the Combined Arms Exercise (CAX) program. The program combines the arms training program for ground (armor, artillery, and infantry units) and air fire support (fixed and rotary wing aircraft) with maneuver at the tactical level and is designed to involve all elements of the Marine Air Ground Task Forces in a live-fire, desert training environment. These exercises utilize the entire Marine Corps weapon inventory and nearly all munitions types. The Mojave Viper exercise, established in 2005, is a similar program that includes additional urban-level operations as a response to ongoing military operations in Iraq and Afghanistan. Approximately 35,000–50,000 DoD military personnel annually train during Mojave Viper, CAX, and other exercises at the installation.

The installation is administratively subdivided into 22 Range Training Areas (RTAs), a cantonment area (Mainside), and a Restricted Area. Five of the RTAs are designated for non-live-fire and maneuver training; these RTAs are located in the southwestern section of the installation, west of Mainside. Live-fire is approved within the remaining RTAs, with some exceptions (e.g., live fire is not allowed within 1,000 meters of the installation boundary). Fifty-four fixed ranges are also present across the installation, with the majority located in the Range RTA. In addition, the installation contains 12 small arms ranges (SARs), all located within the Range RTA. The RTAs are managed by the Range Operations Section / Range Control. Range Control provided military munitions expenditure data for the installation from 2001 through 2005 and noted the training areas that received the greatest level of use, for both current and historical periods.

Conceptual Site Model

MCAGCC Twentynine Palms is located in the high desert region of the Mojave Desert and is characterized by rugged terrain consisting of desert, mountains, and a few dry lakes (playas). Approximately 99% of the installation is undeveloped or unimproved grounds. The Bullion and Lava Bed mountain ranges bisect the center of the installation, trending from the northwest to the southeast. The terrain is characterized by broad alluvial plains, alluvial fans, bedrock uplands, ephemeral washes, dry lake beds, lava flows, and sand dunes. There are no perennial surface water features on the installation. Live-fire training activities are conducted throughout the alluvial deposits; weapons fire is directed at the base of the mountain ranges rather than at higher elevations.

The installation receives an average of 4 inches of precipitation per year; strong summer storms often drop the majority of this total, resulting in flash floods. During a heavy rainfall event, water flows across the bedrock surface of the mountains into drainage channels and rushes rapidly toward the basin floor. Runoff accumulates in playas found throughout the installation and may remain for up to two months. The majority of the surface water is lost to evaporation; very little infiltration occurs due to the low-permeability soils. Although the majority of surface runoff generated within the installation boundaries is captured by on-site playas, some drainages cross the installation boundaries and discharge to playas located off installation (e.g., Dale Lake, Bristol Dry Lake).

Groundwater at MCAGCC Twentynine Palms is found in the alluvium-filled basins that flank the bedrock uplands. Primary groundwater basins include the Twentynine Palms basin on the southwestern margin of the Bullion Mountains (composed of five groundwater subbasins covering parts of MCAGCC Twentynine Palms), the Bristol Valley basin on the northeastern side of the Bullion Mountains, and several smaller intramountain subbasins (portions of the Dale Valley and Lavic Valley) that are located in the Bullion and Lava Bed mountains.

The best-characterized groundwater basin is the Twentynine Palms basin. This basin is part of a larger aquifer system known as the Morongo groundwater basin, which is characterized by small alluvial subbasins that maintain separate groundwater flow, typically terminating just beneath playas. The groundwater subbasins are divided hydrogeologically by bedrock outcrops, faults, and folds. Groundwater within the Twentynine Palms basin is generally deep, although depth to groundwater has been measured between 5 (near playas) and 400 feet below ground surface. Water supply wells at the installation are screened in the Surprise Springs subbasin and provide all potable water to the base. RTAs near the location of these wells are designated for non-live-fire training. Groundwater from basins east of the Twentynine Palms basin has been determined to be nonpotable due to high mineral content.

MC deposited on the primary MC loading areas and RTAs can migrate to potential receptors primarily via surface water transport to playas. MC potentially can accumulate within the playas over time, as the material is deposited in the playa bed following evaporation of the surface water. In addition, leaching to groundwater and subsequent groundwater flow potentially could serve as another MC transport mechanism, though such transport is likely limited by high evaporation rates and deep groundwater.

Potential receptors for MC dissolved in surface water are limited to ecological receptors with habitat within or near the playas receiving runoff. Habitat for the Mojave fringe-toed lizard (MFTL), a California species of special concern, has been identified within and surrounding playas on the installation, as well as in similar habitat off of the installation. In addition, the federally threatened desert tortoise is found throughout the region, both on- and off installation, and may be considered a receptor. However, both of these species are unlikely to consume the intermittent surface water within the playas, as they obtain most of their water requirements through consumption of plants and prey.

Potential receptors utilizing surface water in playas that are located within the installation boundaries were not considered because the REVA program is limited to the assessment of documented or potential off-range MC releases.

Because surface water within playas is not used as a potable water source, no human receptors were identified. Several salt mining operations are present in playas east (Bristol Dry Lake) and southeast (Dale Lake) of the installation. Workers operating in these areas are not exposed to surface water entering the playa, and flooding of the evaporation ponds and trenches used in the salt mining process is extremely rare.

Estimated MC loading rates on training areas were examined, along with the known migration pathways and possible receptors identified in the conceptual site model. The results of this analysis indicate that the greatest potential exists for MC to be transported via surface runoff from two RTAs on the installation boundary to receiving playas located downstream and off installation. These areas are the southern half of the Lead Mountain primary MC loading area, which drains east and empties into Bristol Dry Lake, and the Prospect primary MC loading area, which drains southeast and discharges to Dale Lake, approximately 18 miles downstream.

Screening-Level Surface Water Transport Analysis

Fate and transport analysis of potential MC migration via surface water was conducted as part of the vulnerability assessment for MCAGCC Twentynine Palms. The fate and transport analysis was conducted through screening-level transport analysis for the Lead Mountain and Prospect primary MC loading areas. This methodology was selected to provide conservative estimates of the dissolved-phase concentrations of MC reaching the exposure endpoints for these primary MC loading areas (i.e., Bristol Dry Lake and Dale Lake). MC loading from RTAs / primary MC loading areas located upstream from Lead Mountain and Prospect were also factored into the screening-level analysis. MC concentrations in surface water were estimated under three scenarios:

1. At the edge of the MC loading areas
2. At the final discharge locations (i.e., the playas), accounting for down gradient mixing
3. At the final discharge locations, applying an evaporative concentration factor analysis to account for the accumulation, redissolution, and reprecipitation of MC in the playas due to cyclical evaporation and resuspension processes (—evaporative concentration and accumulation” method)

The screening-level analysis estimated that average annual concentrations of HMX and perchlorate would be below REVA trigger values in runoff at the edges of individual MC loading areas (Tables ES-1 and ES-2). Post-mixing concentrations of RDX, HMX, and perchlorate entering Dale Lake and post-mixing concentrations of HMX and perchlorate entering Bristol Dry Lake from all MC loading areas were also predicted to be below REVA trigger values (Tables ES-1 and ES-2). However, TNT and RDX were predicted to exceed REVA trigger values in runoff at the edges of specific MC loading areas. In addition, post-mixing concentrations of RDX and TNT entering Bristol Dry Lake and of TNT entering Dale Lake from all MC loading areas were predicted to slightly exceed their respective trigger value.

The ―evaporative concentration and accumulation" method described above was used to estimate aqueous phase concentrations of MC in playas that accounted for evaporation and deposition. The predicted concentrations of HMX and perchlorate in playas were below REVA trigger values after the ―evaporative concentration and accumulation" method was applied. However, the concentrations of RDX and TNT in both Bristol Dry Lake and Dale Lake were predicted to be above REVA trigger values.

Table ES-1: Estimated Concentrations of MC from Surface Water Screening-Level Analysis: Prospect Primary MC Loading Area to Dale Lake

MC	Trigger Value	Prospect Primary MC Loading Area		
		Edge of Primary MC Loading Area	Post-Mixing At Dale Lake	Accumulation in Dale Lake
RDX	0.16	**3.8**	0.15	**37**
TNT	0.08	**3.4**	**0.12**	**30**
HMX	0.08	2.4E-04	3.0E-05	7.4E-03
Perchlorate	0.98	1.1E-02	1.3E-03	0.32

Note: All concentrations are provided in µg/L – micrograms per liter.
Shading and bold indicate that the predicted concentration exceeds the REVA trigger value.

Table ES-2: Estimated Concentrations of MC from Surface Water Screening-Level Analysis: Lead Mountain Primary MC Loading Area to Bristol Dry Lake

MC	Trigger Value	Lead Mountain Primary MC Loading Area		
		Edge of Primary MC Loading Area	Post-Mixing At Bristol Dry Lake	Accumulation in Bristol Dry Lake
RDX	0.16	**4.0**	**0.19**	**47**
TNT	0.08	**4.5**	**0.25**	**63**
HMX	0.08	4.1E-05	9.6E-05	2.4E-02
Perchlorate	0.98	1.6E-03	5.4E-04	0.14

Note: All concentrations are provided in µg/L.
Shading and bold indicate that the predicted concentration exceeds the REVA trigger value.

The state-approved Colorado River Basin Plan does not include regulatory criteria for the MC associated with military munitions that might reach surface water bodies (California Regional Water Quality Control Board, 2005). There are no documented uses of the surface water within either Bristol Dry Lake or Dale Lake. An ecotoxicity analysis conducted for ecological receptors potentially interacting with surface water in the playas (MFTL and the desert tortoise) indicates that the toxicity threshold for reptiles is several orders of magnitude above the estimated MC concentrations reaching the playas (Appendix A). Therefore, no further action is warranted for potential MC releases from the Lead Mountain and Prospect RTAs, as well as their upstream contributors.

SAR Assessments

The primary MC of concern at SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. Modeling parameters for lead fate and transport are contingent upon site-specific geochemical data that are generally unavailable during a baseline assessment. Therefore, SARs are qualitatively assessed under the REVA program to identify factors that influence the potential for lead migration.

There are 12 SARs located at MCAGCC Twentynine Palms. Seven of these ranges are located with the Marksmanship Training Unit (MTU) in the southeast corner of the Range RTA. The MTU conducts small arms proficiency and requalification for Marines and transiting units. The other five SARs are fixed ranges located in the central and northern sections of the Range RTA.

The analysis of the 12 SARs at the installation resulted in Minimal environmental concern rankings for all ranges, based on the results of the qualitative assessment of the ranges in the protocol and professional judgment. No ranges received a High environmental concern ranking. The low overall scores for the ranges were due primarily to the low precipitation rate, the large distance between the ranges and their intermittent receiving surface water bodies, and the deep groundwater found at the installation, all of which limit lead migration and potential impacts.

1. Introduction

1.1. Purpose

The United States (U.S.) Marine Corps (Marine Corps) Range Environmental Vulnerability Assessment (REVA) program meets the requirements of the Department of Defense (DoD) Directive 4715.11 *Environmental and Explosives Safety Management on Operational Ranges within the United States* and DoD Instruction 4715.14 *Operational Range Assessments*.

The REVA program is a proactive and comprehensive program designed to support the Marine Corps' environmental range sustainment initiative. Operational ranges across the Marine Corps are being assessed to identify areas and activities that are subject to possible impacts from external influences, as well as to determine whether a release or substantial threat of a release of munitions constituents (MC) from operational ranges to off-range areas creates an unacceptable risk to human health and/or the environment. This is accomplished through a baseline assessment of operational range areas and, where applicable, the use of fate and transport modeling / analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas.

In recent years, the DoD and the Marine Corps have experienced a dramatic increase in encroachment pressures associated with operational range activities. In some instances, encroachment issues have impacted training. The early identification of encroachment issues will allow the Marine Corps installation to minimize external pressures, thereby minimizing potential impacts to training. Operational ranges and maneuver areas are essential to Marine Corps training; therefore, sustaining these areas for use is critical to mission readiness.

The REVA program is a component of the Marine Corps Range Sustainment Program. The operational range assessments conducted through the REVA program enhance the Marine Corps' ability to prevent or respond to a release or substantial threat of a release of MC from an operational range or range complex to off-range areas. The assessments also provide information to support operational range sustainment.

This report presents the assessment results for the operational ranges and training areas at Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, California. This report is the first comprehensive report on MC associated with the operational ranges at MCAGCC Twentynine Palms and, as such, serves as the baseline of environmental conditions and potential vulnerabilities of the ranges. Subsequent vulnerability assessments will be conducted for operational ranges at MCAGCC Twentynine Palms on a five-year cycle or when significant changes are made to existing ranges that potentially affect the determinations made during this baseline assessment, as described in the *REVA Reference Manual* (HQMC, 2006).

1.2. Scope and Applicability

The scope of the REVA program includes Marine Corps operational ranges located within the United States and overseas. Operational ranges (as defined in 10 United States Code 101(e)(3)) include, but are not limited to, fixed ranges, live-fire maneuver areas, small arms ranges (SARs), buffer areas, and training areas where military munitions are known or suspected to be currently or to have been historically used. The presence of other-than-operational ranges is noted where applicable, but they are not assessed under the REVA program. Other-than-operational ranges are being addressed under the Marine Corps' Munitions Response Program.

Site-specific environmental conditions and MC loading rates are used in fate and transport models to assess whether the potential exists for a release or substantial threat of a release of MC from an operational range or range complex area to an off-range area. Fate and transport modeling in REVA utilizes screening-level transport analyses that conservatively estimate the concentrations of MC potentially migrating to off-range exposure points. Exposure pathways considered in the REVA process include consumption of surface water and groundwater for off-range human and ecological receptors, as described in the *REVA Reference Manual* (HQMC, 2006). Other off-range exposures scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation and food chain exposure) currently are not considered in the REVA process.

The MC evaluated in the REVA program include trinitrotoluene (TNT), cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), and perchlorate. TNT, HMX, and RDX are considered to be indicator MC. Studies have shown that they are detected in a high percentage of samples containing MC due to their chemical stability within the environment. They are common high explosives used in a wide variety of military munitions. Perchlorate is a component of the solid propellants used in some military munitions. Perchlorate is also considered an indicator MC, as its high solubility, low sorption potential, and low natural degradation rate make the compound highly mobile in the environment. Additional information pertaining to the physical and chemical characteristics of the REVA indicator compounds is provided in the *REVA Reference Manual* (HQMC, 2006).

The primary MC of concern at SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. Lead is geochemically specific regarding its mobility in the environment; modeling of lead would require site-specific geochemical data that are generally unavailable during a baseline assessment. Therefore, instead of modeling lead transport, active SARs at the installation are qualitatively reviewed and assessed to identify factors that influence the potential for lead migration. These factors include a range's design and layout, the physical and environmental conditions of the area, and current and past operation and maintenance practices. The amount of lead that has been loaded to the operational ranges has also been determined.

The process and assumptions used in estimating the MC deposited onto operational ranges, defined in REVA as MC loading, are discussed in **Section 3**. The fate and transport modeling and analysis methods and assumptions for groundwater and surface water are discussed in **Sections 4** and **5**, respectively.

This report presents the analysis of the data collected during site visits and the results of fate and transport modeling at MCAGCC Twentynine Palms. Additional details of the REVA assessment methods are outlined in the *REVA Reference Manual,* which includes a detailed description of the fate and transport models selected for the baseline range environmental vulnerability assessments, the data needed to run those models, and recommended sources for data. In addition, the *REVA Reference Manual* provides a detailed description of the REVA MC Loading Rate Calculator (HQMC, 2006).

This baseline range environmental vulnerability assessment report presents the conditions of the operational ranges at the time the assessment was conducted. The baseline environmental range assessment was performed using available data and personnel interviews and is supplemented with information from external sources, including reports and documentation.

1.3. Report Organization

This REVA baseline environmental range assessment report for MCAGCC Twentynine Palms is organized into the following sections:

Section 1 – Introduction
Section 2 – Summary of Data Collection Effort
Section 3 – MC Loading Rate and Assumptions
Section 4 – Groundwater Analysis Method and Assumptions
Section 5 – Surface Water Analysis Method and Assumptions
Section 6 – Conceptual Site Model (CSM)
Section 7 – Operational Range Training Areas
Section 8 – Small Arms Range Assessments
Section 9 – References

2. Summary of Data Collection Effort

Data required for the operational range assessments were obtained from Headquarters Marine Corps (HQMC), from the installation during a site visit by the REVA assessment team, and from external data sources. Data obtained from HQMC and the installation includes various documents and reports conducted for the installation (e.g., Master Plans, Archive Search Reports [ASR], and Preliminary Range Assessment [PRA] and Installation Restoration Program [IRP] reports). External data sources include reports and online information from organizations such as the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS).

A site visit was conducted by the REVA assessment team on May 1-5, 2006. HQMC personnel accompanied the team during the site visit. The installation site visit involved a review of various data repositories and interviews with installation personnel from the following offices:

- Natural Resources and Environmental Affairs (NREA) Division
- Range Operations and Control (G3)
- Explosive Ordnance Disposal (EOD)
- Marksmanship Training Unit (MTU)
- Facilities Management Division (FMD)
- Geographic Information System (GIS)

The REVA assessment team interviewed subject matter experts within each of these offices to identify areas of interest and specific concerns pertaining to each office. Specific issues relating to operational range use and potential impacts to training were the focus of these discussions.

3. MC Loading Rates and Assumptions

The REVA fate and transport modeling / analysis requires estimation of the amount of indicator MC deposited on operational ranges over time in order to predict if there is a potential release or substantial threat of a release of MC. Within the REVA program, this deposition and the process by which it is estimated is referred to as MC loading. Operational range usage, boundaries, and other characteristics typically change over time; therefore, an analysis of their history must be performed to map the affected areas over time and to estimate the historical and current MC loading.

For the MC loading estimation, some operational ranges were conceptually subdivided into one or more areas of interest when MC loading was estimated not to be consistent across their area. Similarly, different loading periods were assumed to account for changes in training rates and historical uses. The MC loading for the operational ranges was estimated separately for each area and period of interest and for each REVA indicator MC. For the purposes of the REVA program, MC loading estimates were expressed as the average mass deposited annually in the defined area of interest (kilograms per square meter [kg/m^2]) for the duration of the period that the operational range activities generating the MC loading were conducted.

Assumptions were made throughout the MC loading analysis process pertaining to the spatial distribution of the MC on the MC loading areas, as summarized in **Section 3.1** through **Section 3.4**. **Section 3.5** provides a description of the range training areas (RTAs), fixed firing ranges, and SARs at MCAGCC Twentynine Palms. The overall assumptions for MC loading on the operational ranges at MCAGCC Twentynine Palms are summarized in **Section 3.6**. In **Section 7**, maps are provided to depict the MC loading areas, along with the assumptions made for each operational RTA that was assessed.

3.1. MC Loading Process

The MC loading was estimated based on mass-loading principles. Studies have shown that MC are deposited on the operational range through low and high order detonations and can leach from corroded unexploded ordnance (UXO). These processes are presented in the equation below:

Total MC loading = MC (low orders) + MC (high orders) + MC (UXO)

Notes:
1) MC (low orders) is the amount of MC deposited as a result of low order detonations.
2) MC (high orders) is the amount of MC deposited as a result of high order detonations.
3) MC (UXO) is the amount of MC deposited as a result of UXO with breached casings.

Studies conducted by the DoD have shown that the MC remaining from high order detonations are much less significant than the amount of MC deposited from low order detonations. Corrosion studies conducted by the U.S. Army have shown that it can take a long time for UXO to corrode. Although MC remaining from low order detonations are the most significant contributor to MC loading, the REVA program accounts for MC from all three of these potential sources.

MC loading estimates for low order and high order detonations and UXO for the MC loading areas associated with each operational range were estimated using the equations below:

MC (low order) = (number of military munitions expended) x (low order rate) x (amount of residual remaining from a low order detonation)

MC (high order) = (number of military munitions expended) x (high order rate) x (amount of residual remaining from a high order detonation)

MC (UXO) = (number of military munitions expended) x (dud rate) x (amount of residual exposed as a result of damage to UXO casings)

Dud rate and low order rate data for REVA were estimated based upon the July 2000 study completed by the U.S. Army Technical Center for Explosives Safety entitled *Report of Finding for Study of Ammunition Dud and Low Order Detonation Rates.* Dud and low order rates for military munitions in this report were tracked, reported, and made available according to military munitions DoD Identification Code (DoDIC). For the DoDICs that do not have dud or low order rates available, the default values listed in the referenced report of 3.45% (dud rate) and 0.028% (low order rate) were used. In addition, for the purposes of the REVA program, it was assumed that the amount of residual explosives remaining after a low order detonation and a high order detonation were 50% and 0.1%, respectively. These numbers are consistent with those used in the U.S. Navy's Range Sustainability Environmental Program Assessment.

The primary source of information on the types and amounts of energetic fillers associated with military munitions was the Defense Ammunition Center's Munitions

Items Disposition Action System (MIDAS) Web site. Data were retrieved from MIDAS by performing searches for the MC, which produced a list of military munitions with their respective amounts of MC. The list of military munitions was then evaluated, as more than one matching National Stock Number was often listed, and the highest and lowest MC quantities were captured and averaged for REVA MC loading estimate calculations.

In addition to MIDAS, other sources of MC data included the ORDDATA II software (Enhanced International Deminer's Guide to UXO Identification, Recovery and Disposal; Version 1.0, 1999) and various ordnance technical manuals. In cases where specific military munitions use data were unavailable, the military munitions types selected were based upon common military munitions used during the active time periods of the operational range.

3.2. Expenditure Data

The Range Operations Section / Range Control (henceforth, Range Control) is responsible for the administration and oversight of the widespread training operations conducted on a daily basis at MCAGCC Twentynine Palms. Range Control maintains military munitions expenditure data in electronic format for the operational ranges managed by the installation. Current military munitions expenditures were obtained from Range Control for the years 2001 through 2005. These data were provided to the REVA team in hard copy format and converted to electronic format.

The use of documented expenditure data is preferred in the REVA program. However, there are many cases (including most historical use areas) where expenditure data were not maintained for the entire time the range was in use. In these cases, the amount of military munitions expended over time had to be estimated. Historical expenditure data were estimated based on extrapolation of the 2001–2005 expenditure data back to 1969 (one historical range training zone used from 1942 to 1944 was also included). For operational ranges and historical use areas within operational ranges that were used prior to 1969, discussions with Range Control determined that the military munitions used should reflect those military munitions indicated within the ASR and PRA (USACE, 2001a and 2001b)[1]. Although the military munitions types for the periods of operation between 1942 and 2001 were obtained from the ASR and PRA, the quantification of these items was based on quantities of similar items or groups of items (i.e., mortars, projectiles, or bombs) in the 2001–2005 expenditure data. Therefore, all military munitions expenditure estimates were based on the quantities extracted from the 2001–2005 data and adjusted for changes in types of military munitions used.

[1] The ASR and PRA were conducted by the U.S. Army Corps of Engineers (USACE) to support the Military Munitions Response Program.

3.3. REVA MC Loading Rate Calculator

The REVA MC Loading Rate Calculator and its Training Factor are explained in more detail in the *REVA Reference Manual* (HQMC, 2006). All known data and assumptions input into the MC Loading Rate Calculator for each operational range area assessed are documented in **Section 7**. The following discussion provides a brief summary of the MC Loading Rate Calculator.

The REVA MC Loading Rate Calculator provides an automated method to calculate the overall loading of the operational range based upon the military munitions expenditure estimating methods discussed above. The MC Loading Rate Calculator estimates an average expenditure rate that is then applied to each year the operational range is known or suspected to have been operational where expenditure data are missing or incomplete.

The MC Loading Rate Calculator also applies values for the data discussed earlier (dud rate, low order rate, high order rate, and residual amount of MC remaining) and loading area values (square meters [m^2]) so that the estimated MC concentrations are presented in the units needed for the fate and transport analysis (kg/m^2). Additionally, the calculator applies a Training Factor to account for fluctuations in training due to world events during which there was an increase or decrease in training, such as conflicts and wars.

In some instances, the types of military munitions used at a given RTA do not contain all four of the REVA indicator MC. Under these circumstances, the MC loading rate is considered to be zero for that REVA indicator MC. This is presented in the MC loading tables as not applicable (n/a). For example, expenditures at the Gypsum Ridge RTA between 2001 and 2005 consisted of very limited numbers of small arms ammunition and high explosive munitions. The particular munitions used in the Gypsum Ridge RTA contain HMX, TNT, and perchlorate, but do not contain RDX. Therefore, the estimated annual loading rate of RDX for Gypsum Ridge is annotated as ―n/a,‖ while loading rates are provided for the other three indicator MC, as shown in Table 7.29-1.

3.4. Training Factor

Historically, the level of military training operations has been strongly affected by conflicts and wars. This usually resulted in an increase in training prior to a conflict or war and a tapering off during it, with training increasing again toward the end of the event and then, subsequently, decreasing again to a nonconflict/nonwar level. The REVA program attempts to account for this training effect by developing a training timeline of significant military conflicts and wars from 1914 through today. This timeline accounts for the following:

- World War I
- World War II (WWII)

- The Cold War
- The Korean War
- The Vietnam Conflict
- The Persian Gulf
- Afghanistan
- Iraq

Subject matter experts within the Marine Corps were queried to establish time periods of increased training throughout history. This inquiry resulted in the establishment of a baseline training level period, as well as the development of four periods that increase the MC loading rate by a Training Factor. The periods identified and their associated Training Factors are as follows:

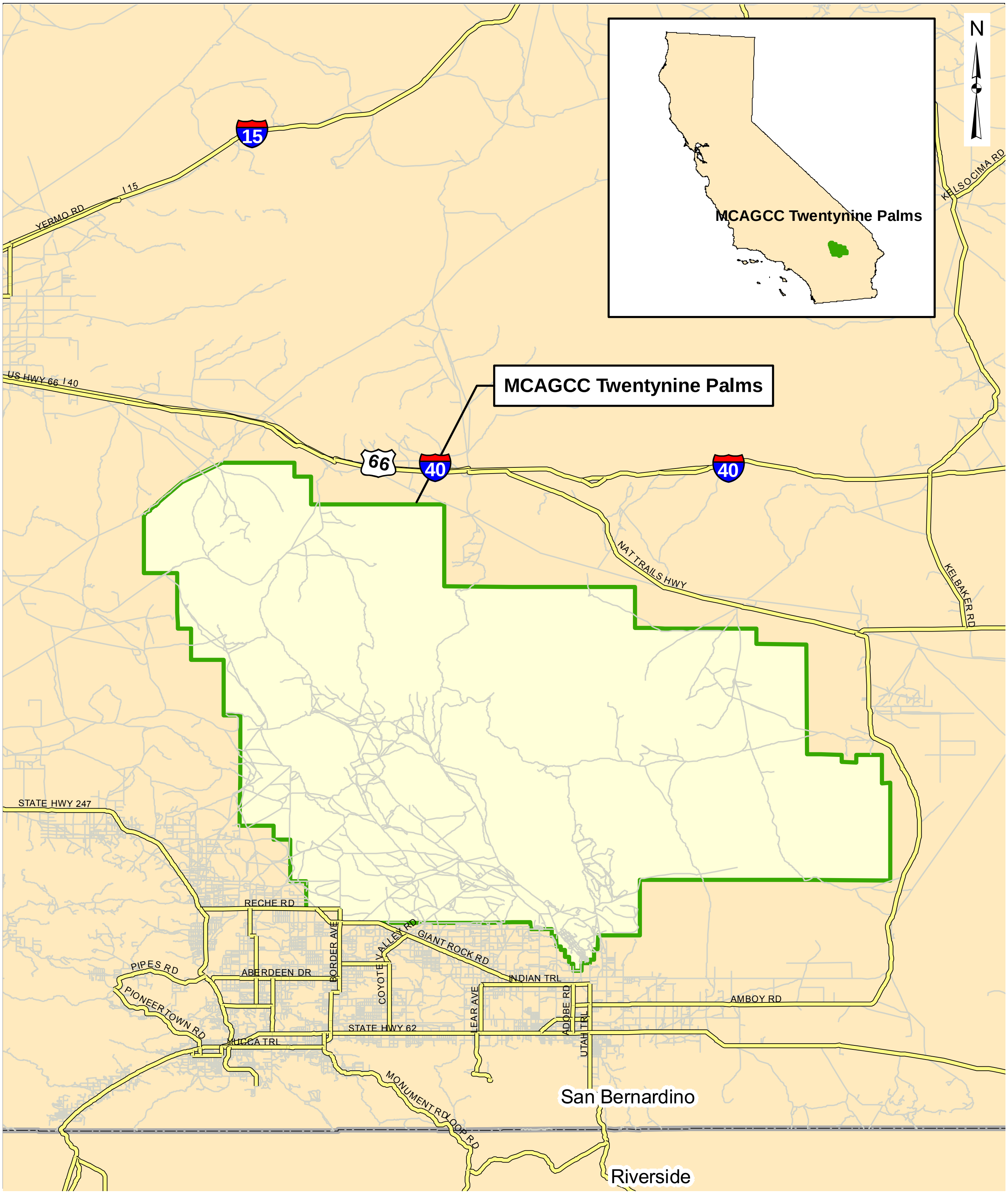
- Period A: 1914–1924 (baseline + 40%)
- Period B: 1925–1937 (baseline)
- Period C: 1938–1976 (baseline + 50%)
- Period D: 1977–1988 (baseline + 20%)
- Period E: 1989–present (baseline + 50%)

The baseline expenditure rate is applied to each year an operational range was in use. The MC Loading Rate Calculator automatically applies the Training Factor adjustments according to the time period so that MC loading rates are estimated for each year the operational range was known or suspected to have been in use.

3.5. Loading at MCAGCC Twentynine Palms

MCAGCC Twentynine Palms is the Marine Corps' largest live-fire training facility, encompassing 599,627 acres in San Bernardino County, California (MCAGCC FMD, 2006). The primary mission of MCAGCC Twentynine Palms is to develop, administer, conduct, support, and evaluate the Marine Corps' training exercises and operations, while supporting the tenant commands of the Marine Expeditionary Force and the Marine Corps Communications and Electronics School (DoN, 2003a). MCAGCC Twentynine Palms provides housing, facilities, and certain logistic and administrative support to tenant Fleet Marine Force and other assigned units. The cantonment area in which these facilities are located is referred to as Mainside. The location of MCAGCC Twentynine Palms is shown in Figure 3.5-1, and the layout of the installation is shown in Figure 3.5-2.

MCAGCC Twentynine Palms annually provides training to one-third of the Fleet Marine Force and Reserves units through the Combined Arms Exercise (CAX) program and numerous other training exercises (MCAGCC, 2006). The installation also provides



LEGEND

- COUNTIES
- MCAGCC TWENTYNINE PALMS
- ROADS
- ROADS

5 2.5 0 5 Miles

SOURCE: MCAGCC/NREA GIS OFFICE 2006, TECOM 2006

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MALCOLM PIRNIE

MCAGCC TWENTYNINE PALMS, CALIFORNIA

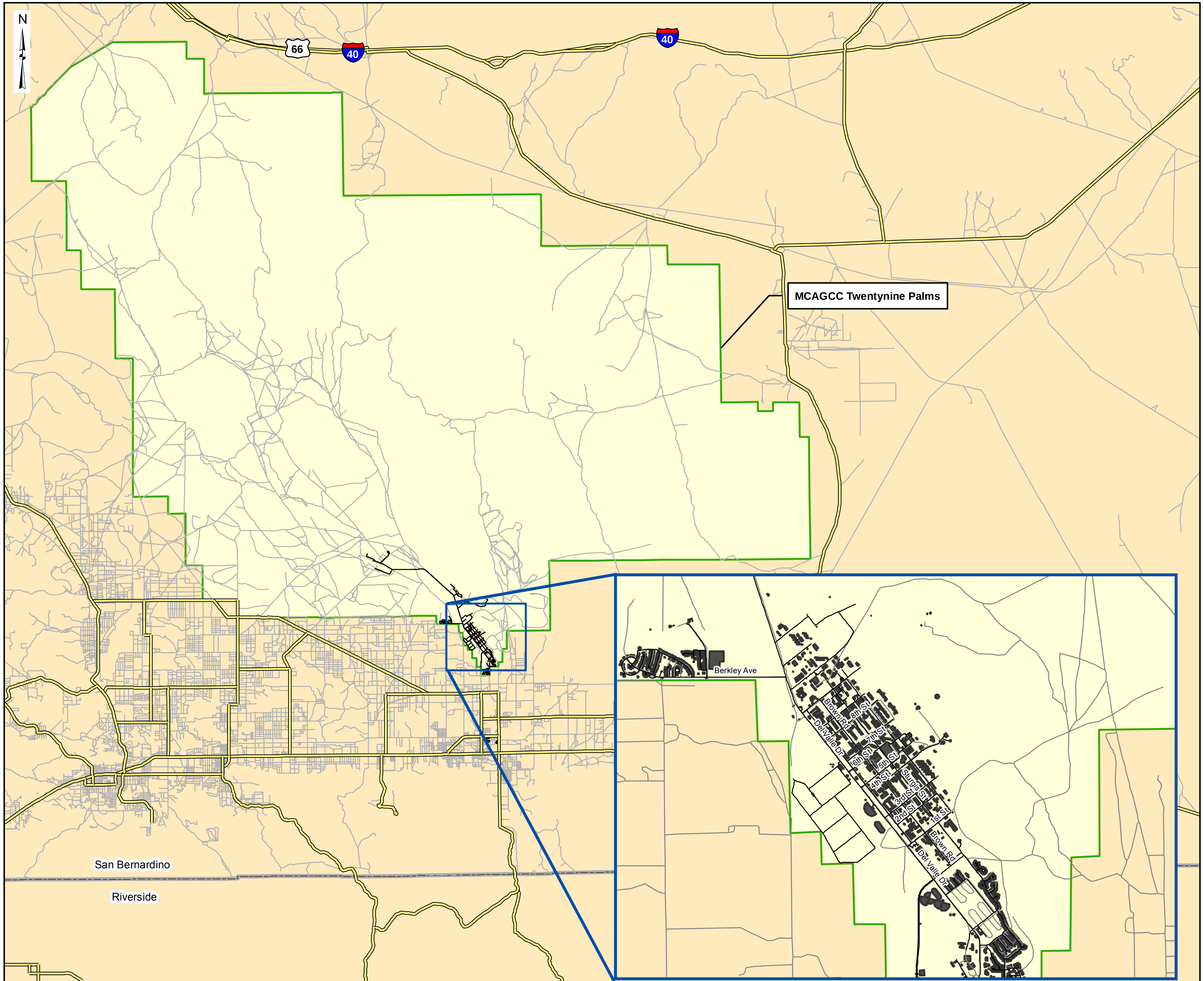
RANGE ENVIRONMENTAL VULNERABILITY ASSESSMENT

SITE LOCATION MAP

MALCOLM PIRNIE, INC.

AUGUST 2008

FIGURE 3.5-1

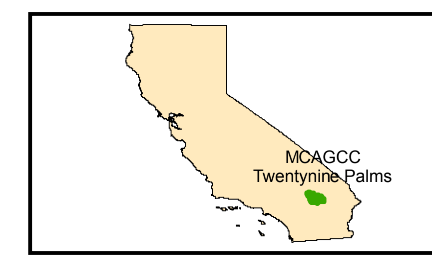


REVA
FIGURE 3.5-2
INSTALLATION LOCATION

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- COUNTIES
- MCAGCC TWENTYNINE PALMS
- ROADS
- ROADS



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Miles

Date: August 2008

Source: MCAGCC/NREA GIS Office 2006

training resources for U.S. Army, Navy, and Air Force units, as well as foreign military elements. Active duty military personnel currently assigned to the Combat Center include 10,500 Marines supported by 1,627 civilian personnel (MCAGCC, 2006). There are 7,492 military dependents. About 35,000–50,000 DoD military personnel annually train during military exercises at the installation. The various live-fire training activities and exercises conducted at MCAGCC Twentynine Palms include the following programs:

- CAX program
- Mojave Viper program
- Steel Knight exercise
- Desert Fire Exercise
- Desert Scimitar exercise
- Fire Support Coordination Application Course
- Tactical Air Control Party Course
- Fallbrook Shoot
- Barstow Shoot

Range Control maintains command and control over the training complex and administers the operational training activities conducted across the installation. These exercises plus other smaller training programs occur through approximately 90% of the year (MCAGCC, 2006). The following sections provide an overall summary of the major training exercises conducted at MCAGCC Twentynine Palms, obtained from existing sources and interviews with Range Control. Detailed descriptions of these exercises are available in the Integrated Natural Resources Management Plan (INRMP) (MCAGCC, 2006), which references the Training Range Study (EDAW, 1994), as well as updates provided by Snover and Kellogg (1999).

CAX

The CAX program was established in 1975 and has been the primary large-scale exercise program conducted at MCAGCC Twentynine Palms. CAX is a comprehensive integrated live-fire training exercise combining ground, air, and support elements. The program combines the arms training program for ground (armor, artillery, and infantry units) and air fire support (fixed and rotary wing aircraft) with maneuver at the tactical level and is designed to involve all elements of the Marine Air Ground Task Forces in a live-fire, desert training environment. The number of participants for each CAX averages between 3,200 and 3,700 Marines (The Environmental Company, 2004). Almost the entire Marine Corps ordnance inventory is deployed during CAX training, including both land- and air-delivered military munitions. Most of the RTAs are employed during this exercise.

Mojave Viper

The Mojave Viper program, established in 2005, has become the primary training exercise conducted at the installation. Mojave Viper is a live-fire training exercise that combines the ground, air, and support elements available to an infantry battalion in preparation for ground combat operations in the Iraqi theater of operations (MCAGCC, 2006).

Objectives of the Mojave Viper exercise are to:

- train units to synchronize air/ground fire in support of the warfare maneuver;
- exercise command, control, communications, intelligence, and fire support coordination of combined arms in desert and urban environments; and
- develop and refine tactics, techniques, and procedures—including cultural considerations—as they relate to the current operating picture in theater.

The Mojave Viper force is composed of an infantry battalion (approximately 800 Marines) supported by a Combat Service Support element consisting of logistical equipment and personnel to provide supplies and repair services to the battalion (MCAGCC, 2006). Training is carried out on most RTAs during the Mojave Viper exercise.

Steel Knight

Steel Knight is a two-week, division-level training event (MCAGCC, 2006). These training scenarios, which vary between each event, include deliberate attack, counterattack, day/night deliberate defense, withdrawal, battlefield interdiction, direct air support, close air support, and night tactical withdrawal not-under-enemy-fire. Exercises also include aerial reconnaissance and surveillance and long-range artillery missions. Most RTAs at the installation are employed for Steel Knight.

DESFIREX

The DESFIREX is primarily an artillery training exercise training two battalions (MCAGCC, 2006). DESFIREX focuses exclusively on artillery unit training and can include infantry, reconnaissance, and armored units. Other training schemes can include helicopter-borne raids, Joint Air Batteries, and unmanned aerial vehicle operations. DESFIREX uses most RTAs. The heaviest artillery impact areas are Quackenbush, southern Gays Pass, Lead Mountain, and northern Bullion, with moderate artillery firing into the Black Top, Lavic Lake, Delta, and north-central Lava RTAs (Snover and Kellogg, 1999).

Desert Scimitar

The Desert Scimitar exercise originated in the 1990s as a large-scale operation similar to DESFIREX (MCAGCC, 2006). In 2001, the objective changed fundamentally into a command and control / logistics exercise that, using relatively small numbers of personnel and equipment, simulates the movement of large forces between MCAGCC Twentynine Palms and Yuma, Arizona, including an expeditionary bridge across the Colorado River and the use of several different categories of public and private land. This exercise has not been conducted recently, but remains a potential future operation.

Fire Support Coordination Application Course

This training course involves live-fire, mostly air and artillery, in the Delta, Quackenbush, and Prospect RTAs, and non-live-fire in the Gypsum Ridge RTA (Snover and Kellogg, 1999).

Tactical Air Control Party Course

This exercise involves considerable live-fire air support (MCAGCC, 2006) and is conducted in the Quackenbush RTA, but the Lava and Lead Mountain RTAs have been utilized in the past.

Fallbrook and Barstow Shoots

The Barstow Shoot is used to test howitzers that have been rebuilt by the Marine Corps Logistics Base, Barstow (MCAGCC, 2006). This shoot is conducted in the southeast portion of the Delta RTA. The Fallbrook Shoot is scheduled by the Naval Ordnance Center, Pacific Division (MCAGCC, 2006).

EOD personnel provide periodic range clearance operations across the RTAs and support all large-scale training exercises. A routine clearance schedule has been developed, with individual RTAs cleared on a rotating basis. The current schedule requires biennial clearance of all RTAs, with annual clearances conducted at the Delta and Quackenbush RTAs (MCAGCC, 2001). Range clearances are conducted following every major exercise. Visiting CAX EOD units also assist in the range clearances. All UXO are rendered safe on the RTAs; UXO are not removed or transported to an off-range area for disposal. Munitions debris and other range debris are processed through the NREA RRPS for recovery and resale of metal.

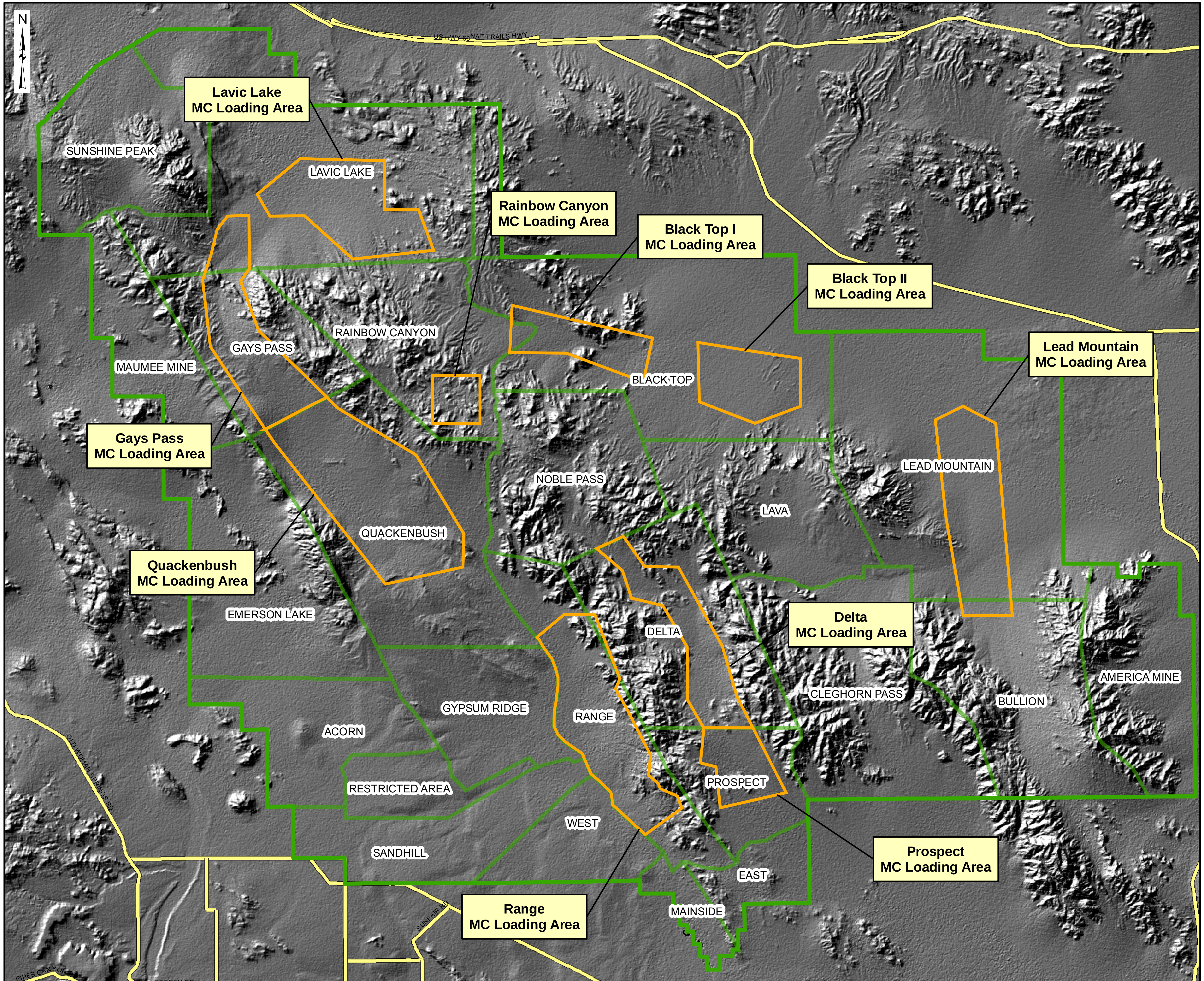
With the exception of Mainside (which is considered a special-use area) and several restricted areas, the entire area within MCAGCC Twentynine Palms has been designated as an operational training range complex. For scheduling purposes, the installation has been divided into 22 separate RTAs. The RTAs differ in size, terrain, and training usage. The boundaries of each RTA are defined by training requirements, topography, and other constraints. Different types of training can be conducted simultaneously in multiple RTAs without jeopardizing safety. The RTAs (or portions thereof) may also be subject to limitations or restrictions on the use for maneuvers, live fire, or other training activities (DoN, 2003b). Fifty-four fixed ranges are located within the RTAs, covering approximately 19,240 acres. The fixed ranges vary in the types of weapons and munitions used, allowable maneuvers, and impact areas (DoN, 2003b).

Discrete MC loading areas associated with the operational ranges on the installation are those areas where MC have been deposited. These areas can be target or impact areas associated with current ranges or historical ranges that lie within the footprint of the operational ranges and training areas. These discrete MC loading areas are not likely to resemble the operational surface danger zones (SDZs) or range fans, as they are intended to reflect the area where the majority of the MC was likely to have been deposited. At MCAGCC Twentynine Palms in particular, training operations are conducted across large-scale maneuver areas that contain few specifically designated firing points and impact areas; subsequently, weapons can be fired from and toward any location within the RTAs. Although designated fixed ranges are present at the installation, the majority of training (live-fire and non-live-fire) is conducted within these large-scale maneuver areas. The primary MC loading areas identified for MCAGCC Twentynine Palms are shown in Figure 3.5-3. These are based on logical assumptions regarding the zones within the RTAs in which weapons fire is concentrated (per installation personnel, a review of GIS-marked CAX target locations, topography, and historical use as described in the ASR and PRA report conducted by the USACE).

Restricted Areas

Although the fire of military munitions is allowed generally anywhere within a live-fire RTA, several areas within the installation are protected due to the presence of cultural and natural resources, as defined in Combat Center Order 5090.1C (MCAGCC, 2006). Restricted areas have been established and are prescribed as areas with no impact, no mechanized maneuvers, no bivouacs, no off-road vehicles, nor any training involving vehicle activity. These areas include the following:

- Restricted Area RTA – Surprise Spring / Sand Hill
- Foxtrot petroglyphs
- Cultural Resources Management Area
- Historic sites
- Historical mines or prospects

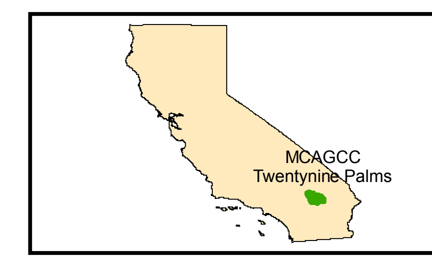


REVA
FIGURE 3.5-3
RTAs AND PRIMARY
MC LOADING AREAS

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- MCAGCC TWENTYNINE PALMS
- OPERATIONAL RTAs
- PRIMARY MC LOADING AREAS
- ROAD



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Date: August 2008

Source: MCAGCC/NREA GIS Office 2006
TECOM 2006

- Lead Mountain study plots

Areas designated as Environmentally Sensitive Areas do not have limitations to training; however, military units are cautioned to be aware of sensitive natural and cultural resources. These areas include the following:

- Sand Hill RTA
- Emerson Lake and Acorn RTAs
- Cleghorn Pass (outside the fixed ranges)
- Wood Canyon
- Northern Sunshine Peak
- Southern Bullion RTA
- All dry lake beds (playas)

The following sections describe the current operational profile at MCAGCC Twentynine Palms, including the location and general training conducted at the RTAs, fixed ranges, and SARs.

3.5.1. RTAs

RTAs provide the Marine Corps with large open areas of land on which to conduct live-fire maneuver training. The current RTAs and fixed ranges located at MCAGCC Twentynine Palms are illustrated in Figure 3.5-3. An RTA is defined as an area that does not have specific firing or target points, and its boundaries are limited by natural barriers (USACE, 2001a). Artillery and aviation firing and target points on RTAs are generally exercise-dependent and are moved accordingly. Thus, few specific impact areas are designated at MCAGCC Twentynine Palms, and munitions are distributed throughout the RTA. Firing is allowed anywhere throughout the RTA, with the exception of a 1,000-meter (m) buffer established along the interior of the installation boundary to prevent military munitions from being fired beyond the installation borders, as well as the restricted areas noted above.

Five RTAs (Acorn, East, Gypsum Ridge, Sand Hill, and West) located in the southwest corner of the base are designated as non-live-fire maneuver areas. Limited live firing is allowed from the East RTA; however, all fire from this zone is directed into the Prospect and Delta RTAs. Training is not conducted in the Mainside cantonment area or the 7,900-acre Restricted Area.

The remaining 17 RTAs allow live-fire training anywhere within the training area, although most firing is directed at CAX targets and typically no higher in elevation than the base of any nearby mountain ranges. Interviews with Range Control and a review of expenditure data indicate that areas within the Quackenbush, Lavic Lake, Delta, Lead

Mountain, and Range RTAs receive the greatest amount of live-fire military munitions related training and, thus, the estimated greatest amount of MC loading at the installation. In addition, Range Control personnel indicated that Range 601 in the Rainbow Canyon RTA (Sensitive Fuze Impact Area) and areas within the Gays Pass, Prospect, and Black Top RTAs also receive significant loading, though to a lesser degree. These areas are designated as primary MC loading areas in Figure 3.5-3. Historical MC loading, dating to 1969, generally is consistent with these current primary loading areas. Historical loading prior to 1969 is not well defined, as the installation was not subdivided into RTAs.

Various target structures are spread throughout the boundaries of MCAGCC Twentynine Palms to support training operations. Permanent target emplacements consist of two forms: the Infantry Remote Engagement Target System and the CAX target system. The former target variants are pop-up stationary or rail-mounted targets typically used for infantry fire. CAX targets consist of stationary pop-up targets for armor fire or infantry anti-tank fire (MCAGCC, 2006). Other stationary targets, consisting of vehicle hulks, tire stacks, or wooden silhouettes, are placed throughout the installation. Maintenance of all main supply routes (MSRs), targets, impact berms, and supporting structures is conducted by the Range / Training Areas Management Section (RTAMS). RTAMS also ensures cleanup of RTAs following all large-scale exercises.

The training activities conducted at MCAGCC Twentynine Palms are evaluated continuously. Training approaches continue to evolve based on emerging requirements observed from current operations in Iraq and Afghanistan. As such, training activities at the RTAs may change or be adjusted in the future.

3.5.2. Fixed Ranges

There are 54 fixed ranges within the installation, one-half of which are located within the Range RTA (27 ranges). Seven SARs are utilized for rifle and pistol qualification for Marines, administered by the MTU. Several newer ranges have been established, including 10 fixed convoy course stations (convoy live-fire maneuver with predominantly small arms fire). The 54 fixed ranges associated with the installation are listed in Table 3.5-1. Additionally, as of May 2006, a new combined arms military operations in urban terrain (MOUT) training facility (CAMOUT) is under construction in the Quackenbush RTA.

Table 3.5-1: Fixed Ranges at MCAGCC Twentynine Palms

Fixed Range	RTA	Range Type	Area (1,000 m^2)
LIVE-FIRE RANGES			
Convoy Course Station 2 (portion in Prospect)	Delta	Convoy course	131.15
Convoy Course Station 3	Delta	Convoy course	724.90
Convoy Course Station 4	Delta	Convoy course	894.08
Convoy Course Station 5	Delta	Convoy course	252.12
Convoy Combat (C.C.) Course Station 1	Lead Mountain	C.C. course	329.76
C.C. Course Station 2	Lead Mountain	C.C. course	621.80
C.C. Course Station 3	Lead Mountain	C.C. course	775.09
CAMOUT	Quackenbush	Live-fire MOUT training	3,611.66
Range 620	Quackenbush	To be determined (TBD)	1,004.71
Range 630	Quackenbush	TBD	4,008.16
Range 051	Range	EOD demilitarization range	149.12
Range 101[a]	Range	Armor, gun training range (subcaliber)	1,084.81
Range 101A [a]	Range	Small arms battle sight zero (BZO) range	3.72
Range 103	Range	Automated squad defensive firing range	1,531.86
Range 104	Range	Anti-mechanized/grenade range	1,357.37
Range 105	Range	Gas chamber	242.48
Range 105A [a]	Range	Small arms BZO range	22.83
Range 106	Range	Mortar range	3,260.82
Range 106A	Range	Basic hand grenade range	31.92
Range 107	Range	Infantry squad assault range	4,391.54
Range 108	Range	Infantry squad battle course	5,140.27
Range 109	Range	Anti-armor live-fire tracking range	3,845.76
Range 110	Range	Machine gun range	2,639.35
Sensitive Fuze Impact 1	Range	Range 110 impact area	3,429.19
Range 110A	Range	Grenade range	77.93
Range 111	Range	MOUT assault course	583.66
Range 113 [a]	Range	Multipurpose machinegun range	3,997.60
Range 113A [a]	Range	Machine gun BZO range	3.87
Range 114	Range	Combat Engineer demolition range	337.85
Range 1 [a]	Range	Known distance rifle range	
Range 1A [a]	Range	Unknown distance rifle range	
Range 2 [a]	Range	Known distance pistol range	
Range 2A [a]	Range	Combat pistol range	523.90
Range 3 [a]	Range	BZO grouping range	
Range 3A [a]	Range	BZO grouping range	
Range 4 [a]	Range	Multipurpose range	
C.C. Course Station 4	Black Top	C.C. course	409.62
Convoy Course Station 1	Prospect	Convoy course	340.43

Fixed Range	RTA	Range Type	Area (1,000 m²)
Range 601 (portion in Delta)	Rainbow Canyon	Sensitive fuze impact range	9,000.00
Range 210	Bullion	Live-fire MOUT training facility	578.08
Range 400	Cleghorn Pass	Company live-fire and maneuver range	2,907.13
Range 410	Cleghorn Pass	Platoon live-fire and maneuver range	941.40
Range 410A	Cleghorn Pass	Rifle platoon hasty attack and maneuver range	1,188.56
Range 500	Cleghorn Pass	Armor multipurpose range complex	7,381.31
C.C. Course Station 5	Lava	C.C. course	727.11
NON-LIVE-FIRE RANGES			
Range 100	East	Squad maneuver range	4,887.86
Range 200	East	Non-live-fire MOUT training facility	193.10
Range 215	East	Non-live-fire MOUT training facility	577.83
Range 215A	East	Non-live-fire MOUT training facility	4.13
Forward Operating Base (FOB) 1	East	FOB support for Ranges 200 and 215	270.35
FOB 2	East	FOB support for Ranges 200 and 215	178.99
FOB 3	East	FOB support for Ranges 200 and 215	320.51
Range 102	West	Land navigation range	2,454.34
Range 112 (portion in Delta)	Range	NREA range residue processing area	1013.49

[a] A SAR, which is qualitatively assessed under REVA

3.5.3. SARs

There are 12 SARs located at MCAGCC Twentynine Palms; all are in the Range RTA (Table 3.5-1). Seven of these ranges are located within the MTU range complex. . The MTU trains more than 10,000 active duty Marines per year for service rifle and pistol requalification. The other remaining SARs, which are part of the 100 Series fixed ranges, are located further north in the RTA.

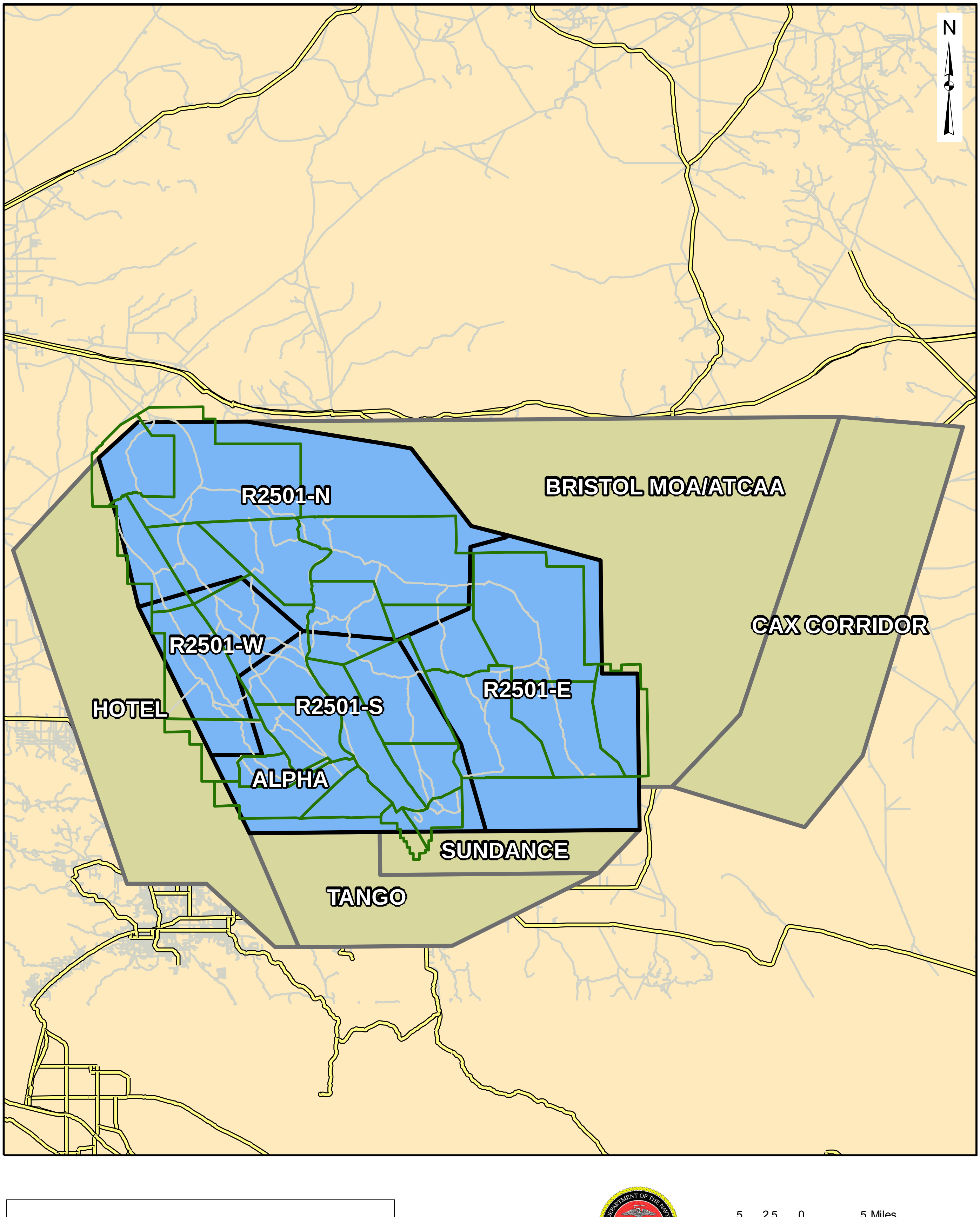
Fate and transport of lead at SARs is strongly influenced by site-specific geochemical conditions that cannot be determined solely by physical observation. Therefore, MC loading and fate and transport modeling were not conducted for the SARs. Rather, the SARs were qualitatively assessed through the REVA SAR Assessment Protocol. This assessment employs a consistent qualitative approach to identify and assess factors that influence the potential for lead migration at an operational range. Operational ranges exclusively used for small arms training at MCAGCC Twentynine Palms include those described in Table 3.5-2. The results of the SAR assessments are provided in **Section 8**.

Table 3.5-2: Operational SARs at MCAGCC Twentynine Palms

Range Number	Range Type
Range 1	Known distance rifle range
Range 1A	Unknown distance rifle range
Range 2	Known distance pistol range
Range 2A	Combat pistol range
Range 3	BZO grouping range
Range 3A	BZO grouping range
Range 4	Multipurpose range
Range 101	Armor, gun training range (subcaliber)
Range 101A	Small arms BZO range
Range 105A	Small arms BZO range
Range 113	Multipurpose machine gun range
Range 113A	Machine gun BZO range

3.5.4. Other Related Training Areas

Restricted airspace R-2501 includes subdivisions R-2501N, R-2501E, R-2501S, and R-2501W (USACE, 2001a). This airspace covers most of the installation, but it is not a range. Aerial exercises within R-2501 use ranges on MCAGCC Twentynine Palms, which include fixed aviation targets, as well as exercise-specific targets. In addition, two Military Operation Areas have been established around the facility. These areas are considered Special Use Airspace under Federal Aviation Administration (FAA) control that may by activated by the installation for military use (MCAGCC, 2006). Range Control coordinates the airspace usage around the facility with the FAA. R-2501 is shown in Figure 3.5-4.



SOURCE: MCAGCC/NREA GIS OFFICE 2006, TECOM 2006

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MALCOLM PIRNIE

MCAGCC TWENTYNINE PALMS, CALIFORNIA

RANGE ENVIRONMENTAL VULNERABILITY ASSESSMENT

RESTRICTED AIRSPACE

MALCOLM PIRNIE, INC.

AUGUST 2008

FIGURE 3.5-4

3.6. MC Loading Assumptions

The MC loading analysis process required various assumptions pertaining to the spatial distribution of the MC on the areas of interest. Because live-fire training operations are conducted across large areas within the RTAs and there are few specific impact areas at the installation, it was conservatively assumed that the areas previously described in **Section 3.5.1** within the Quackenbush, Lavic Lake, Delta, Lead Mountain, Black Top, Rainbow Canyon, Gays Pass, Prospect, and Range RTAs represent the zones in which the majority of military munitions are directed. These areas essentially serve as impact areas; thus, the greatest amount of MC loading is assumed to occur there. This assumption is based on interviews with Range Control, topographic features (military munitions are not fired into the mountains, only the base of the mountains), and a review of target emplacements. MC loading was not assumed to occur across the entire area of these RTAs because this would produce an unrealistically low estimate of the concentration of MC deposited into the RTA. Therefore, these areas have been identified as the primary MC loading areas for MCAGCC Twentynine Palms, indicating the generally higher levels of loading occurring within these portions of the RTAs.

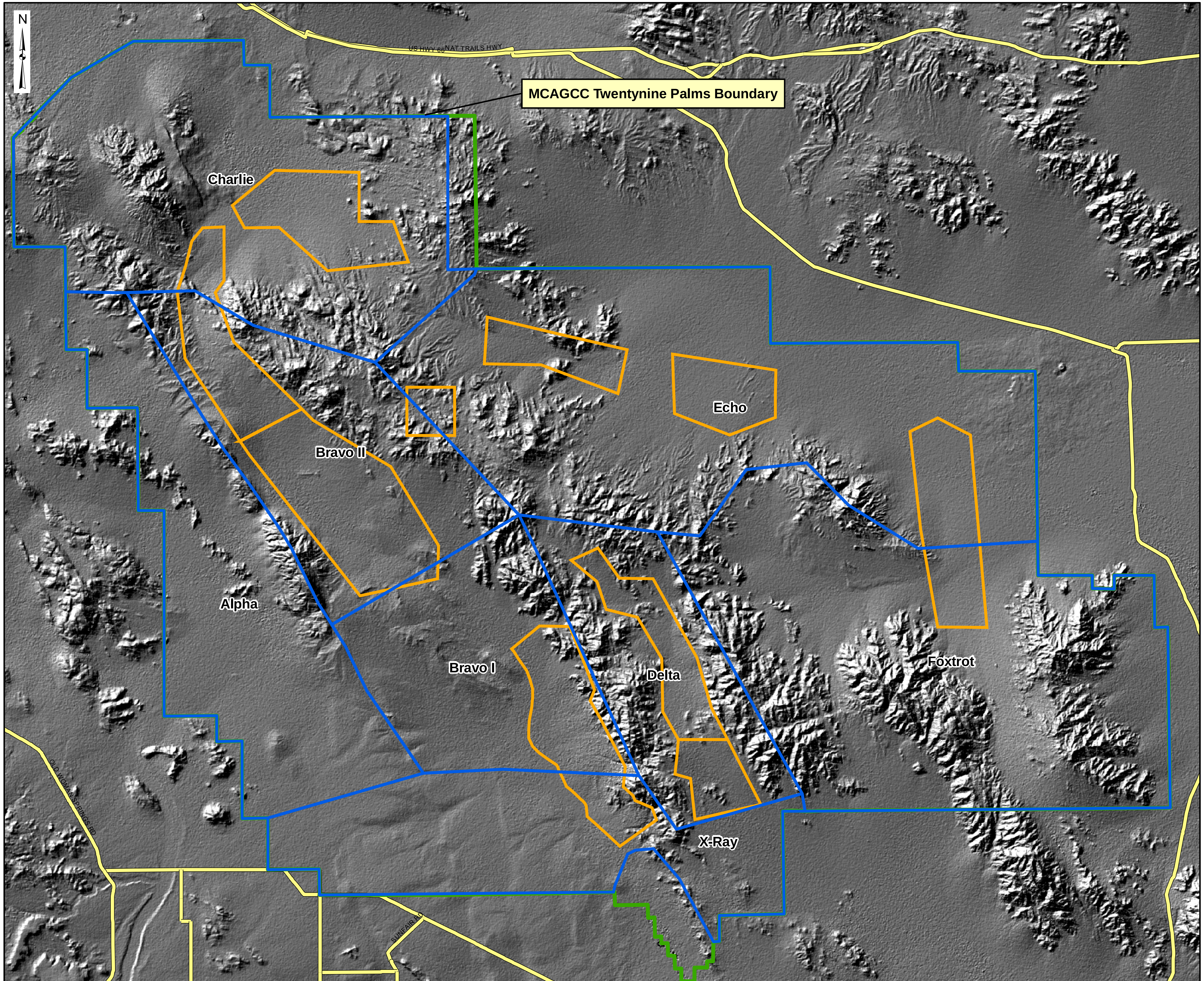
Although the primary MC loading areas represent the highest MC loading rates at MCAGCC Twentynine Palms, MC loading is also occurring at the other live-fire and non-live-fire RTAs at the installation. As such, MC loading calculations were conducted for all RTAs for which munitions expenditure data were available. This includes current non-live-fire RTAs where MC loading may occur due to the use of illumination rounds and/or may have occurred due to historical live-fire training in the RTA. Thus, MC loading areas were defined for each of the remaining 13 current RTAs. Since averaging the MC loading rate over the entire RTA area would produce a diluted loading rate and a smaller overall MC loading area (rather than the entire RTA footprint) is likely more representative of actual training operations, a 10% area was assumed for RTAs that did not contain a primary MC loading area. This is a conservative, arbitrary assumption, based on the information that is currently available. Selecting this percentage for the area in which MC loading would be performed, produced an MC loading rate that is an order of magnitude higher than if loading had been conducted across the entire RTA area. The 10% assumption provides an additional layer of conservatism to the MC loading process to address uncertainties in the actual munitions deposition locations within RTAs.

MC loading was not estimated for three RTAs (Acorn, Sand Hill, and West) because no expenditure data were available from Range Control for these designated non-live-fire training areas. However, historical MC loading for these RTAs is captured through the loading of the historical RTAs that were initially established in these areas prior to their creation and designation as non-live-fire zones.

The historical MC loading process for MCAGCC Twentynine Palms had several major uncertainties. First, although the ASR and PRA delineate the historical boundaries of the previous RTAs, these documents do not include substantive information regarding historical expenditures within the historical use RTAs. Secondly, the documents do not delineate specific impact areas or general areas in which military munitions were directed. However, based on discussions with Range Control, the primary MC loading areas described above were also likely to receive the greatest portion of military munitions in previous decades, particularly from 1969 to 1979 when the installation was subdivided into eight larger RTAs. Therefore, estimation of MC loading for historical use operational ranges was conducted following a two-fold decision process. Portions of the historical use RTAs that shared the same footprint with the primary MC loading areas shown in Figure 3.6-1 were assumed to have been loaded with all of the estimated expenditures from the historical use RTA. If no overlap exists between the historical RTA and current MC loading area, which was the case for only one historical RTA (Alpha), then loading was conducted over 10% of the total historical RTA area. This approach is similar to the conservative assumption noted above for current RTAs that did not have identified primary MC loading areas.

MC loading rates were not estimated for the installation between 1952 (when the installation was established as a Marine Corps base) and 1969 (when eight large RTA were established at the installation for training purposes). During this timeframe, the installation was not subdivided into separate RTAs; rather, the entire installation was considered a single range. Interviews with Range Control described the training at the installation as —quiet” during this period. Large-scale, intensive training did not occur until the CAX program was initiated in the mid- to late 1970s. No records were found that describe primary impact areas, and only a few target locations were identified within the installation from 1952 to 1969 (USACE, 2001a, 2001b). Therefore, to perform MC loading for the installation during this timeframe, the entire acreage of the installation (approximately 590,000 acres outside of Mainside) would be used in the calculation of the MC loading rate. This would result in an extremely low MC loading rate over the entire installation for this period during which little training reportedly occurred. Therefore, MC loading was not conducted for the period between 1952 and 1969.

Five complete years of expenditure data (2001 through 2005), as well as a portion of the 2006 expenditures, were obtained for the RTAs and fixed ranges. The data were evaluated for the overall relative use of each range and the types of military munitions used at each range. The expenditure data were also used to extrapolate the rate of historical use of military munitions at the fixed ranges over time. The expenditure data for the fixed ranges were integrated into the total MC loading rates for each of the MC loading areas delineated by RTA.

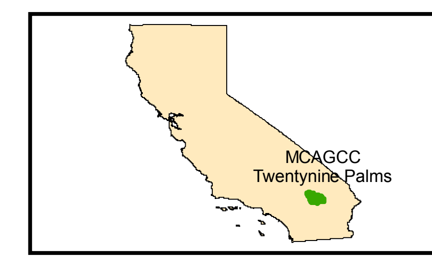


REVA
FIGURE 3.6-1
HISTORICAL USE RTAs,
1969 TO 1979

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- MCAGCC TWENTYNINE PALMS
- HISTORICAL USE RTAs
- CURRENT PRIMARY MC LOADING AREAS
- ROAD



0 1 2 4 6
Miles

Date: August 2008

Source: MCAGCC/NREA GIS Office 2006
TECOM 2006; USACE, 2001

4. Groundwater Analysis Method and Assumptions

The analysis of potential groundwater impacts for MCAGCC Twentynine Palms was conducted following the REVA process described in the *REVA Reference Manual* (HQMC, 2006). The initial step is a qualitative analysis of the groundwater conditions based on the CSM, described in detail in **Section 6**, including the identification of potential exposure pathways and migration routes and the identification of potential receptors (human and ecological). If this qualitative analysis indicates there is potential for MC migration from loading areas to groundwater receptors, a screening-level MC transport analysis is performed to quantitatively estimate potential concentrations of indicator MC (RDX, HMX, TNT, and perchlorate) to migrate in groundwater to a receptor or beyond the installation boundaries.

4.1. Qualitative Analysis

The qualitative groundwater analysis looked at multiple data sources, which are detailed in **Section 6**. The following key information sources were used in the qualitative assessment:

- Military munitions expenditure data
- MCAGCC FMD GIS data
- IRP site data
- USGS topographic maps and regional groundwater resources report
- USDA NRCS soil survey

The primary groundwater basins at MCAGCC Twentynine Palms include:

- the Twentynine Palms basin, southwest of the Bullion Mountains;
- the Bristol Valley basin on the northeastern side of the Bullion Mountains; and
- several smaller intramountain subbasins that are located in the Bullion and Lava Bed mountains.

The groundwater basins, potential for MC migration in the vadose zone and saturated zones, and the presence of potential groundwater receptors at off-range locations are described in more detail in **Section 6.5**.

4.2. Screening-Level Analysis

Following the qualitative assessment of the groundwater at MCAGCC Twentynine Palms, the REVA assessment team determined that groundwater screening-level analysis at MCAGCC Twentynine Palms would not be beneficial. These issues and supporting justification are listed below and discussed in greater detail in the CSM (**Section 6**).

- All known human health and ecological receptors associated with groundwater pathways can be eliminated as potential concerns.
- None of the primary MC loading areas are located near the installation drinking water supply wells, and groundwater flow to the wells does not originate from any of these loading areas.
- The primary MC loading areas are located in the alluvium valleys, where rainfall is minimal and almost all precipitation is lost to evaporation and transpiration. For this reason, there is very little groundwater recharge associated with MC loading areas. Most groundwater recharge occurs near the interface between the bedrock mountains and the alluvium valleys, but MC are not significantly loaded in these areas.
- The hydrogeologic system at MCAGCC Twentynine Palms is complicated by numerous faults that interrupt or redirect the groundwater flow. The screening-level modeling that would be conducted in Phase 1 of REVA would not be able to sufficiently reproduce these groundwater conditions and thereby accurately account for the time necessary for groundwater to flow from recharge areas to the installation boundary.
- The hydrogeologic properties of the sediments underlying the numerous playas (dry lakes) in the region are largely unknown. Groundwater-playa interactions are more complex than can be adequately characterized in a screening-level model.
- Groundwater beneath the playas, the only known potential groundwater discharge locations, naturally contains total dissolved solids (TDS) concentrations that are orders of magnitude above drinking water criteria; therefore, the groundwater beneath playas is not suitable as a potable water supply.

5. Surface Water Analysis Method and Assumptions

Under REVA, surface water fate and transport modeling consisting of screening-level transport analysis is used to estimate the MC concentrations in surface water runoff at the edge of the MC loading areas. If this analysis predicts impacts at the edge of the loading area, then further calculations are performed to estimate the MC concentrations at a downstream receptor. Average annual surface water concentrations of the indicator MC (TNT, RDX, HMX, and perchlorate) are estimated based on the average annual MC loading of each indicator MC to each MC loading area. For MCAGCC Twentynine Palms, the surface water screening analysis was carried out for the time period from 1969 to 2005. MC loading was not estimated for the years 1952 through 1969, due to a lack of data on specific training operations and MC loading areas within the installation during this timeframe, as described in **Section 3.6**. **Section 3** provides more details on the assumptions for MC loading for MCAGCC Twentynine Palms.

The estimation of MC concentrations in surface water assumes that a portion of the MC potentially could enter the surface water by several mechanisms: (1) erosion of particulate or adsorbed MC in soil; (2) direct dissolution of MC in surface water runoff; and (3) connectivity of groundwater and surface water. At MCAGCC Twentynine Palms, it was assumed that MC enter surface water through either erosion or dissolution into surface water runoff and that there is minimal interaction between groundwater and surface water. Minimal interaction between groundwater and surface water was assumed because groundwater at MCAGCC Twentynine Palms does not typically discharge into surface water. Groundwater at MCAGCC Twentynine Palms is generally deep in the mountainous areas and alluvial plains, outside of the playas in the region (**Section 6**). There is generally minimal interaction between groundwater and surface water; however, during certain seasonal periods in which precipitation occurs, some limited communication between shallow groundwater and surface water retained in playas is potentially possible.

The mass loading of the indicator MC on each operational range was estimated as described in **Section 3**. Based on the procedures defined in the *REVA Reference Manual* for surface water modeling purposes, it was conservatively assumed that the entire annual MC load was uniformly mixed in the upper 6 inches of soil and was uniformly distributed across the loading area. Thus, the MC load present in the upper 6 inches of the soil was available for surface transport. A conservative, screening-level modeling approach was taken to estimate the annual average concentrations of MC in surface water runoff from the MC loading areas. Results of the surface water screening-level analysis were compared to the REVA trigger values (Table 5-1) to evaluate the potential for MC releases to off-range receptors. The REVA trigger values are applicable to all water sources. (If groundwater screening-level analyses had been conducted for MCAGCC Twentynine Palms, the concentrations would have been compared to these REVA trigger values.) The screening-level analysis method is described briefly in the following sections. Additional details on the method are provided in the *REVA Reference Manual* (HQMC, 2006).

Table 5-1: REVA Trigger Values for MC

MC	Trigger Value (µg/L)
RDX	0.16
TNT	0.08
HMX	0.08
Perchlorate	0.98

Note: µg/L – micrograms per liter

5.1. Losses to Surface Water in Target (Impact) Areas

The primary transport mechanisms at MCAGCC Twentynine Palms were assumed to be erosion and direct dissolution into surface water runoff. These mechanisms are quantified in this section.

5.1.1. Erosion

The amount of soil eroded was estimated using the Revised Universal Soil Loss Equation (RUSLE), which incorporates the major factors affecting erosion to predict the rate of soil loss in mass per area per year. The RUSLE is expressed as follows:

$$A = RKLSCP$$

Where:

A = predicted soil loss, metric tons per hectare per year
R = rainfall and runoff factor
K = soil erodibility factor
LS = topographic factor (factor influenced by length and steepness of slope)
C = cover and management factor
P = erosion control practice factor

These factors were estimated for each modeled MC loading area using available information, such as soil type from the USDA Natural Resources Conservation Service (NRCS) soil survey of MCAGCC Twentynine Palms, California (1999), land use, land cover, and topography. The estimated amount of soil eroded from the MC loading area was used to calculate the mass of MC transported with the eroded soil from MC loading areas to downstream receptors. Estimation of the soil erosion to calculate transported MC mass is especially important for MC that strongly adsorb to soil (such as TNT).

5.1.2. Surface Water Runoff

Annual surface runoff rates were estimated by multiplying the annual precipitation rate runoff coefficients selected from published tabular values (McCuen, 1998) and the surface area of the MC loading area. Annual precipitation data were provided by NREA personnel at MCAGCC Twentynine Palms for the period from 1948 through 2005. The average annual precipitation rate calculated from these data was 4.78 inches/year.

5.1.3. Partitioning into Surface Water

A multimedia partitioning model, CalTOX, was used to estimate the mass of MC transported from surface soil to surface water runoff. This model simulates the major transport mechanisms (erosion of adsorbed MC in soil and direct dissolution in runoff and leaching to the subsurface environment) that are likely to affect MC from their point of origin in surface soils to their release into surface water runoff. The rate at which MC will partition between these media is dependent upon both the chemical properties of the MC and the physical/hydrological properties of the site. CalTOX requires the input of both landscape properties of the MC loading areas and chemical properties of the compounds of interest. Values of landscape and chemical properties were selected based on local reports, soil surveys, mapping information, and scientific literature. Estimates of soil erosion and surface water runoff were calculated as described in previous sections and entered into CalTOX.

The CalTOX output of interest for the surface water screening-level analysis was the MC mass transferred from surface soil to surface water, which CalTOX expresses as an average daily load in grams per day. This daily mass transfer rate was divided by the daily runoff volume to estimate the MC concentration in surface water runoff at the edge of the MC loading area, prior to down gradient mixing/dilution in streams and washes. Although CalTOX requires input of daily loading rates, the MC mass loading is available only as annual values. For this reason, the model has an effective time step of one year, and the results are interpreted as annual average concentrations in surface water runoff.

For MC that have elevated soil partition coefficient values, such as TNT and RDX, the residual mass in surface soil after each time step (one year) was calculated as the product of the MC partition coefficient, the dissolved MC concentration in runoff, and the mass of the surface soil. This provided an estimate of the mass of MC that would be sorbed to the surface soil compartment assuming sorption equilibrium. The estimated residual MC mass was added to the ―new” MC loading to surface soil for the following year.

5.2. Estimation of MC Concentration Entering Playas

The loading areas of interest drain from the MC loading areas to downstream playas. To estimate the order of magnitude reduction in MC concentrations due to mixing with runoff from nonloading areas, the estimated concentrations at the edge of MC loading areas were multiplied by the ratio of the loading area to the total drainage area of the playas. GIS data were used to delineate the boundaries and the size of the total drainage areas of the playas. The down gradient, ―mixed" concentrations at the lakes were estimated as an areally weighted sum of the concentrations from the individual loading areas draining to the playas:

$$C_{mixed} = [\sum (C_{runoff} \times A_{LA})] / A_{DA}$$

Where:

C_{mixed} = post-mixed concentrations in playas (µg/L)
C_{runoff} = concentration in runoff from loading areas (µg/L)
A_{LA} = area receiving MC loading (m^2)
A_{DA} = total drainage area of playas (m^2)

Inherent in this method is the assumption that all areas other than MC loading areas contribute runoff that has negligible MC concentrations. In addition, these analyses assume that all MC leaving the MC loading areas are deposited in the playas without attenuation. These are highly conservative assumptions intended to produce an upper bound estimate.

5.3. Evaporative Concentration Factor

Water that accumulates in playas primarily is lost through evaporation. As the water evaporates, MC washed into the playas can potentially precipitate and accumulate in the sediment of the playa bed. MC concentrations estimated through the methods discussed above are aqueous phase concentrations reaching playas, not accounting for evaporation after the water reaches the playas. Evaporation in playas was considered by using an evaporative concentration factor. Theoretically, evaporation could cause the concentrations of nonvolatile MC to increase to very high levels as the volume of water decreases toward zero. However, when dissolved solid concentrations reach a level beyond which biota can tolerate, salinity alone would preclude most biotic uses of playa water, eliminating any potential receptors. The evaporative concentration factor is thus defined as the increase in initial salinity that would preclude most aquatic life uses of playa water.

To estimate the evaporative concentration factor, lower and upper limit salinity values were derived from literature. The lower limit was set as a typical salinity that would be expected in runoff from washes to the playas and was defined as 330 milligrams per liter (mg/L) based on a USGS study of desert runoff in southern California (Kent and Belitz, 2004). Studies indicate that aquatic biota can be adversely affected when salinity exceeds 1,000 mg/L (Nielsen et al., 2003; Hart et al., 1990, 1991). Therefore, an upper limit for the salinity tolerance level for aquatic biota in the playas conservatively was set at 3,330 mg/L, representing concentration of MC by one order of magnitude from arrival at the playas to the end concentration. The evaporative concentration factor was calculated as the ratio of the upper limit to the lower limit (i.e., 10).

Estimated annual average MC concentrations predicted to reach playas were multiplied by the evaporative concentration factor to estimate the increase in MC concentration resulting from evaporation. The MC mass estimated to be present in a playa during a time step (one year) was added to the mass from runoff during the next year to estimate the total mass present in the lake during the next time step. This calculation of MC concentrations in the playas is highly conservative because it does not account for MC losses that are likely to be encountered in the washes and playas, such as decay, loss to groundwater, and sediment deposition.

5.4. Interpretation of Results

The estimated concentrations of indicator MC resulting from each of the three phases of the screening analysis were compared to the REVA trigger values to determine the potential for off-range releases to surface water present within the playas. Where the screening-level analysis resulted in estimated concentrations of MC exceeding the REVA trigger values, a more detailed analysis of potential pathways and receptors at the ultimate exposure points was conducted. Because ecological receptors are potentially exposed to surface water in playas, the additional analysis involved an ecological receptor exposure and toxicity assessment (as described in Appendix A). This assessment was done to determine if estimated concentrations of MC in surface water in playas were at levels of concern for ecological species exposed to the water. If the detailed receptor analysis indicates potential impacts, soil sampling would be considered as a potential next step for REVA at the installation.