Marine Corps Installation Command

FINAL

Range Environmental Vulnerability Assessment

Five Year Review
Marine Corps Air Ground Combat Center Twentynine Palms, California

June 2012
6262-031

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Infrastructure · Water · Environment · Buildings

Marine Corps Installations Command

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Five-Year Review

MCAGCC Twentynine Palms

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Acronym List

Acronym	Definition
°F	Degrees Fahrenheit
µg/L	Microgram per Liter
amsl	Above Mean Sea Level
ASR	Archive Search Report
bgs	Below Ground Surface
BLM	Bureau of Land Management
BZO	Battle Site Zero
cal	Caliber
CRWQCB	California Regional Water Quality Control Board
CSM	Conceptual Site Model
DoD	Department of Defense
DoDI	Department of Defense Instruction
DoDIC	Department of Defense Identification Code
EOD	Explosive Ordnance Disposal
EMV	Enhanced Mojave Viper
EPA	Environmental Protection Agency
FMD	Facilities Management Division
ft	Feet
ft/d	Feet per Day
GIS	Geographic Information System
HE	High Explosive
HMX	Cyclotetramethylene Tetranitramine
HQMC	Headquarters Marine Corps
IED	Improvised explosive device
In/yr	Inches per year
INRMP	Integrated Natural Resource Management Plan
IRP	Installation Restoration Program
kg/m^2	Kilograms per Square Meter
lb	Pound
m^2	Square Meters

Acronym	Definition
Marine Corps	United States Marine Corps
MC	Munitions Constituents
MCAGCC	Marine Corps Air Ground Combat Center
MCL	Maximum Contaminant Level
MCTC	Marine Corps Training Center
MFTL	Mojave Fringe-Toed Lizard
mg/Kg	Microgram per Kilogram
mg/L	Milligram per Liter
MGD	Million Gallons per Day
MIDAS	Munitions Items Disposition Action System
mm	Millimeter
MMRP	Military Munitions Response Program
MOUT	Military Operations in Urban Terrain
MTU	Marksmanship Training Unit
NEW	Net Explosive Weight
NRCS	Natural Resources Conservation Service
NREA	Natural Resources and Environmental Affairs
NWIS	National Water Information System
O&T	Operations and Training
OEHHA	Office of Environmental Health Hazard Assessment
RDX	Cyclotrimethylene Trinitramine
REVA	Range Environmental Vulnerability Assessment
RFMSS	Range Facility Management Support System
RMUS	Range and Munitions Use Subcommittee
RSL	Regional Screening Level
RTA	Range Training Area
RTAA	Range Training Area and Airspace
RUSLE	Revised Universal Soil Loss Equation
SACON	Shock-absorbing concrete
SAR	Small Arms Range
SARAP	Small Arms Range Assessment Protocol

Acronym	Definition
SESAMS	Special Effects Small Arms Marking System
SOP	Standing Operating Procedure
TDS	Total Dissolved Solids
TECOM	Training and Education Command
TNT	Trinitrotoluene
U.S.	United States
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UXO	Unexploded Ordnance

Executive Summary

The United States 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 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 periodic five-year review assessments, and, where applicable, the use of fate and transport modeling of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas. Results of the model-predicted MC concentrations are compared to an established set of REVA trigger values. Each trigger value is a median value of method detection limits. Modeling results that exceed a trigger value may warrant further investigation to determine if a release or threat of a release may be present.

Site-specific sampling is conducted under REVA if screening-level fate and transport analyses significantly exceed trigger values. The sampling is performed to further evaluate the potential of MC release and support the installation and HQMC in assessing the potential for degradation of groundwater and/or surface water quality. The results of sampling will be compared to DoD Range and Munitions Use Subcommittee (RMUS) screening values to determine if the release is a threat to human health and/or the environment.

This report presents the five-year review assessment results for the operational ranges and training areas at Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, located in Southern California. This report serves as the first five-year review assessment documenting the period of munitions loading from 2006 through 2010. The baseline assessment conducted in 2006 documented munitions use through 2005.

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. Current live-fire training at the installation is focused on the the Enhanced Mojave Viper exercise. Approximately 4,000 Marines and Sailors participate in each training cycle, starting with small-unit training and culminating with MAGTF integration (MCAGCC Twentynine Palms, 2011).

The installation is administratively subdivided into 23 Range Training Areas (RTAs), including a cantonment area (Mainside) and a Restricted Area. Six of the RTAs are designated for non-live-fire and maneuver training; these RTAs are located in the southwestern section of the installation. 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). Forty-six fixed ranges are also present across the installation, with the majority located in the Range RTA. In addition, the installation contains seven small arms ranges (SARs), all located within the Range RTA. The RTAs are managed by the Range Operations Section / Range Control.

MC loading areas are where the majority of MC are deposited within an operational range. MC loading areas were identified and evaluated during the baseline assessment. Prior to assessing the current data, the results of the baseline assessment were considered. **Table ES-1** provides a summary of the results of the baseline assessment.

During the five-year review process, 30 MC loading areas were identified at MCAGCC Twentynine Palms. These MC loading areas are distributed throughout the installation. The MC loading areas were categorized as "Primary" (those that received the greatest amount of MC loading within the installation) or "Other" (those that receive some level of MC loading but not to the same degree as the Primary MC loading areas). Nine of the primary MC loading areas identified and evaluated in the baseline assessment, as well as three new primary MC loading areas, were reassessed in the five-year review. Four of the primary MC loading areas identified and evaluated during the baseline assessment were split into two or more primary MC loading areas for the five-year review. Twelve SARs were evaluated in the baseline assessment, and ten SARs are included in the five-year review as a result of realignments and change in range usage since the baseline assessment.

Table ES-1: Summary of Baseline Assessment Results for MCAGCC Twentynine Palms

Primary MC Loading Area	Screening-Level Modeling Results Potentially Exceed REVA Trigger Values		Sampling Conducted?	Assessing in Five-Year Review	Baseline Acreage	Five-Year Review Acreage
	Surface Water[a]	Groundwater				
Lead Mountain	Yes	Groundwater screening-level analysis was not conducted.	No	Yes	11,017	6,966[b]
Black Top I	Not Modeled		No	Yes	5,422	3,626
Black Top II	Not Modeled		No	Yes	6,216	2,424
Lavic Lake	Not Modeled		No	Yes	10,116	6,861[b]
Quackenbush	Not Modeled		No	Yes	18,245	7,744
Gays Pass	Not Modeled		No	Yes	10,143	4,532[b]
Delta	Yes		No	Yes	7,938	6,243
Prospect	Yes[c]		No	Yes	4,329	4,329
Range	Not Modeled		No	Yes	12,796	9,672[b]
Rainbow Canyon	Not Modeled		No	No	2,224	--
Lava	Not previously identified as a primary MC loading area					853
Cleghorn Pass I	Not previously identified as a primary MC loading area					1,913
Cleghorn Pass II	Not previously identified as a primary MC loading area					1,267

Assessed Using Small Arms Range Assessment Protocol (SARAP)	Surface Water Concern	Groundwater Concern	Assessing in Five-Year Review
Range 1	Minimal	Minimal	Yes
Range 1A	Minimal	Minimal	Yes
Range 2	Minimal	Minimal	Yes
Range 2A	Minimal	Minimal	Yes
Range 3	Minimal	Minimal	Yes
Range 3A	Minimal	Minimal	Yes
Range 4	Minimal	Minimal	No
Range 101	Minimal	Minimal	Yes
Range 101A	Minimal	Minimal	No
Range 105A	Minimal	Minimal	Yes
Range 113	Minimal	Minimal	Yes
Range 113A	Minimal	Minimal	Yes

[a] Portions of the loading areas within the America Mine, Bullion, Cleghorn Pass, Lava, and Noble Pass RTAs were included in the screening-level transport analysis for accuracy and completeness.

[b] Indicates that the MC loading area from the baseline assessment was split into multiple, smaller loading areas for the five-year review

[c] A portion of the loading area within the Cleghorn Pass RTA and limited contributions from the loading areas within the Bullion and Delta RTAs were included in the screening-level transport analysis for accuracy and completeness.

Eighteen of the 30 identified MC loading areas were prioritized based on munitions use and potential for surface water and sediment receptor exposure. These prioritized areas underwent surface water screening-level modeling during the five-year review. Ten of these were included in the surface water screening-level modeling in the baseline assessment; however, MC loading area boundaries were revised during the five-year review in order to more accurately reflect loading at the MC loading areas.

Five of the 30 identified MC loading areas were prioritized based on use and potential for groundwater receptor exposure. These areas underwent screening-level modeling during the five-year review. Screening-level groundwater transport analysis was not conducted during the baseline assessment.

Seven SARs and ten additional military operations in urban terrain (MOUT) facilities were evaluated in the five-year review. Twelve SARs were evaluated in the baseline assessment; however, several ranges changed use or were realigned since the time of the baseline assessment. MOUTs were not part of the REVA evaluation process in the baseline assessment.

The REVA assessment team estimated MC loading rates for identified MC loading areas, in addition to lead loading rates for current SARs and live-fire MOUTs at MCAGCC Twentynine Palms. A conceptual site model was developed for the training areas to qualitatively assess the potential for MC transport from the loading areas to impact identified off-range human and ecological receptors.

Conceptual Site Model for MCAGCC Twentynine Palms

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 natural 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.

Across most of the installation area, precipitation averages between 3 and 4 inches 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 2 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 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. The installation currently is evaluating utilizing groundwater from the Deadman Lake subbasin as a supplemental potable supply source due to concerns with overdraft of the Surprise Spring groundwater subbasin (pers comm, MCAGCC Twentynine Palms NREA staff, 2010). Live-fire training is conducted on the land surface above this groundwater subbasin. If used, the water withdrawn from this subbasin would be blended with water currently withdrawn from the Surprise Springs subbasin to augment potable water supplies.

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 may potentially serve as another MC transport mechanism, though

such transport likely is limited by high evaporation rates and deep groundwater. Sediment containing MC may be transported to playas and evaporation ponds in the same manner as described for surface water.

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, 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. MC from the installation are expected to be a negligible component of the mined salt, but there could be a potential human exposure pathway through dermal contact during the salt mining process from MC remaining in the sediments of the playa lake beds.

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for 18 MC loading areas located within six watershed areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing high explosives (HE) and surface drainages to potential receptor exposure locations. Annual average MC concentrations in surface water runoff and sediment at the edge of each MC loading area were estimated. Also estimated were MC concentrations in surface water runoff entering identified downstream receptor exposure locations (playa lakes) and MC concentrations in the sediment of playa lake beds resulting from potential MC accumulation in the playa lake beds. MC concentrations in surface water runoff at the edge of all MC loading areas were estimated to be above REVA trigger values, while MC concentrations in sediment at the edge of all MC loading areas were estimated to be below REVA trigger values. Annual average MC concentrations in surface water runoff entering five playa lakes were predicted to be above REVA trigger values, and the cumulative MC concentrations in the sediment of all

identified playa lake beds were predicted to be above REVA trigger values. However, none of the modeled scenario results exceeded the RMUS surface water or sediment screening values. Predicted MC concentrations in sediment within the playas were also significantly lower than the U.S. Environmental Protection Agency Region 9 and California Office of Environmental Health Hazard Assessment (OEHHA) industrial soil screening values.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for five MC loading areas located within the Twentynine Palms groundwater subbasin. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and their proximity to potential future groundwater receptors. The initial groundwater screening-level analysis (estimation of MC concentration in infiltration water) predicted MC concentrations at MC loading areas leaching into the vadose zone above REVA trigger values. Therefore, vadose zone modeling was conducted at the MC loading areas. Subsequent screening-level analysis of the saturated zone at the MC loading areas was not conducted because results of the vadose zone modeling indicated no current concern of MC migration to groundwater, and there are no current water supply wells within the study area or the pathway to ecological receptors is unlikely. However, the construction and development of water supply wells within the study area is being considered; if implemented, migration through the saturated zone might be reevaluated as part of the following five-year review period.

Results and Conclusions of the REVA Five-Year Review

A summary of the results and conclusions for the MC loading areas assessed at MCAGCC Twentynine Palms in the REVA five-year review are presented on **Table ES-2**.

Small Arms Range 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 unless site-specific investigations are conducted. Therefore, SARs are qualitatively assessed under the REVA program to identify factors that influence the potential for lead migration.

There are seven SARs located at MCAGCC Twentynine Palms. Six 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 SAR is a fixed range located north of the MTU in the Range RTA. The analysis of the seven 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.

Four MOUT facilities also were evaluated using the SARAP. The four MOUT facilities that were evaluated are located in Prospect, Delta, Range, and Bullion RTAs. The analysis of the four MOUT facilities at the installation resulted in Minimal overall rankings for each range.

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.

Table ES-2. Summary of Five-Year Review Assessment Results for MCAGCC Twentynine Palms

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Bristol Dry Lake	Cyclotrimethylene trinitramine (RDX) and trinitrotoluene (TNT) in runoff at the edge of all MC loading areas were predicted to be above REVA trigger values. Cyclotetramethylene tetranitramine (HMX) and perchlorate in runoff were predicted to be above REVA trigger values at the edge of three MC loading areas (Lead Mountain II/Bullion, Lava, and Lead Mountain I) and two (Lead Mountain II/Bullion and Lava), respectively. The average annual concentrations of MC in surface water runoff entering the Bristol Dry Lake were predicted to be below REVA trigger values.	The average annual MC concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values.	Limited potential exists for MC migration to groundwater, and no known groundwater receptor exposure locations are present down gradient of the MC loading areas. Therefore, the MC loading areas within the Bristol Dry Lake watershed are not considered areas of concern for MC migration in groundwater.	No further analysis at this time is required.
Dry Lake	RDX and TNT in runoff at the edge of all four MC loading areas were predicted to be above REVA trigger values. HMX in runoff was predicted to be above the REVA trigger value at the edge of the Lava and the Lead Mountain I MC loading areas; perchlorate was predicted to be above the REVA trigger value at the edge of the Black Top I, the Lava and the Black Top II MC loading areas. All predicted MC concentrations in surface water runoff entering the Dry Lake were at least two orders of magnitude lower than the Range and Munitions Use Subcommittee (RMUS) freshwater values and at least three orders of magnitude lower than the RMUS marine water values. As a result, the ecological receptors identified to potentially use the water in Dry Lake playa are unlikely to be impacted by MC release to the playa lake.	The average annual MC concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values.	Limited potential exists for MC migration to groundwater, and no known groundwater receptor exposure locations are present down gradient of the MC loading areas. Therefore, the MC loading areas within the Dry Lake watershed are not considered areas of concern for MC migration in groundwater.	No further analysis at this time is required.

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Dale Lake	RDX and TNT in runoff at the edge of all four MC loading areas were predicted to be above REVA trigger values. HMX and perchlorate in runoff at the edge of the Cleghorn Pass II and the Cleghorn Pass I MC loading areas were predicted to be above REVA trigger values. All predicted MC concentrations in surface water runoff entering Dale Lake were at least three orders of magnitude lower than the RMUS freshwater and marine water values. As a result, the ecological receptors identified to potentially use the water in Dale Lake playa are unlikely to be impacted by MC release to the playa lake.	The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Dale Lake watershed were predicted to be below REVA trigger values	Limited potential exists for MC migration to groundwater, and there are no known potable wells present within the Dale Lake watershed. There are nonpotable wells located near the salt mine operations at Dale Lake playa south of the installation boundary, but these wells are located at such significant distances from the loading areas within the watershed that MC are highly unlikely to reach the wells. Therefore, the MC loading areas within the Dale Lake watershed are not considered areas of concern for MC migration in groundwater.	No further analysis at this time is required.

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Deadman Lake	Perchlorate in runoff at the edge of all five MC loading areas was predicted to be above the REVA trigger value. RDX and TNT were predicted to be above REVA trigger values in runoff at the edge of four MC loading areas (Range I, Range III, Range IV and Quackenbush) and three MC loading areas (Range I, Range IV and Quackenbush), respectively . Additionally, HMX in runoff at the edge of the Quackenbush MC loading area was predicted to be above the REVA trigger value. All predicted MC concentrations in surface water runoff entering Deadman Lake, including those exceeding REVA trigger values, were at least two orders of magnitude lower than the RMUS freshwater and marine water values. As a result, the ecological receptors identified to potentially use the water in Deadman Lake playa are unlikely to be impacted by MC release to the playa lake.	The average annual MC concentrations in sediment at the edge of all the primary MC loading areas draining within the Deadman Lake watershed were predicted to be below REVA trigger values.	In the Part I groundwater screening analysis, all MC concentrations were estimated to exceed REVA trigger values at the Range I and the Quackenbush MC loading areas. Additionally, RDX and perchlorate were estimated to exceed REVA trigger values at the Range II, Range III, and Range IV MC loading areas, and TNT was estimated to exceed the REVA trigger value at the Range III and Range IV MC loading areas. Vadose zone modeling was performed, which indicated that there are no current concerns of MC migration to groundwater. No current concerns were identified for the proposed future potable use of the groundwater within the Deadman Lake subbasin.	Additional analysis, such as saturated zone modeling, is not required at this time. However, migration through the saturated zone might be reevaluated as part of the following five-year review assessment or if conditions change warranting review sooner.

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Lavic Lake	RDX and TNT in runoff were predicted to be above REVA trigger values at the edge of all four MC loading areas draining within the Lavic Lake watershed. Perchlorate was predicted to be above the REVA trigger value at the edge of the Lavic Lake I and the Lavic Lake II MC loading areas, and HMX was predicted to be below the REVA trigger value at the edge of all four primary MC loading areas draining within the Lavic Lake watershed. All predicted MC concentrations in surface water runoff entering the Lavic Lake were at least two orders of magnitude lower than the RMUS freshwater values and at least three orders of magnitude lower than the RMUS marine water values. As a result, the ecological receptors identified to potentially use the water in Lavic Lake playa are unlikely to be impacted by MC release to the playa lake.	The average annual MC concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values.	Limited potential exists for MC migration to groundwater, and no known groundwater receptor exposure locations are present down gradient of the MC loading areas. Therefore, the MC loading areas within the Lavic Lake watershed are not considered areas of concern for MC migration in groundwater.	No further analysis at this time is required.

Watershed	Surface Water Screening-Level Analysis Results	Sediment Screening-Level Analysis Results	Groundwater Screening-Level Analysis Results	Conclusion
Quacken-bush	RDX and TNT in runoff at the edge of both MC loading areas were predicted to be above REVA trigger values. HMX and perchlorate in runoff was predicted to be above the REVA trigger value at the edge of the Quackenbush MC loading area. All predicted MC concentrations entering the Quackenbush Lake playa, including the MC predicted to exceed REVA trigger values, were at least one order of magnitude lower than the RMUS freshwater values and at least two orders of magnitude lower than the RMUS marine water values. As a result, the ecological receptors identified to potentially use the water in the Quackenbush Lake playa are unlikely to be impacted by MC release to the playa lake.	The average annual MC concentrations in sediment at the edge of both primary MC loading areas draining within the Quackenbush Lake watershed were predicted to be below REVA trigger values.	Limited potential exists for MC migration to groundwater, and no known groundwater receptor exposure locations are present down gradient of the MC loading areas. Therefore, the MC loading areas within the Quackenbush Lake watershed are not considered areas of concern for MC migration in groundwater.	No further analysis at this time is required.

1. Introduction

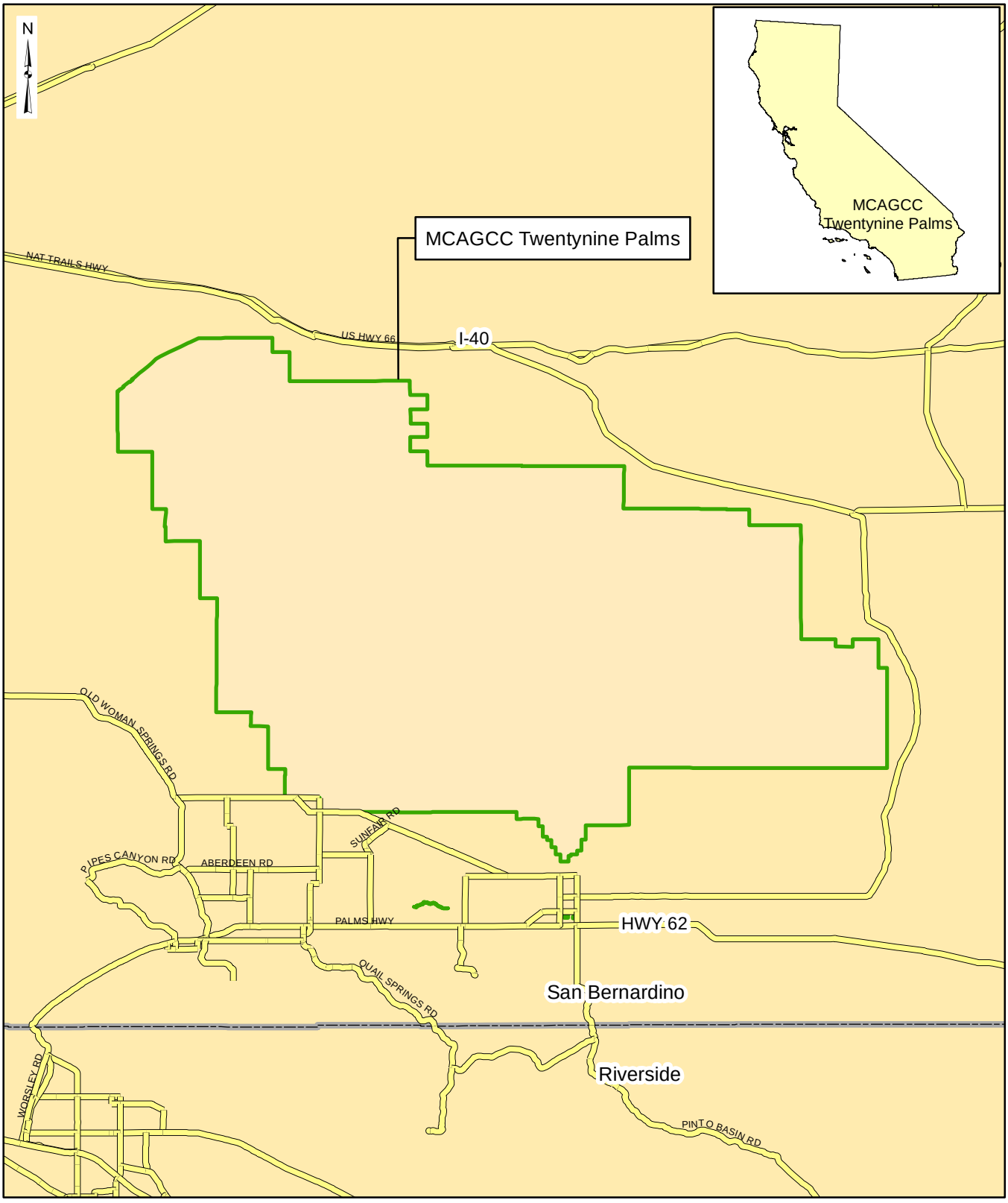
1.1. Purpose

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 (DoDI) 4715.14 *Operational Range Assessments*.

The REVA program is a proactive and comprehensive program designed to support the Marine Corps' Range Sustainment Program. 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 assessments of operational range areas and periodic five-year review assessments, 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.

This report presents the five-year review results for the operational ranges and training areas at the Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, located in Southern California. This report serves as the first five-year review assessment documenting the period of munitions loading from 2006 through 2010. The baseline assessment conducted in 2006 documented munitions use at MCAGCC Twentynine Palms through 2005.

MCAGCC Twentynine Palms maintains operational ranges and training areas within the installation boundaries. It encompasses approximately 600,000 acres in San Bernardino County, California, and is located east of Los Angeles and northeast of Palm Springs. The installation is bounded by Interstate 40 on the north and Highway 62 on the south. A site location map is provided as **Figure 1-1**.



REVA
FIGURE 1-1
MCAGCC TWENTYNINE PALMS
SITE LOCATION MAP

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

ARCADIS MALCOLM PIRNIE
Infrastructure Water Environment Buildings

Legend

- Road
- Installation Boundary
- County Boundary

0 2.5 5 10 15
Miles

Coordinate System: UTM
Zone: 11N
Datum: NAD83
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
ESRI GIS Server 2011

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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 currently to be or historically to have been used. Operational ranges used exclusively for small arms training are evaluated qualitatively under REVA. The Marine Corps (specifically the Training and Education Command [TECOM]) purposely separates operational ranges and training areas. For ease of understanding, in this document, the term "operational range" includes both operational ranges and training areas.

A number of range types are specifically excluded from the DoDI 4715.14 and are not assessed as part of the REVA program. Operational ranges that have a Resource Conservation and Recovery Act Subpart X permit are excluded since these ranges are monitored under a specific regulatory program. Military Munitions Response Program (MMRP) sites are excluded, as they are nonoperational ranges; therefore, they no longer are used for their intended purpose. Additionally, the management and funding of MMRP sites are conducted under a separate DoD program. Skeet/trap ranges used solely for recreation are excluded; these recreational facilities are not deemed operational ranges as defined under Title 10. Any ranges located wholly indoors also are not included, as any MC associated with these ranges are assumed to be contained and not available to the environment.

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. Modeling is conducted for MC loading areas, which are delineated based on the area in which the majority of MC is deposited within an operational range. Fate and transport modeling in REVA uses screening-level transport analyses that conservatively estimate the concentrations of MC potentially migrating to off-range exposure points. Receptor groups considered in the REVA process include human as well as ecological receptors (defined in the REVA analysis as any threatened or endangered species or species of concern). Human exposure pathways considered include consumption of surface water and groundwater for off-range human receptors, as described in the *REVA Five-Year Review Manual* (HQMC, 2010b). Exposure pathways for off-range ecological receptors include direct consumption of surface water and direct exposure to surface water and sediment. Other off-range exposure scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation, and food chain exposure) currently are not considered in the REVA process unless site-specific considerations warrant an evaluation. Environmental

sampling and analysis (i.e., field data collection) is conducted if the results of the screening-level fate and transport modeling suggest an off-range release of MC where receptors may be present. Field data collection activities are conducted to determine whether an off-range release has occurred and whether such a release constitutes an unacceptable risk to human health and the environment.

The MC evaluated in the REVA program include trinitrotoluene (TNT), cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), perchlorate, and lead. TNT, HMX, and RDX are considered indicator MC. Studies have shown that they are detected in a high percentage of samples containing MC because they are common high explosives (HEs) used in a wide variety of military munitions and because of their chemical stability within the environment. Perchlorate is a component of the solid propellants used in some military munitions. Perchlorate also is considered an indicator MC because 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, 2009).

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, and thus, fate and transport modeling of lead requires site-specific geochemical data that usually are unavailable during a REVA assessment. Therefore, instead of modeling lead transport, operational 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, current and past operation and maintenance practices, and the amount of lead that has been loaded to the operational range.

Lead loading associated with small arms and munitions components at HE ranges was estimated as part of the five-year review process. Lead is present primarily in expenditures at the point of impact as an inert compound and, consequently, does not undergo low-order or high-order detonations. As such, lead loading was estimated based on the total amount of lead content based on the munition DoD Identification Code (DoDIC) multiplied by the total number of items of each DoDIC fired into the range or MC loading area. The total lead loaded at the site aids in determining if additional actions, such as sampling, are necessary.

The process and assumptions used in estimating the amount of MC deposited onto operational ranges, defined in REVA as MC loading, are discussed in **Section 3**. The

screening-level fate and transport modeling and analysis methods and assumptions for surface water and groundwater are discussed in **Section 5**.

This report presents the analysis of the data collected during site visits and the results of screening-level fate and transport modeling for MC loading areas. 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 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 tool used to estimate MC deposition on operational ranges (HQMC, 2009).

This five-year review REVA report presents the conditions of the operational ranges at the time the assessment was conducted. The assessment was performed using available data and personnel interviews and is supplemented with information from external sources, including reports and documentation.

1.3. Data Collection Effort

A thorough review of data collected during the baseline assessment was conducted prior to collecting data from the installation. Data required for the operational range assessments were obtained from the installation during a site visit by the REVA assessment team, from Headquarters Marine Corps (HQMC), and from external data sources. Data collected include various documents and reports prepared for the installation (e.g., expenditure data, range operating procedures, natural and cultural resource surveys), weather records, and geographic information systems (GIS) files.

The REVA assessment team conducted a site visit to MCAGCC Twentynine Palms from 25 to 29 October 2010. HQMC and TECOM 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
- Explosive Ordnance Disposal (EOD)
- Marksmanship Training Unit (MTU)
- Facilities Management Division (FMD)
- GIS

Subject matter experts within each of these offices were interviewed 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.

During the five-year review installation visit, site visits were performed at 18 operational ranges. The REVA assessment team surveyed the physical condition of each range, noting firing points, impact areas, engineered controls, and other environmental factors (e.g., areas of erosion, potential migration routes).

1.4. Report Organization

This REVA five-year review environmental range assessment report for MCAGCC Twentynine Palms is organized into the following sections:

Section 1 – Introduction

Section 2 – Baseline Results and Installation Changes

Section 3 – Munitions Constituents Loading Rate and Assumptions

Section 4 – Conceptual Site Model (CSM)

Section 5 – Modeling Assumptions and Parameters

Section 6 – Screening-Level Assessment Results

Section 7 – Small Arms Range Assessments

Section 8 – References

2. Baseline Results and Installation Changes

The baseline assessment for MCAGCC Twentynine Palms was conducted using data from 2001 to 2005. At the time of the baseline assessment, all identified operational range areas and historical data were used to assess the impact of munitions loading on operational range lands. The results of the baseline assessment are documented in the *Range Environmental Vulnerability Assessment Marine Corps Air Ground Combat Center Twentynine Palms* (Malcolm Pirnie, 2007). Specific details of the methodology implemented in calculating MC loading and determining surface water and groundwater pathways and receptors in the baseline assessment are identified in the report. The following sections provide a brief summary of the baseline assessment results that provide a framework for the structure and areas of focus for the five-year review.

A total of 10 primary MC loading areas and 13 other MC loading areas were identified in the baseline assessment. The MC loading areas were categorized as "Primary" and "Other" to differentiate training areas that received the greatest amount of MC loading within the installation from those that received less loading. Of the 10 primary MC loading areas, two – Lead Mountain and Prospect – were prioritized for screening-level modeling based on MC loading and surface water characteristics. The MC loads from adjacent MC loading areas were also included in the screening-level analysis if they were located within the same watersheds as Lead Mountain or Prospect. The MC loading areas are summarized in **Table 2-1**. In general, the surface water screening-level modeling at these MC loading areas indicated that MC were not likely to migrate off range or may do so but at levels that would not represent an exposure concern to receptors.

Screening-level transport analysis for groundwater was not conducted during the baseline assessment for the following reasons:

- Primary MC loading areas were not located in proximity groundwater supply wells screened in the aquifer the installation uses as its source of drinking water (Surprise Springs), and groundwater flow to the wells does not originate from any of these loading areas.

- Groundwater beneath the playas, the only known potential groundwater discharge locations, naturally contains total dissolved solids (TDS) concentrations that are

Table 2-1: Summary of MC Loading Areas and SARs Evaluated in the Baseline Assessment

Primary MC Loading Area	Screening-Level Modeling Results Exceed REVA Trigger Values		Sampling Conducted?	Assessing in Five-Year Review	Baseline Acreage	Five-Year Review Acreage
	Surface Water[a]	Groundwater				
Lead Mountain	Yes	Groundwater screening-level analysis was not conducted.	No	Yes	11,017	6,966[b]
Black Top I	No		No	Yes	5,422	3,626
Black Top II	No		No	Yes	6,216	2,424
Lavic Lake	No		No	Yes	10,116	6,861[b]
Quackenbush	No		No	Yes	18,245	7,745
Gays Pass	No		No	Yes	10,143	4,532[b]
Delta	Yes		No	Yes	7,938	6,243
Prospect	Yes		No	Yes	4,329	4,329
Range	No		No	Yes	12,796	9,672[b]
Rainbow Canyon	No		No	No	2,224	--
Lava	Not previously identified as a primary MC loading area					853
Cleghorn Pass I	Not previously identified as a primary MC loading area					1,913
Cleghorn Pass II	Not previously identified as a primary MC loading area					1,267

Assessed Using SARAP	Surface Water Concern	Groundwater Concern	Assessing in Five-Year Review
Range 1	Minimal	Minimal	Yes
Range 1A	Minimal	Minimal	Yes
Range 2	Minimal	Minimal	Yes
Range 2A	Minimal	Minimal	Yes
Range 3	Minimal	Minimal	Yes
Range 3A	Minimal	Minimal	Yes
Range 4	Minimal	Minimal	No
Range 101	Minimal	Minimal	Yes
Range 101A	Minimal	Minimal	No
Range 105A	Minimal	Minimal	Yes
Range 113	Minimal	Minimal	Yes
Range 113A	Minimal	Minimal	Yes

[a] Portions of the loading areas within the Bullion, Cleghorn Pass, and Lava RTAs were included in the screening-level transport analysis for accuracy and completeness.

[b] Indicates that the MC loading area from the baseline assessment was split into multiple, smaller loading areas for the five-year review

orders of magnitude above drinking water criteria; therefore, the groundwater beneath playas is not suitable as a potable water supply.

All known human health and ecological receptors associated with groundwater pathways can be eliminated as potential concerns.

A Small Arms Range Assessment Protocol (SARAP) was completed for 12 SARs identified by the REVA team. The SARAP employs a consistent methodology to identify and assess factors that influence the potential for lead migration at an operational range. Some of these factors include range design and layout, physical and chemical characteristics of this area, and past and present operation and maintenance practices. In addition, potential receptors and pathways are identified, and the potential for an identified receptor to be impacted by MC migration through a recognized pathway is evaluated. Through this protocol, ranges are prioritized for possible further assessment or management practices. The Military Operations in Urban Terrain (MOUT) facilities at MCAGCC Twentynine Palms were not evaluated during the baseline; however, these military training ranges are evaluated in this five-year review report, using the SARAP.

Eleven historical use areas were identified in the baseline report. Training activities conducted in these areas overlap with the existing RTAs; MC loading contributions for these historical use areas were assessed in the baseline report. As such, the historical use areas at MCAGCC Twentynine Palms will not be re-evaluated during the five-year review.

2.1. Installation Changes

Training at MCAGCC Twentynine Palms has undergone some changes since the baseline assessment, most notably in the current focus on the Enhanced Mojave Viper (EMV) training exercises, the establishment of new fixed ranges, increases or decreases in expenditures at particular RTAs, and other less-defined changes (potential shifting of target locations within the RTA, etc.). However, the basic RTA boundaries have remained generally the same, and the same non-live-fire and live-fire RTA designations are in place as during the baseline assessment.

Since the 2006 baseline assessment, eight new fixed ranges (Range 225, Range 230, Range 401, Range 620, Range 630, Range 700, Range 705, and Range 800) have been established. In addition, range use at two ranges have changed since the 2006 baseline assessment. Range 215A was identified during the baseline as a non-live-fire MOUT facility. In the 2010 standing operating procedures (SOPs) for Range Training Area and

Airspace (RTAA), Range 215A was identified as a tactical exploitation site. Range 112 was identified in the baseline assessment as an NREA range residue processing area. In the 2010 RTAA SOP, Range 112 was identified as an EOD training range. In addition, Range 4 and Range 3A within the MTU were combined into Range 3A. Range 101 and Range 101A in Range RTA were consolidated into Range 101.

MC prioritization in the baseline assessment was determined by evaluating the level of use, duration of MC loading (to include historical loading), expected presence of REVA indicator MC, size, and current status for each MC loading area. Each of these categories was ranked to determine an overall priority. Due to the increased tracking of expenditures by Marine Corps installations, expenditure data accurately reflecting range use were available during the five-year review; therefore, actual loading rates were calculated. MC prioritization for the five-year review was determined based on MC loading rate (mass of MC/area), surface water transport and receptor factors, groundwater transport and receptor factors, and sediment transport and receptor factors.

Lead was considered only for SARs in the baseline assessment. However, to provide an initial understanding of the amount of lead deposition on HE ranges and training areas, lead loading was estimated for all ranges, including non-SARs, in the five-year review. The total estimated lead deposition on these ranges was estimated based on installation expenditure records. However, similar to SAR evaluations, the potential for lead migration was not quantitatively assessed because fate and transport parameters for lead are dependent on site-specific geochemical properties, which are generally not available without site-specific investigations.

The Marine Corps currently is evaluating the expansion of the installation's boundaries in an effort to expand large-scale training activities necessary to meet future training requirements. Although these plans are still in the development phase, the preferred expansion plan includes obtaining portions of the Johnson Valley Off Highway Vehicle Area to utilize as dual-purpose military and public lands. These areas are not assessed in this five-year review as munitions use/training is not currently conducted in these areas. However, the possible land expansion is noted in the event this area requires assessment in the next five-year review.

No other significant changes to operational range boundaries, training mission, training tempo, or other parameters were identified during the five-year review data gathering effort that would impact input parameters for fate and transport modeling.

2.2. Summary

The baseline assessment report identified 23 MC loading areas (generally matching existing RTAs) and 12 SARs. Based on the results of the baseline assessment as detailed

above and additional data collected for the five-year review effort, 30 MC loading areas were defined and seven SARs were evaluated during the five-year review effort. MC loading areas include the following:

- Acorn *(included in baseline assessment)*
- America Mine *(included in baseline assessment)*
- Black Top I *(included in baseline assessment)*
- Black Top II *(included in baseline assessment)*
- Cleghorn Pass I *(included in baseline assessment under Cleghorn Pass)*
- Cleghorn Pass II *(included in baseline assessment under Cleghorn Pass)*
- Delta *(included in baseline assessment)*
- East *(included in baseline assessment)*
- Emerson Lake *(included in baseline assessment)*
- Gays Pass I *(included in baseline assessment under Gays Pass)*
- Gays Pass II *(included in baseline assessment under Gays Pass)*
- Gypsum Ridge *(included in baseline assessment)*
- Lava *(included in baseline assessment)*
- Lavic Lake I *(included in baseline assessment under Lavic Lake)*
- Lavic Lake II *(included in baseline assessment under Lavic Lake)*
- Lead Mountain I *(included in baseline assessment under Lead Mountain)*
- Lead Mountain II / Bullion *(included in baseline assessment under Lead Mountain and Bullion, respectively)*
- Maumee Mine *(included in baseline assessment)*
- Noble Pass *(included in baseline assessment)*
- Prospect *(included in baseline assessment)*
- Quackenbush *(included in baseline assessment)*
- R-051 *(not included as an MC loading area in baseline assessment)*
- Rainbow Canyon *(included in baseline assessment)*
- Range I *(included in baseline assessment under Range)*
- Range II *(included in baseline assessment under Range)*
- Range III *(included in baseline assessment under Range)*
- Range IV *(included in baseline assessment under Range)*

- Sand Hill *(included in baseline assessment)*
- Sunshine Peak *(included in baseline assessment)*
- West *(included in baseline assessment)*

SARs evaluated in the five-year review include the following:

- Range 1 *(included in the baseline assessment)*
- Range 1A *(included in the baseline assessment)*
- Range 2 *(included in the baseline assessment)*
- Range 2A *(included in the baseline assessment)*
- Range 3 *(included in the baseline assessment)*
- Range 3A *(included in the baseline assessment)*
- Range 101 *(included in the baseline assessment)*

3. Munitions Constituents Loading Rates and Assumptions

The conceptual and screening-level analyses conducted under REVA require estimation of the amount of indicator MC deposited on operational ranges over time in order to determine if there is a release or substantial threat of a release of MC. The deposition of indicator MC that is estimated under the REVA program is referred to as MC loading.

Operational range usage, boundaries, and other characteristics typically change over time. The objective of the five-year review is to determine the impact of MC loading since the baseline assessment. For this five-year review of training at MCAGCC Twentynine Palms, MC loading estimates include the period from2006 to 2010. No new RTAs were established at MCAGCC Twentynine Palms since the baseline assessment, and consequently no further review of historical loading prior to 2006 was required since it was addressed in the baseline assessment. Eight fixed ranges—located within the existing RTAs—began operations after the baseline assessment; these were incorporated into this review.

The MC loading process for a baseline assessment is outlined in the *REVA Reference Manual* (HQMC, 2009), while specifics pertaining to MCAGCC Twentynine Palms are discussed in its baseline REVA Report (Malcolm Pirnie, 2007). This five-year review utilizes and builds upon this process, developing MC loading estimates expressed as the average areal loading rate (kilograms per square meter [kg/m^2]) deposited annually in the defined area(s) of interest for the most recent time period (from baseline assessment to five-year review). Assumptions were made throughout this 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 training areas and ranges at MCAGCC Twentynine Palms and defines the specific MC loading areas identified for the installation as well as the overall assumptions for MC loading on the operational ranges. The range-specific assumptions used in the process and the results of the MC loading are provided in **Section 5**.

3.1. Munitions Constituents Loading Process

The MC loading was estimated based on mass-loading principles. One key consideration for MC loading estimates is the MC content of each type or specific item(s) used at a

given MC loading area. Information on the types and amounts of energetic fillers associated with military munitions was developed primarily through the use of Internet-based sources, such as the Defense Ammunition Center's Munitions Items Disposition Action System (MIDAS) Web site and ORDATA database (2011).

Additional key considerations for MC loading estimates are dud, low order, and high order detonation rates. Studies have shown that MC are deposited on operational ranges through low and high order detonations and through the leaching of corroded unexploded ordnance (UXO). MC loading estimates are based upon the sum of the MC deposition associated with each outcome (e.g., high order, low order, and UXO) for a given MC loading area. Details on this process are included in the MCAGCC Twentynine Palms baseline report (Malcolm Pirnie, 2007) and the *REVA Reference Manual* (HQMC, 2009).

When calculating MC loading for a range/training area that is determined to be regularly and intensely managed for explosive hazards (e.g., demolition or engineering range), dud and low order rates were set to zero. Dud/UXO rates associated with DoDICs that were reported in the expenditure data were not used in place of the standard dud assumptions used in the REVA MC Loading Rate Calculator because these data were not reported for a long enough period to develop meaningful dud rates and the data may not have been reported consistently. As such, the standard REVA methodology and dud rate assumptions were used in order to maintain a higher level of conservatism in the estimate.

Deposition of metals, specifically lead, was further considered during this five-year review. Small arms are presumed to be the most significant contributor to lead deposition at operational ranges and training areas, though the metal may also be part of other HE munitions components to varying degrees. Using a similar MC loading methodology, the annual areal deposition of lead for any given MC loading area was estimated; the results are included in **Section 6**. Deposition rates may provide an initial measure of potential impact from lead on training ranges; however, it is important to note such rates differ from other MC loading rates due to key considerations. Given the nature of metals, lead deposition estimates assume no consumption from impact of this REVA indicator MC. Further, actual exposure of munitions-based lead to the environment cannot be predicted at the impact point and, therefore, is disregarded in the estimate. This is further complicated at demolition or other ranges where management practices may involve collection of scrap metals, which would reduce the overall lead presence at that location. In such instances, unless information indicates otherwise, it is conservatively assumed that lead deposition is 5% of the munitions' lead content. Finally, as described in other sections, fate and transport parameters for lead are dependent on site-specific geochemical properties, which may vary across a designated MC loading area and cannot be determined solely by physical observation. For these

reasons, lead deposition rates are not used to make a quantitative or qualitative analysis with regard to potential transport from the loading area. In the case of a SAR, range design typically concentrates the impact point to a small, restricted area, and the SARAP may be used to qualitatively assess it, as covered in **Section 7**.

Additional specifics regarding how these data were incorporated are explored in the aforementioned *REVA Reference Manual* and baseline *REVA Report for MCAGGCC Twentynine Palms*.

3.2. Expenditure Data

Operations & Training (O&T) is responsible for the administration and oversight of the training operations conducted at MCAGCC Twentynine Palms. O&T coordinates primary recordkeeping for munitions expenditures at the operational ranges of the installation through use of the Range Facility Management Support System (RFMSS). Summaries of current munitions expenditures primarily were based upon RFMSS data produced by Range Control. The dates of the records incorporated into this assessment range from January 2006 to October 2010.

The use of documented expenditure data is preferred in the REVA program. A quality review of the expenditure data provided by the installation resulted in a series of assumptions applicable across operational training areas at MCAGCC Twentynine Palms:

- The expenditure summaries contain some DoDICs for which data regarding MC content were not available in MIDAS or other inventories.
  - In some of these instances, a general description of the munitions associated with these DoDICs was identified, either as part of the installation data or as found in other readily available sources. This was reviewed, along with available information regarding the associated range, its design, and its regulations, and professional judgment was used to select surrogate MC loading factors from available data for similar munitions for use in MC loading calculations.
  - In other instances, no description of the munitions was provided. The associated expenditure counts for the unknown DoDICs were proportionally distributed among other known DoDICs, based on totals for the other DoDICs listed for the same range within that given year.
- The expenditure data for calendar year 2010 represented only 10 months of training data. To estimate totals for the entire span of 2010, expenditure counts were increased by 20%.

Given these considerations, data spanning approximately six years (January 2006 through October 2010) were used for MC loading calculations associated with current MC

loading areas at MCAGCC Twentynine Palms, as well as to determine lead loading estimates. Other general assumptions regarding application of these expenditure data to calculate MC loading are discussed in **Section 3.6**. Assumptions and data specific to individual MC loading areas or ranges are discussed as appropriate in **Section 6**.

3.3. REVA Munitions Constituents Loading Rate Calculator

The REVA MC Loading Rate Calculator is used to provide an automated method to calculate the overall loading of the operational range area in the units needed for the fate and transport analysis (kg/m^2). It utilizes information regarding the size of MC loading areas, the military munitions expenditure data obtained from the installation, and information and assumptions related to duds, low order, and high order detonations. Additionally, it utilizes training factors (discussed in **Section 3.4**) to account for fluctuations in training during periods of use where no expenditure data are available.

Further explanation regarding the REVA MC Loading Rate Calculator may be found in the *REVA Reference Manual* (HQMC, 2009). All known data and assumptions input into the MC Loading Rate Calculator for each operational range area assessed are documented elsewhere in **Section 3** and in **Section 6**.

3.4. Training Factor

Typically, the REVA program assesses the potential influence of historical MC loading through the use of training factors in the MC Loading Calculator. Training factors are associated with different time periods and are based on fluctuations associated with the start and cessation of a conflict or war. Subject matter experts within the Marine Corps were queried to establish training factors and time periods (a total of five periods), and this information is used to extrapolate historical MC loading across the entire known time period of range operation using current expenditure data:

- 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–baseline REVA assessment (baseline + 50%)

Training factors were used to complete the baseline REVA assessment of MCAGCC Twentynine Palms. However, since no additional historical MC loading was identified during this five-year review, training factors were unnecessary for MC loading calculations. A "Period F" was established to represent the time period covered by this

five-year review; no training factor was applied to this time period since actual expenditure data was obtained from RFMSS.

3.5. Munitions Constituents Loading at MCAGCC Twentynine Palms

MCAGCC Twentynine Palms is the Marine Corps' largest live-fire training facility, encompassing approximately 600,000 acres in San Bernardino County, California (MCAGCC Twentynine Palms, 2010). MCAGCC Twentynine Palms is home to the Marine Air Ground Task Force (MAGTF) Training Command , whose primary mission is to conduct relevant live-fire combined arms training, urban operations, and Joint-/Coalition-level integration training that promotes operational forces readiness as well as to provide the facilities, services, and support responsive to the needs of resident organizations, Marines, Sailors, and their families today and tomorrow (MCAGCC Twentynine Palms, 2011). 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. MCAGCC Twentynine Palms provides housing, facilities, and certain logistic and administrative support to tenant Fleet Marine Force and other assigned units.

Since the 2006 baseline assessment, the training focus has shifted from the Combined Arms Exercise Program to the EMV Program. These exercises and other smaller training programs occur throughout the year (MCAGCC Twentynine Palms, 2006a). Current live-fire training at the installation is focused on the Enhanced Mojave Viper exercise, which employs combined-arms integration techniques and procedures at the company level and fire and movement/maneuver at the platoon level that culminates in the integration of large-scale maneuver with direct, indirect and aviation fires involving all elements of the exercise force. The exercise also incorporates urban-level operations where units are presented with facilities, role players and scenarios that closely replicate the environment to which they will deploy.

MCAGCC Twentynine Palms contains 597,478 acres dedicated to maneuver, live-fire, and tactical training. There are currently 23 operational RTAs, with 17 of the areas designated for live-fire and six designated for non-live fire. Within the installation, there are a total of 46 fixed ranges designated for a variety of training activities. Seven of the fixed ranges are designated as SARs, and 10 operate as MOUT facilities. Since the 2006 baseline assessment, eight new fixed ranges (Range 225, Range 230, Range 401, Range 620, Range 630, Range 700, Range 705, and Range 800) have been established. In addition, the use of two ranges have changed since the 2006 baseline assessment. Range 112 was identified in the baseline assessment as an NREA range residue processing area. In the 2010 standard operating procedure (SOP) for Range Training Area and Airspace

(RTAA), Range 112 was identified as an explosive ordnance disposal (EOD) training range. Range 215A was identified as a non-live-fire MOUT facility in the baseline assessment; in the 2010 RTAA SOP, Range 215A was identified as a tactical exploitation site. Additionally, Range 4 and Range 3A within the MTU were combined into Range 3A; Range 101 and Range 101A within Range RTA were consolidated into Range 101.

A summary of each range and training area, including information regarding location, size, and usage profile is provided in **Table 3-1**.

3.6. Munitions Constituents Loading Assumptions

3.6.1. Selection of Munitions Constituents Loading Areas

The REVA assessment team reviewed existing operational ranges and training areas to determine the locations of MC loading areas at MCAGCC Twentynine Palms. These areas represent the locations at which significant MC loading is occurring or is suspected to have occurred as a result of training with munitions containing HE (HMX, RDX, and TNT) or illumination rounds/munitions containing solid propellants (perchlorate). Lead deposition was evaluated for all operational ranges during the five-year assessment. Based on the information provided in this section, 30 MC loading areas at MCAGCC Twentynine Palms were delineated for the five-year review:

- Acorn
- America Mine
- Black Top I (West)
- Black Top II (East)
- Cleghorn Pass I (West)
- Cleghorn Pass II (East)
- Delta
- East
- Emerson Lake
- Gays Pass I (South)
- Gays Pass II (North)
- Gypsum Ridge
- Lava
- Lavic Lake I (West)
- Lavic Lake II (East) / Bullion
- Lead Mountain I (North)
- Lead Mountain II (South)
- Maumee Mine
- Noble Pass
- Prospect
- Quackenbush
- R-051
- Rainbow Canyon
- Range I (South)
- Range II (South Central)
- Range III (North Central)
- Range IV (North)
- Sand Hill
- Sunshine Peak
- West

Table 3-1
Summary of Operational Ranges and Training Areas, MCAGCC Twentynine Palms
MCAGCC Twentynine Palms, California

Range Training Area	Fixed Range	Small Arms Range	MOUT	Size (acres)	Notes / Comments
Non-Live Fire RTAs					
Mainside RTA				**5,263**	**Cantonment area only.**
	Range 700			10	New range installed since the 2005 REVA baseline. Training Facilities (Physical Fitness Training)
	Range 705 (portion in West)			105	New range installed since the 2005 REVA baseline. Combat Vehicle Operator Training (CVOT) Course. Size is based on length of course with an assumed width of 50 feet.
East RTA				**6,502**	**Non-live fire RTA.**
	Range 100			1,084	Squad maneuver range (land navigation, non-live fire)
	Range 200		X	48	Non-live-fire MOUT
	Range 215		X	143	Non-live fire MOUT
	Range 215A				Change in range use since 2005 REVA baseline (identified in 2005 as non-live fire MOUT facility). Identified in updated range SOP as Tactical Exploitation Site
West RTA				**9,966**	**Non-live fire RTA.**
	Range 102			739	Squad maneuver range (land navigation, non-live)
	Range 225		X	45	New range installed since the 2005 REVA baseline. Non live-fire MOUT
	Range 705 (portion in Mainside)			105	New range installed since the 2005 REVA baseline. Combat Vehicle Operator Training (CVOT) Course
	Range 800			12	New range installed since the 2005 REVA baseline. Improvised Explosive Device Range. Size is based on length of course with an assumed width of 50 feet.
Sand Hill RTA				**15,810**	**Non-live fire RTA.**
Acorn RTA				**17,369**	**Non-live fire RTA.**
Gypsum Ridge RTA				**18,265**	**Non-live fire RTA.**
Live-Fire RTAs					
Prospect RTA				**13,189**	**Live-fire RTA.**
	Range 205 (Portion in Delta)		X	87	Live-fire convoy operations course. Begins in Prospect RTA and extends into Delta RTA.
	Range 205A		X	*Range not depicted on map or installation GIS data	Live-fire MOUT facility
Maumee Mine RTA				**16,141**	**Live-fire RTA.**
Gays Pass RTA				**18,316**	**Live-fire RTA.**
America Mine RTA				**20,809**	**Live-fire RTA.**
Range RTA				**20,158**	**Live-fire RTA.**
	Range 051			35	Explosive ordnance disposal training range
	Range 101	X		133	Change since 2005 REVA baseline - 101 and 101A combined to 101. Small arms battle sight zero.
	Range 103			573	Squad defensive fire range (automated)
	Range 104			475	Anti mechanized/grenade range
	Range 105			6	Gas chamber
	Range 105A			196	Small arms BZO, CMP tables 3 and 4, block I/II, IT3 and TSLUC training facility
	Range 106			474	Mortar range
	Range 106A			8	Grenade range
	Range 107			923	Infantry squad assault range
	Range 108			1,170	Infantry squad battle course
	Range 109			553	Anti-armor live-fire tracking range
	Range 110			748	MK-19 range
	Range 110A			14.8	M203 grenade range
	Range 111		X	294	MOUT Assault course (MAC)
	Range 112			2,786	Change in range use since 2005 REVA baseline (identified in 2005 as an NREA range residue processing area). Identified in updated range SOP as EOD training range. Small portion extends into Delta RTA.
	Range 113			1,189	Multi-purpose machine gun range
	Range 113A			190	Machine gun BZO/EMP range
	Range 114			87	Combat engineer demolition range
	Range 1	X		47.7	Known distance rifle range
	Range 1A	X		23.5	Unknown distance rifle range
	Range 2	X		2.7	Known distance pistol range
	Range 2A	X		1.3	Combat pistol range
	Range 3	X		1.4	Rifle field expedient BZO/Grouping range
	Range 3A	X		3.4	Multi-purpose rifle/pistol range

Table 3-1
Summary of Operational Ranges and Training Areas, MCAGCC Twentynine Palms
MCAGCC Twentynine Palms, California

Range Training Area	Fixed Range	Small Arms Range	MOUT	Size (acres)	Notes / Comments
Lava RTA				**22,925**	**Live-fire RTA.**
Sunshine Peak RTA				**22,859**	**Live-fire RTA.**
Noble Pass RTA				**24,315**	**Live-fire RTA.**
Rainbow Canyon RTA				**25,348**	**Live-fire RTA.**
	Range 601			247.7	Sensitive Fused Munitions Range
Bullion RTA				**28,129**	**Live-fire RTA.**
	Range 210		X	145	Live-fire MOUT facility
Delta RTA				**29,791**	**Live-fire RTA.**
	Range 205 (Portion in Prospect)		X	87	Live-fire convoy operations course. Begins in Prospect RTA and extends into Delta RTA.
	Range 230		X	45	Live-fire MOUT facility expected to be completed in June 2011.
	Range 401			218.9	New range installed since the 2005 REVA baseline. Company Fire and Maneuver Range
Emerson Lake RTA				**32,287**	**Live-fire RTA.**
Cleghorn Pass RTA				**36,358**	**Live-fire RTA.**
	Range 400			722.6	Company Fire and Maneuver Range
	Range 410			234.9	Platoon Fire and Maneuver Range
	Range 410A			293.9	Platoon Hasty Attack and Maneuver Range
	Range 500			15.2	Armor Multi-purpose Range Complex
Quackenbush RTA				**42,037**	**Live-fire RTA.**
	Range 220		X	898	Combined Arms MOUT (CAMOUT)
	Range 620			246	Urban Array (Collateral Damage Only)
	Range 630			1,010	Aviation range.
Black Top RTA				**50,894**	**Live-fire RTA.**
Lead Mountain RTA				**53,314**	**Live-fire RTA.**
Lavic Lake RTA				**56,985**	**Live-fire RTA.**
Restricted Area: Wells				**7,896**	**No live fire training allowed.**

Notes:
New ranges since the 2005 baseline are noted with gray shading.
No historical information regarding the period of use and the types of munitions historically used at the ranges was available.
Total acreage of fixed ranges based on the range footprint relevant to REVA assessment purposes (do not include SDZ acreage). These acreages may not match those officially established and tracked by Range Control.
Total acreage of RTAs based on installation GIS.

As described in this section, MC loading areas were selected to capture the use of munitions at various operational training areas and ranges under the administration of MCAGCC Twentynine Palms. This five-year assessment includes more MC loading areas (30) than were included in the baseline report (23) because some of the original MC loading areas were subdivided in this five-year assessment. This subdivision was performed to more accurately estimate likely MC depositional areas.

Based on interviews with Range Control and a review of expenditure data, 18 of the 30 MC loading areas were identified for significant MC loading and, consequently, are designated to be *primary MC loading areas*, as shown in **Figure 3-1**. The boundaries of each primary MC loading area were selected based on training-specific information (e.g., operational range boundaries, target locations), which does not necessarily capture the complete potential spatial distribution of MC loading. This results in a realistic yet conservative estimate of MC loading rates for the following:

- Black Top I (West)
- Black Top II (East)
- Cleghorn Pass I (West)
- Cleghorn Pass II (East)
- Delta
- Gays Pass I (South)
- Gays Pass II (North)
- Lava
- Lavic Lake I
- Lavic Lake II
- Lead Mountain I
- Lead Mountain II / Bullion
- Prospect
- Quackenbush
- Range I (South)
- Range II (South Central)
- Range III (North Central)
- Range IV (North)

For the other 12 MC loading areas, boundaries were based on RTA boundaries designated by the installation, with the exception of the R-051 MC loading area, which was based on range boundary of the eponymous EOD range. In order to provide for conservative estimates of MC loading rates for these areas, surface area values used for calculations were reduced to 10% of the actual size of each MC loading area.

3.6.2. Fixed Ranges

There are 46 fixed ranges within the installation that have been designated for various training activities, as shown in **Figure 3-2**. Seven of the fixed ranges are designated as SARs, and 10 operate as MOUT facilities. Details regarding location, size, and usage profile for each range and training area are provided in **Table 3-1**. Since the 2006 baseline assessment, Range 225, Range 230, Range 401, Range 620, Range 630, Range 700, Range 705, and Range 800 have been completed. In addition, the use of two ranges has changed since the 2006 baseline assessment. Range 215A was identified as a non-

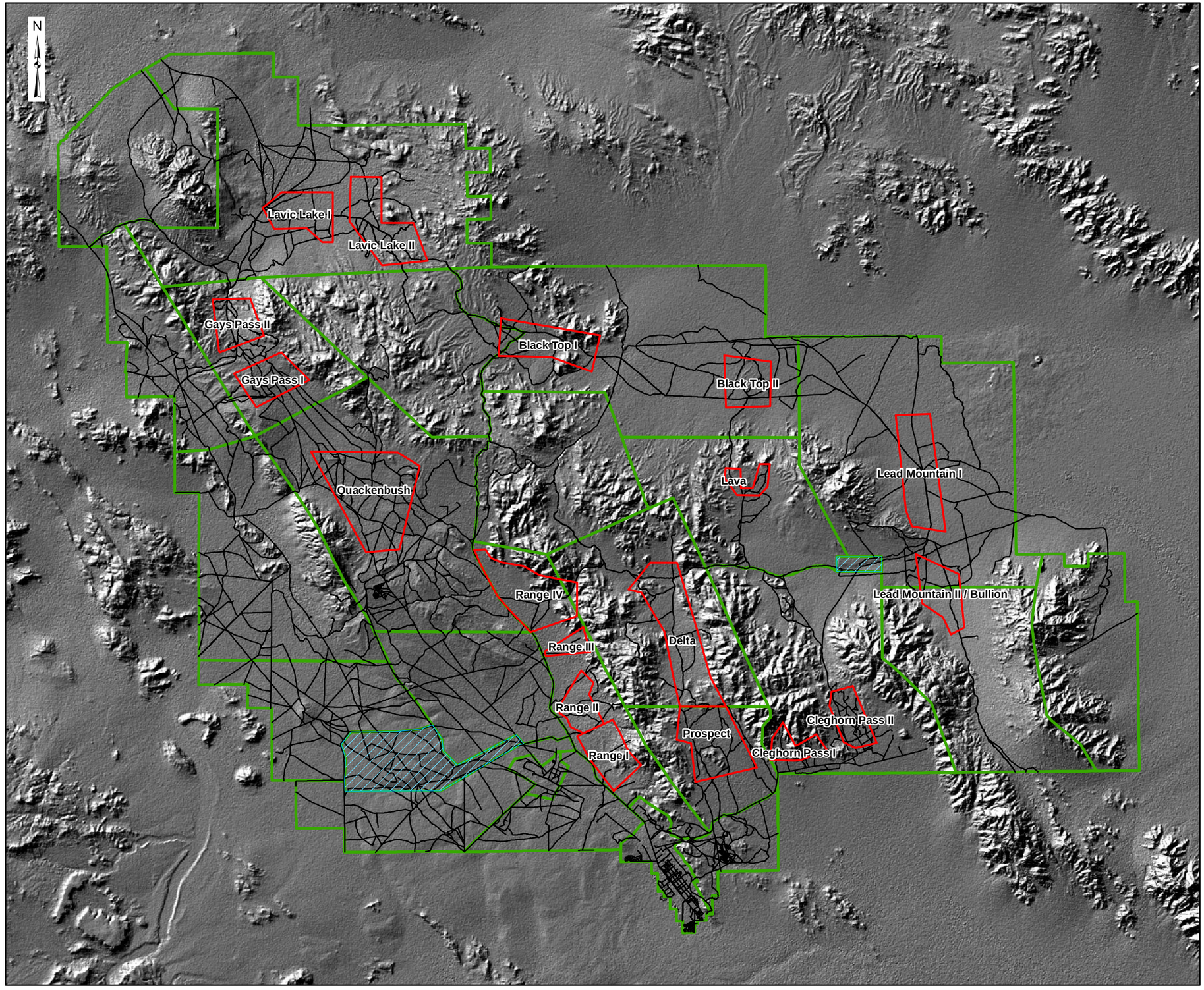
live-fire MOUT facility. In the 2010 SOPs for RTAA, Range 215A was identified as a tactical exploitation site. Range 112 was identified in the baseline assessment as an NREA range residue processing area. In the 2010 SOPs for RTAA, Range 112 was identified as an EOD training range.

3.6.3. Overarching Assumptions

To estimate MC loading for operational ranges, assumptions were developed to apply to the datasets collected during the baseline assessment and the five-year review. Complete details and background of these assumptions and data are available in the *REVA Reference Manual for Baseline Assessments* (HQMC, 2009). The following bullets represent the primary assumptions used in the MC loading assessment.

- Only the main fillers and perchlorate components (REVA indicator MC) are included in the estimates. The amount of MC in fuzes, boosters, and other components is not considered significant enough, by comparison, to impact the MC loading amounts.
- All REVA indicator MC are considered 100% pure and, therefore, more readily transported in the environment.
- Dud and low order detonation rate estimates are from the *Report of Findings for: Study of Ammunition Dud and Low Order Detonation Rates, United States Army Defense Ammunition Center* (DAC, 2000). In the event rate estimates are not available, the default values listed in the referenced report of 3.45% (dud rate) and 0.028% (low order detonation rate) are used.
- One hundred percent of all UXO result in exposed MC. Following deposition of UXO, 1% of the total MC mass within the UXO is considered exposed and available for transport.
- For low order detonations, it is assumed that 50% of the total MC per item was consumed, resulting in deposition of the other 50% of the MC mass on the loading area (DAC, 2000). For high order detonations, it is assumed 99.9% of the total MC per item is consumed, resulting in deposition of 0.1% of the MC mass on the loading area , as detailed in the R*EVA Reference Manual* (HQMC, 2009).
- In the event that data are unavailable for the entire training period identified, other methods or assumptions for estimating MC loading will be implemented.

HE and perchlorate were evaluated at MC loading areas where significant HE use has been documented; lead was evaluated at operational SARs. Calculation of representative annual values of expenditures at the ranges was performed to help characterize respective MC and lead loading; the recorded totals by DoDIC for applicable years were averaged together, with all fractional values conservatively rounded up to the next whole number. The specific methodologies and assumptions used to conduct the MC loading at each loading area are detailed in Section 6, as applicable.



REVA
FIGURE 3-1
MCAGCC TWENTYNINE PALMS
RTAS AND PRIMARY MC
LOADING AREAS

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- Restricted Areas
- MC Loading Areas - 5-Year
- Main Supply Routes

0 0.75 1.5 3 4.5
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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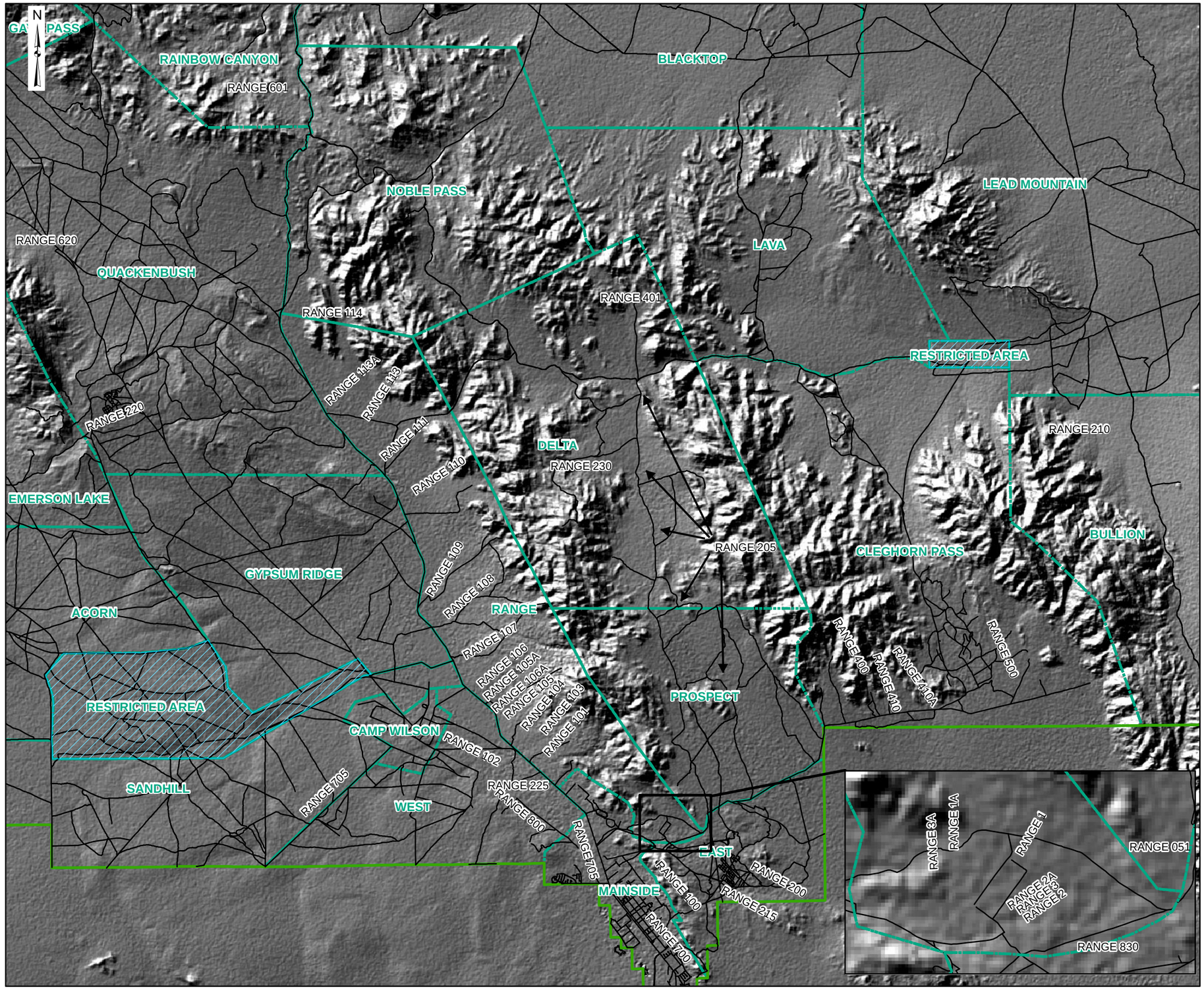

REVA
FIGURE 3-2
MCAGCC TWENTYNINE PALMS
RTAS, FIXED RANGES AND
PRIMARY MC LOADING AREAS

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

Legend

- Installation Boundary
- Range Training Areas (RTAs)
- Restricted Areas
- Main Supply Routes

0 0.5 1 2 3
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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4. Conceptual Site Model

Predicting off-range migration of MC requires the evaluation of potential exposure pathways, such as surface water and groundwater flow characteristics, and possible receptors (human and ecological) that might be affected. To this end, the REVA assessment team developed CSMs to characterize the dynamics at MCAGCC Twentynine Palms that can affect MC migration. The primary components of these CSMs include:

- delineation of the MC loading areas;
- identification of REVA indicator MC at individual MC loading areas;
- a synthesis and interpretation of various environmental data to identify potential MC migration pathways and receptors; and
- identification of data gaps.

A CSM was developed for the operational ranges at MCAGCC Twentynine Palms. Key information sources used in the development of the CSM include the following:

- Military munitions expenditure data
- MCAGCC FMD GIS data
- Installation Restoration Program (IRP) site data
- Installation-specific data, including:
  - Water quality data for drinking water wells
  - Drinking water vulnerability assessment report
  - Precipitation data
- U.S. Geologic Survey (USGS) topographic maps and regional groundwater resource reports
- California Regional Water Quality Control Board (CRWQCB) Colorado River Basin Plan
- MCAGCC Twentynine Palms Integrated Natural Resources Management Plan (INRMP)
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil survey
- Marine Corps Archive Search Report (ASR)
- Marine Corps Preliminary Range Assessment

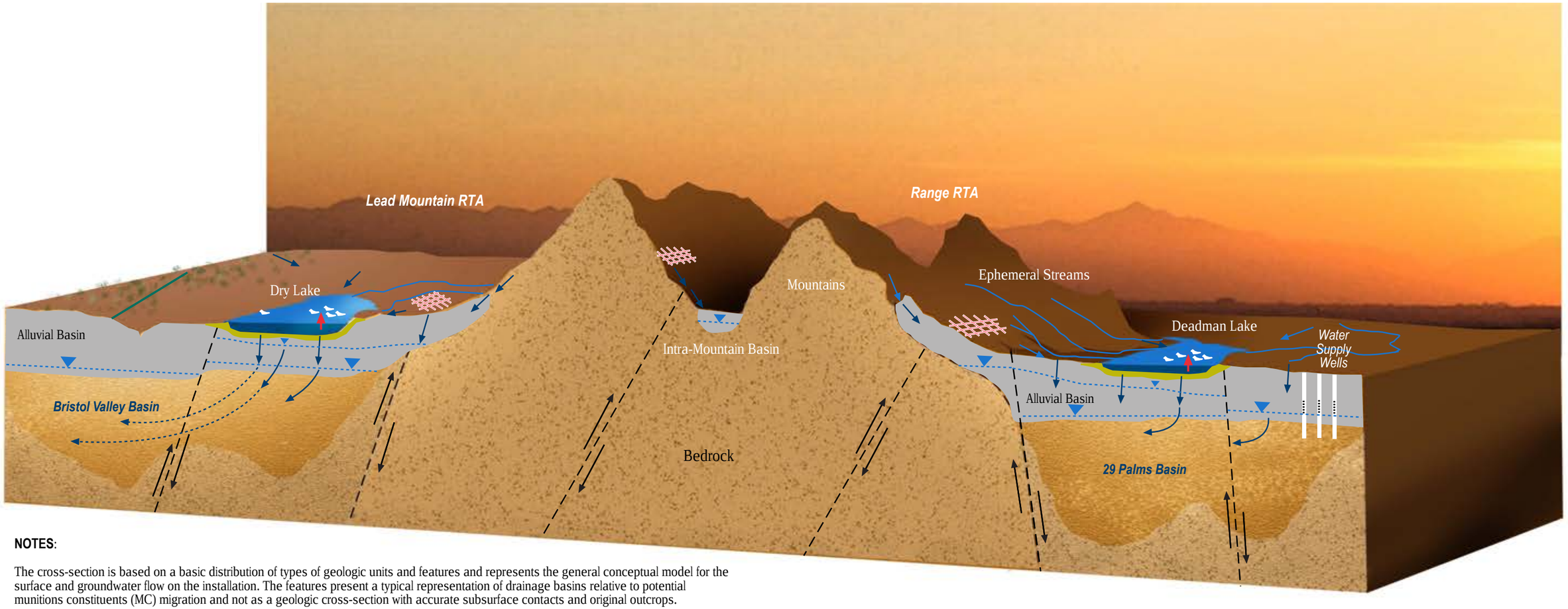
Where detailed information of site-specific characteristics and information did not exist, available regional information was used to estimate local characteristics.

A schematic diagram depicting the site conditions addressed in the CSM is presented in **Figure 4-1**. The geomorphology is shown relative to generalized MC loading areas, the installation boundary, and potential receptors (e.g., drinking water wells, ecological receptors).

The site-specific CSMs for the MC loading areas are provided in **Section 6**.

4.1. Installation Profile

CSM Information Profiles – Installation Profile	
Information Needs	**Preliminary Information**
Installation location	MCAGCC Twentynine Palms is located in southern San Bernardino County in the Morongo Basin of the Mojave Desert. The installation is approximately 130 miles east of Los Angeles and 54 miles northeast of Palm Springs. The installation is bounded by Interstate 40 to the north and Highway 62 to the south. The areas along the northern, eastern, and western boundaries are undeveloped or sparsely developed. The majority of this land is under the control of the Bureau of Land Management (BLM), including the Johnson Valley Off Highway Vehicle Area on the western edge of the installation. The southern boundary of the installation is adjacent to the city of Twentynine Palms. Other communities near MCAGCC Twentynine Palms include Joshua Tree, Yucca Valley, and Landers. Other neighboring federal land uses include the Joshua Tree National Park to the south and the Cleghorn Lakes BLM Wilderness Area adjacent to the southeastern corner of the base. The Johnson Valley Off Highway Vehicle Area is located on the western boundary of the installation.
Date of Installation establishment	The Marine Corps began operating at Twentynine Palms in 1952, when Camp Pendleton established the Camp Detachment Marine Corps Training Center (MCTC) Twentynine Palms. In 1953, the site was redesignated as the MCTC Twentynine Palms. By 1956, most of the base construction was completed, and the Marine Corps staged several training exercises during the winter of 1956. In February 1957, MCAGCC Twentynine Palms began to administer itself and was redesignated Marine Corps Base Twentynine Palms.
Installation area and layout	The installation 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 or playas. Approximately 99% of the installation is undeveloped or unimproved grounds. The only developed area is at Mainside, located in the southernmost portion of the installation. Mainside contains administration, housing, maintenance, supply and support, and community facilities for the installation. The remaining area is reserved for military training activities.



NOTES:

The cross-section is based on a basic distribution of types of geologic units and features and represents the general conceptual model for the surface and groundwater flow on the installation. The features present a typical representation of drainage basins relative to potential munitions constituents (MC) migration and not as a geologic cross-section with accurate subsurface contacts and original outcrops.

Four major processes control MC migration:

1. Potential surface water and sediments transport from MC loading areas to dry lakes (playas) via ephemeral streams
2. Potential direct groundwater recharge due to washoff into quaternary deposits
3. Potential infiltration of MC from dry lakes and surrounding surface soil through vadose zone to shallow groundwater
4. Potential migration of MC from shallow groundwater to deeper groundwater

- Alluvial Basin - Quaternary & Tertiary **Alluvial** Fan Deposits (upper and middle aquifer)
- Alluvial Basin - Tertiary Older Sedimentary Deposits (lower aquifer)
- Groundwater Flow Direction
- Potential MC Migration
- Potential MC Interaction
- Primary MC Loading Area
- Ephemeral Streams
- Water Table
- Playa Soil
- Bedrock
- Strike-Slip Faults
- Ecological Receptors
- Installation Boundary

Bedrock: comprise of precambrain igneous and metamorphic complex, Jurassic grantic rocks and quaternary basalts and related volcanic deposits

Alluvial Basin-Tertiary Older Sedimantary Deposits: comprised of poorly sorted medium to course arkosic sand, silt, and gravel

Alluvial Basin-Quaternary & Tertiary Alluvial Fan Deposits: comprised of material derived from uplifted bedrock highs and may also contain reworked sediment from Tertiary deposits

Playa Soils: comprised of thin veneer of very poorly drained clayey loam

Strike-Slip Faults: potentially act as hydraulic barriers

Ecological Receptors: includes the Desert Tortoise and the Mojave Fringe-Toed Lizard

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Figure 4-1
Conceptual Site Model

MCAGCC Twentynine Palms
Twentynine Palms, CA

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CSM Information Profiles – Installation Profile	
Information Needs	**Preliminary Information**
Installation area and layout (continued)	The Marine Corps currently is evaluating the expansion of the installation's boundaries in an effort to expand large-scale training activities necessary to meet future training requirements. Although these plans are still in the development phase, the preferred expansion plan includes obtaining portions of the Johnson Valley Off Highway Vehicle Area to utilize as dual-purpose military and public lands.
Installation mission	The mission is to conduct relevant live-fire combined arms training, urban operations, and Joint-/Coalition-level integration training that promotes operational forces readiness as well as to provide the facilities, services, and support responsive to the needs of resident organizations, Marines, Sailors, and their families today and tomorrow (MCAGCC Twentynine Palms, 2010). MCAGCC Twentynine Palms is the only installation that provides a realistic training environment that allows troops to maneuver through open impact areas under conditions simulating combat conditions. MCAGCC Twentynine Palms annually provides training to one-third of the Fleet Marine Force and Reserves units through numerous training exercises, including the EMV. The MCAGCC Twentynine Palms training mission is expected to evolve with the development of new weapons systems and tactics; therefore, the impact to the resources is likely to change as well (MCAGCC Twentynine Palms, 2006).

4.2. Operational Range Profile

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
MC loading areas	The 18 primary MC loading areas, as shown in **Figure 3-1**, identified for assessment during the five-year review are as follows: · Lavic Lake I · Lavic Lake II · Gays Pass I · Gays Pass II · Quackenbush · Black Top I · Black Top II · Lava · Range I · Range II · Range III · Range IV · Prospect · Delta

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
	· Cleghorn Pass I · Cleghorn Pass II · Lead Mountain I · Lead Mountain II/Bullion The MC loading areas were determined based on a review of existing operational ranges and evaluation of munitions expenditures tracked by the installation.
Range names	The installation is subdivided into 23 RTAs and several restricted areas. Forty-six fixed ranges exist on the installation within 10 RTAs. The RTAs and fixed ranges located within MCAGCC Twentynine Palms are presented in **Table 3-1**.
Date of range establishment	In 1969, the installation was administratively subdivided into eight RTAs for training purposes. The exact date of establishment of the fixed ranges is not known. Ranges have been present at the installation since its construction. Several additional ranges have been established since the 2006 baseline. See Range Design and Use section.
Range design and use	*Range Training Areas* 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. Training activities in these RTAs consist mainly of non-live-fire maneuvering and may include the use of blank ammunition, smoke grenades, and illumination rounds. 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 7,900-acre Restricted Area, which contains the 11 installation drinking water production wells as well as protected habitat for the threatened desert tortoise. The remaining 17 RTAs permit live-fire training anywhere within the training area, except for a 1,000-meter (m) buffer area inside the installation boundary. These RTAs are authorized for the use of all conventional weapons and munitions in the Marine Corps inventory. *Fixed Ranges* There are 46 fixed ranges within the installation, the majority of which are located within the Range RTA (24 ranges). The 46 fixed ranges associated with the installation are listed in **Table 3-1**. Of the 46 fixed ranges, 10 operate as MOUT training facilities and 7 operate as SARs. *Small Arms Ranges* There are seven SARs located within MCAGCC Twentynine Palms. Six of these ranges are located within the MTU range complex, which trains more than 10,000 active duty Marines per year for service rifle and pistol requalification (NAVFAC, 2002). The one remaining SAR is located within the Range RTA.

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
	Since the 2006 REVA baseline assessment, the following ranges have been established: · Range 225: a non-live-fire MOUT in West RTA · Range 230: a live-fire MOUT · Range 401: a company fire and maneuver area in Delta RTA · Range 620: an urban array MOUT facility · Range 630: an aviation range / MOUT facility · Range 700: a physical fitness training facility in Mainside RTA · Range 705: a combat vehicle operator training course in Mainside and West RTAs · Range 800: an improvised explosive device range in West RTA Since the baseline assessment, the following ranges have changed use: · Range 112 was listed as the NREA range residue processing area in the 2006 baseline assessment and is now listed as an EOD training range. · Range 215A was listed as a non-live-fire MOUT facility in the 2006 baseline assessment and is now listed as a tactical exploitation site.
Range security	The installation is actively patrolled; however, the perimeter is not under constant surveillance. The installation is not completely fenced in, and a main access gate, located near Mainside, provides access to the installation. Approved military access must be provided to pass through this access gate. Trespassers seeking metal scrap have been known to illegally enter areas of the installation that are not under constant surveillance.
Military munitions usage	For the non-live-fire RTAs, authorized military munitions include blanks, simulators, pyrotechnics, less-than-lethal for direct weapons, and no fires or effects of fires for indirect weapons. For the RTAs designated as live fire, authorized military munitions include all conventional munitions (air/ground) where safety footprint can remain within 1000 m from the scheduled RTA(s)/installation boundary. The restricted areas have been designated as areas where no live-fire training is allowed.
Munitions constituents	The types of munitions used at the non-live-fire RTAs (blanks, simulators, and pyrotechnics) have relatively small amounts of REVA indicator MC (TNT, HMX, RDX, and perchlorate). All five REVA indicator MC are potentially present on the live-fire RTAs. Targets where MC are likely to accumulate are present throughout the installation. However, 17 RTAs allow live-fire training anywhere within the training area; therefore, the potential exists for these MC to be deposited sporadically across the RTAs. The only indicator MC present at SARs is likely to be lead.

CSM Information Profiles – Operational Range Profile	
Information Needs	**Preliminary Information**
Maintenance	Range sweeps of the fire and maneuver areas for removal of UXO are conducted by EOD to maintain safe training conditions. These sweeps are done in conjunction with semiannual retargeting operations. High frequency use ranges are swept as often as schedule allows. In addition, the NREA Range Clearance Team removes munitions debris from operational ranges to enhance range safety. The munitions debris is inspected and processed through the recycling center at the installation.
Engineered controls	Protective earthen berms prevent run-on of surface water from higher elevations at some fixed ranges throughout the installation and at most of the MTU ranges, and sand periodically is added to the faces of the berms where bullet pockets are formed from range use. A bullet trap has been installed on the Known Distance Pistol Range and the Battle Sight Zero (BZO) range for greater capture and containment of lead fragments.

4.3. Physical Profile

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Climate	The climate at MCAGCC Twentynine Palms is typical of an arid upland desert and is characterized by hot days and cool nights. The yearly mean temperature is 68 degrees Fahrenheit (^{0}F), but temperatures can range from 13^{0}F in January to 118^{0}F in July. Relative humidity ranges from 2% in the summer to 60% in the winter. Across most of the installation area, precipitation averages between 3 and 4 inches per year. At the higher elevations, precipitation has been as high as 7 inches in some years (USDA NRCS, 1999). Winter rainstorms are relatively gentle and occur from November through April. Violent summer thunderstorms occur during July through September and can cause flash flooding throughout the area (The Environmental Company, 2004). The winter and summer rainstorms equally account for approximately 60% of the total annual precipitation that occurs (USDA NRCS, 1999).
Elevation	The majority of MCAGCC Twentynine Palms lies at elevations ranging between 1,500 and 3,000 feet (ft) above mean sea level (amsl). The highest elevation, at 4,699 ft amsl, is in the Bullion Mountains, which trend northwest to southeast across the installation. The lowest elevation, at 604 ft amsl, is in the northeastern corner of the installation near Bristol Dry Lake (USDA NRCS, 1999).
Topography and geologic features	MCAGCC Twentynine Palms is located within the Bullion and Lava Bed mountain ranges, along the western margins of the Basin and Range physiographic province of southeastern California (USDA NRCS, 1999). The terrain is characterized by broad alluvial plains, alluvial fans, bedrock uplands, ephemeral washes, playas, lava flows, and sand dunes. The

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	alluvial fans slope from the bedrock highlands into the alluvial plains, with numerous dry washes crossing the alluvial plains toward the playas. At least nine playas are located on the installation. Volcanic activity is evidenced by Quaternary lava flows in the Lavic Lake and Lava RTAs, as well as several small volcanic craters located near MCAGCC Twentynine Palms. Sand dunes are located throughout the base but are especially prevalent along the western flanks of the Bullion and Lava Bed mountains. The area generally is characterized by rugged mountain ranges and broad alluvium-filled desert basins. The Bullion and Lava Bed mountain ranges comprise the majority of the mountainous areas and trend northwest to southeast across the installation. The mountain ranges consist of crystalline bedrock, which also underlies the basin deposits (Riley et al., 2001). The crystalline bedrock is composed of a Precambrian igneous and metamorphic complex, Jurassic granitic rocks, and Quaternary basalts and related volcanic deposits. The crystalline bedrock is described in greater detail by Riley et al. (2001), Dibblee (1967a, 1967b, 1967c, 1968), and Riley and Worts (1952). The alluvium-filled basins are located on the flanks of the crystalline bedrock highs and are the dominant surface geologic unit at the installation. The most extensive alluvial basins are located on the northeastern and southwestern flanks of the Bullion and Lava Bed mountains. Smaller sedimentary basins are located within the mountain ranges, such as those found within the Delta and Prospect RTAs (**Figure 4-2**). MCAGCC Twentynine Palms is located in a seismically active area of the Western Mojave Desert known as the Mojave Sheer Zone. The area is characterized by northwest- to southeast-trending right-lateral strike-slip faults that separate the bedrock highs from basin lows. North- and west-trending faults, as well as a large west-trending anticline (Transverse Arch), are observed in the San Bernardino basin to the west of the installation (Riley et al., 2001). These geologic structures divide the basin into several subbasins and can form hydrogeologic controls to lateral groundwater flow. The barrier effect of faults is caused by the low permeability of the fault zone resulting from the compaction and extreme deformation of the water-bearing deposits immediately adjacent to the faults and by lateral juxtaposition of high and low permeability units (Li and Martin, 2008). Geologic mapping and water level data indicate that the Bullion Mountains, Mesquite, Surprise Spring, and Emerson faults and the Transverse Arch are groundwater flow barriers (Li and Martin, 2008). Also, other faults within the Surprise Spring groundwater subbasin have been identified as partial groundwater barriers (Londquist and Martin, 1991). **Figure 4-2** displays the major faults that are recognized in the area, which include the Bullion, Emerson, Galway Lake, Hidalgo, Ludlow, Mesquite Lake, Pisgah, and West Calico faults (Riley et al., 2001; USDA NRCS, 1999; Riley and Worts, 1952). The Transverse Arch is also labeled in **Figure 4-2**.

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
Stratigraphy	The stratigraphy described in this section covers the western parts of MCAGCC Twentynine Palms located southwest of the Bullion Mountains within the Morongo groundwater basin. The stratigraphic units were defined by Li and Martin (2008) based on data from geologic mapping, geological and geophysical logs of wells, and investigations of outcrops in this area. Limited stratigraphic data are available for the northern and eastern parts of MCAGCC Twentynine Palms; however, the stratigraphy in these areas is expected to be similar to the stratigraphy described here. There are five geologic units within the western part of MCAGCC Twentynine Palms. These units, from the oldest to youngest, consist of 1) basement complex of pre-Tertiary age, 2) older sedimentary deposits of Tertiary age (Miocene and Pliocene), 3) volcanic rocks of Tertiary age (late to middle Pliocene), 4) alluvial fan deposits of tertiary-Quaternary age (late Pliocene to Pleistocene), and 5) younger alluvium and playa deposits of Quaternary age (Pleistocene to Holocene). The basement complex consists predominately of plutonic intrusive rocks, including abundant Jurassic quartz monzonite. This unit forms the surrounding mountains and highlands and underlies the MCAGCC Twentynine Palms area (Li and Martin, 2008). The unit is intensively weathered to clay or clayey sand locally near its contact with overlaying sedimentary units; however, the crystalline basement rocks are relatively impermeable and are not considered a water-bearing unit. Tertiary volcanic rocks that are also generally non-water-bearing outcrop in the San Bernardino Mountains located southwest of the installation and in the Bullion Mountains located within the installation. Tertiary and Quaternary sediments overlie the basement rocks throughout most of the MCAGCC Twentynine Palms area. The thickness of these deposits varies significantly; the maximum thickness is close to 22,000 ft in the Deadman subbasin (Roberts et al., 2002). The older sedimentary deposits consist of sand, gravel, and subordinate silt and clay that are commonly indurated. Abundant detritus of Jurassic quartz monzonite and Tertiary volcanic rocks, which are derived from the Bullion Mountains and neighboring areas of the southern Mojave Desert, are found in this unit (Li and Martin, 2008). The older sedimentary deposits become more consolidated with depth and yield a very limited amount of water to wells (Londquist and Martin, 1991). The alluvial fan deposits that generally overlie the older sedimentary deposits consist of varying amounts of gravel, sand, silt, and clay that originated predominantly from the eastern San Bernardino Mountains in the north and the Little San Bernardino and Pinto Mountains in the south. The thickness of these deposits ranges from 250 ft to more than 1,000 ft (Li and Martin, 2008). The younger alluvium and playa or dry-lakebed deposits overlie the alluvial fan deposits as a thin veneer of typical thickness less than 50 ft throughout most of the installation area. These deposits vary from poorly sorted sand and gravel in the alluvial fans to fine sand, silt, and clay in the playa

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	deposits (Londquist and Martin, 1991). In general, these deposits are above the water table and, therefore, are not an important water-bearing unit. The playa deposits typically are found at dry lakes, such as Emerson, Deadman, and Mesquite dry lakes. From borehole data, the playa deposits are known to be about 50 ft thick at Deadman and Mesquite Lakes (Li and Martin, 2008).
Soil and vadose zone characteristics	The soils at MCAGCC Twentynine Palms are composed of gravelly sandy loam, sand, and gravelly coarse sand that range from well drained to excessively well drained. The soils formed mainly in colluvium and residuum or alluvium (USDA NRCS, 1999). The soils that formed in colluviums and residuum are mainly on the bedrock hills and mountains throughout MCAGCC Twentynine Palms. The soils that formed in alluvium are in basins and alluvial fans and fan remnants of intermontane valleys (USDA NRCS, 1999). The predominant soil types include the Arizo and Carrizo series and the Dalvord-Goldroad-Rock-Outcrop association (MCAGCC Twentynine Palms, 2006). The Arizo and Carrizo series soils are very deep, excessively drained, sandy-skeletal soils formed in mixed alluvium. The Arizo series are the most dominant soil types at MCAGCC Twentynine Palms, occupying about 20% of the total area. They occur in the northwestern, central, and southeastern parts of the installation on alluvial fans and drainage ways. The Carrizo series occupies about 16% of the installation area. They occur in the northeast part of the installation on alluvial fan, fan aprons, and drainage ways. The Dalvord-Goldroad-Rock-Outcrop association soils are very shallow to shallow, loamy-skeletal soils formed in residuum and colluvium from granitic and metamorphic sources. They are found mostly in the southeastern part of the installation on granitic mountains and cover approximately 18% of the total installation area. Other less dominant soil types at MCAGCC Twentynine Palms include the Haleburu series, the Cajon-Bluepoint association, the Edalph-Narea-Calico association, the Eastrange-Owlshead-Gayspass association, the Sunrock-Haleburu-Lava Flows association, and playa soils.
Erosion potential	The predominant soil types at MCAGCC Twentynine Palms mostly have very low erodibility, with a typical soil erodibility factor of 0.02 tons/acre (USDA NRCS, 1999). However, some of these soil types, such as a few of the Arizo soil series, have a soil erodibility factor as high as 0.24 tons/acre, which corresponds to moderate soil erodibility. MCAGCC Twentynine Palms generally has low precipitation and high rates of evaporation/evapotranspiration, indicating a low runoff rate that in turn results in lower soil erosion. However, the soil erosion rate is increased during flash flood events, resulting from heavy rainfall that occurs infrequently. The installation is located on a widely varying topography with steep slopes on the rocky uplands (as high as 90%) and more level slopes on the broad alluvial plains. The vegetation cover is sparse throughout the installation. The overall erosion potential at MCAGCC Twentynine Palms ranges from low to moderate. The erosion potential is

CSM Information Profiles – Physical Profile	
Information Needs	**Preliminary Information**
	higher in steeper areas with moderate inherent soil erodibility factors and lower at areas with lower slopes and low inherent soil erodibility factors. Areas where the vegetation and soil have been disturbed by military operations, such as the identified MC loading areas, can have moderate potential for erosion. Wind erosion is fairly significant at MCAGCC Twentynine Palms. It occurs when bare, loose, dry soil is exposed to wind of sufficient speed to cause soil movement (USDA NRCS, 1999). Soil disturbances caused by military activities can accelerate wind erosion. The USDA NRCS (1999) has measured the susceptibility of soils to wind erosion. The predominant soil types at MCAGCC Twentynine Palms generally are rated to be least susceptible; however, a few of the Arizo soil series have higher susceptibility to wind erosion.
Potential MC release mechanisms	Potential MC release mechanisms include mobilization in surface or groundwater. Due to the low precipitation and limited natural leaching of soluble materials in soil at MCAGCC Twentynine Palms, MC can accumulate in the soil at MC loading areas. The infrequent rainstorms can be torrential and often result in flash floods. This phenomenon can transport accumulated MC in soil through dissolution in runoff water or erosion of soil and sediments. Thus, runoff events can be a major transport mechanism of MC in surface water. MC transported to stream beds and dry washes during storm events can be migrated down to groundwater through the alluvial deposits. During storm events, the majority of the surface runoff accumulates in ephemeral playas. Playa soils are composed of fine clay that allows relatively little infiltration. As a result, most of the ponded water evaporates. Recharge processes from the playa lakes to more permeable quaternary deposits surrounding the playas are not well understood but could represent an MC migration pathway to shallow groundwater (DoN, 2003).

4.4. Surface Water Profile

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water drainage	Surface water drainage at MCAGCC Twentynine Palms is ephemeral or intermittent. There are no natural perennial surface water features within the installation. Streambeds are dry except after infrequent, heavy rainfall (USDA NRCS, 1999). However, there are several types of hydrologic features that are of particular interest at the installation. These include playas, dry washes, seeps, and springs. An unnamed active spring is located in the northwest portion of the installation, within the Sunshine Peak RTA (**Figure 4-3**). Seasonal seeps are located in the Imperial Lode mining area, the Lead Mountain area, and several mine shafts through the installation (DoN, 2003a; DoN, 2003b).

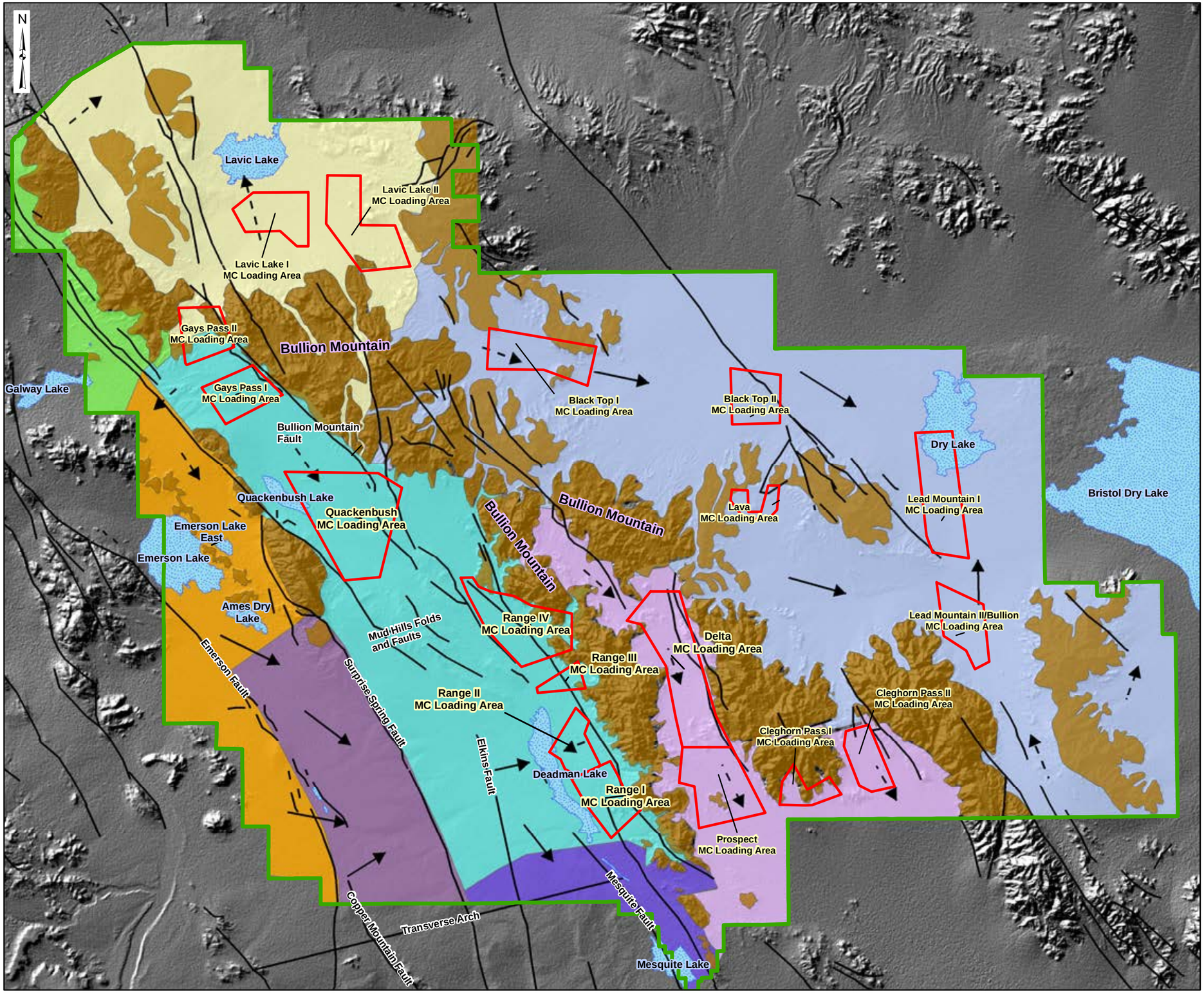

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FIGURE 4-2
MCAGCC TWENTYNINE PALMS
GROUNDWATER FEATURES

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

LEGEND

- INSTALLATION BOUNDARY
- MC LOADING AREA
- PLAYA LAKE (INTERMITTENT)
- EXPOSED BEDROCK
- GEOLOGIC FAULT

TWENTYNINE PALMS BASIN

- BESSEMER VALLEY SUBBASIN
- DEADMAN LAKE SUBBASIN
- GIANT ROCK SUBBASIN
- SURPRISE SPRING SUBBASIN
- TWENTYNINE PALMS VALLEY SUBBASIN

BRISTOL VALLEY BASIN

INTRAMOUNTAIN BASIN

- DALE VALLEY SUBBASIN
- LAVIC VALLEY SUBBASIN
- GROUNDWATER FLOW (KNOWN)
- GROUNDWATER FLOW (INFERRED)

NOTE: GROUNDWATER FLOW DIRECTIONS BASED ON SOURCE INFORMATION LISTED BELOW AND PROFESSIONAL JUDGMENT WHERE NO DATA EXISTS.

0 1 2 4 6
Miles

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053
Groundwater Flow Direction Based on: Schaefer, 197ℓ, Koehler, 1983; Londquist & Martin, 1991; Izbicki & Michel, 2004, Stamos, 2004; Londquist & Martin, 1989; and Lewis, 1972.

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CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water drainage (continued)	The ephemeral stream channels within and around the installation generally drain to dry washes and eventually discharge into playas. During heavy rainfall events, water runs off the bedrock surfaces of the hills and mountains into deeply incised drainage channels and flows rapidly toward the basin floor. As the water reaches the basin floor, it begins to merge with other flows in the ephemeral playas (USDA NRCS, 1999). Most of this water is lost from the playas and drainage channels to evaporation. However, some small amounts of water may infiltrate to recharge the groundwater along the ephemeral streambeds and dry washes. The low hydraulic conductivity of the playa sediments likely prevents significant groundwater recharge in the playa lakes. The playas may hold standing water once or twice a year after heavy storms, and the water remains in low-lying areas for a period of a few days to a few weeks (Malcolm Pirnie, 2007). Major floods are infrequent, occurring approximately once every 10 years. The last major flood occurred in between late 2008 and early 2009.
Hydrological unit & watershed areas	MCAGCC Twentynine Palms is located within the Bessemer, Emerson, Lavic, Deadman, Dale, and Bristol hydrologic units. According to data obtained from the MCAGCC Twentynine Palms NREA Division (MCAGCC Twentynine Palms, 2010), 16 watershed areas have been delineated within the MCAGCC Twentynine Palms installation boundary. These watershed areas mostly consist of ephemeral stream systems that drain to playas and range in size from 12,800 to 471,700 acres (**Figure 4-3**). Drainage is generally in the form of rapid runoff following occasional heavy rainfalls. All except one of the watershed areas extend beyond the MCAGCC Twentynine Palms installation boundary. The largest playas within the installation include Deadman, Dry, Emerson, Lavic, and Mesquite lakes (USDA NRCS, 1999). Primary MC loading areas are located in 6 of the existing 16 watersheds within MCAGCC Twentynine Palms' installation boundary. These include Dry Lake, Deadman Lake, Bristol Dry Lake, Lavic Lake, Dale Lake, and Quackenbush watershed areas (**Figure 4-3**).
Bristol Dry Lake Watershed	The Bristol Dry Lake Watershed is the largest drainage at MCAGCC Twentynine Palms. This 471,700-acre watershed contains an ephemeral stream network with a combination of dendritic and parallel drainage patterns that flow into Bristol Dry Lake playa. Bristol Dry Lake is located east of MCAGCC Twentynine Palms, just outside the installation boundary. There are salt mine operations in Bristol Dry Lake. Approximately 20% of the watershed area is located within the installation boundary. The ephemeral stream channels within the installation flow in easterly and northerly directions to the Bristol Dry Lake playa. All of the Lead Mountain II / Bullion, approximately 99% of the Delta, approximately 2% of the Lead Mountain I, and approximately 2% of the Prospect MC loading areas are located within this watershed.

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Dry Lake Watershed	The Dry Lake Watershed is located on the northeastern part of MCAGCC Twentynine Palms. This 251,100-acre watershed contains numerous ephemeral stream channels and the Dry Lake playa. Stream channels drain to dry washes and eventually discharge into Dry Lake, a playa located in the northeast portion of the installation, outside the installation boundary. Approximately 50% of this watershed area is located within the installation. The main stream channel of the ephemeral stream network within the installation drains in a northeast direction into Dry Lake. A few short channels that originate from a basaltic lava field east of Dry Lake drain westward to Dry Lake. A stream network originating outside the installation boundary drains southward into Dry Lake playa. All of the Black Top I and the Black Top II, approximately 98% of the Lead Mountain I, and approximately 2% of the Lava MC loading areas are located within this watershed.
Dale Lake Watershed	The Dale Watershed is located in the southeast corner of MCAGCC Twentynine Palms. Only a small portion of this watershed area (approximately 16%) is located within the installation boundary. This 212,000-acre watershed contains an ephemeral stream system with a parallel drainage pattern. These streams flow southward within the installation boundary and join a stream network that primarily discharges into Dale Lake, which is located 18 miles southeast of the installation boundary. There are salt mine operations in Dale Lake. All of the Cleghorn Pass I and the Cleghorn Pass II and approximately 98% of the Prospect MC loading areas are located within this watershed.
Deadman Lake Watershed	The Deadman Lake Watershed includes much of the western portion of MCAGCC Twentynine Palms. This 136,200-acre watershed contains an ephemeral stream network with a parallel drainage pattern that flows into Deadman Lake playa located on the southern side of the installation, approximately 4 miles northwest of Mainside. The majority of the watershed (approximately 92%) is located within the installation boundary. The branched stream network includes Rainbow Canyon on the northeast side of the watershed and Wood Canyon on the west that flows into Bullion Wash. Bullion Wash, in turn, flows in a southerly direction into Deadman Lake. The southwestern portion of this watershed contains Surprise Spring, which was an important and reliable surface water source, but which no longer flows due to groundwater pumping at the installation near the spring. All of the Range I, the Range II, the Range III, and the Range IV and approximately 90% of the Quackenbush MC loading areas are located within this watershed.
Lavic Lake Watershed	The Lavic Lake Watershed is located on the northwest corner of MCAGCC Twentynine Palms. This 88,400-acre watershed contains an ephemeral stream network that drains to the Lavic Lake playa, which is bordered by the Lava Bed Mountains on the north and west. Approximately 87% of the watershed area is located within the installation boundary. The ephemeral stream network has a parallel drainage pattern, and the streams flow radially into Lavic Lake. An unnamed active spring exists on the northwest part of the installation within the Lavic Lake Watershed. All of the Lavic Lake I, the

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
	Lavic Lake II, and the Gays Pass II and approximately 1% of the Gays Pass I MC loading areas are located within this watershed.
Quackenbush Watershed	The Quackenbush Watershed is located on the western side of MCAGCC Twentynine Palms. Quackenbush is the only watershed that is entirely located within the installation boundary. This 12,800-acre watershed contains an ephemeral stream network with a parallel drainage pattern and the Quackenbush Lake playa. Ephemeral streams within the watershed flow in a southerly direction to Quackenbush Lake. Approximately 99% of the Gays Pass I and 10% of the Quackenbush MC loading areas are located within this watershed.
Designated beneficial uses	The ephemeral streams and washes at MCAGCC Twentynine Palms have been designated by the CRWQCB Colorado River Basin Plan to have intermittent beneficial uses for groundwater recharge, noncontact water recreation and wildlife habitat (CRWQCB, 2005). Surface water at MCAGCC Twentynine Palms is not used for municipal and domestic supply. The Surprise Spring used to be an important surface water source, but flow in the spring has stopped due to groundwater pumping near the spring. Other springs and seeps at the installation are valuable biological resources.
Supported habitats/ ecosystems	Wildlife species at MCAGCC Twentynine Palms are typical of Mojave Desert fauna with the exception of a wide variety of non-desert-adapted species inhabiting Mainside, where man-made perennial surface water features exist. The animal species at the installation are widely dispersed, and many are nocturnal. Small mammals and reptiles, highly adapted to harsh desert conditions, are common. Birds usually occur in greatest near washes and springs where more structures and complex vegetative assemblages occur (MCAGCC Twentynine Palms, 2006). Seeps, springs, and man-made water bodies provide sources of water and a high concentration of vegetation and cover that contribute to increased wildlife diversity in these areas. Playas provide little wildlife habitat because they are largely devoid of vegetation. However, they do contain endemic microbiological communities of algae that support brine shrimp. In addition, migratory waterfowl and large mammals may visit these areas after periods of heavy rainfall (MCAGCC Twentynine Palms, 2006). Mojave Creosote bush shrub and desert saltbush scrub are the predominant vegetation types found at MCAGCC Twentynine Palms. Other major vegetation types also include Mojave wash scrub and blackbrush scrub (MCAGCC Twentynine Palms, 2006). One species at MCAGCC Twentynine Palms is federally listed as threatened (the desert tortoise), and several species have been identified as California special concern species. Additional information of threatened and endangered and species of special concern is provided in the Natural Resources Profile.
Gaining or losing streams	Surface water flows through ephemeral stream channels and dry washes resulting from seasonal direct precipitation recharge the alluvium-filled basins. As a result, streams at MCAGCC Twentynine Palms are losing.

CSM Information Profiles – Surface Water Profile	
Information Needs	**Preliminary Information**
Surface water collection points	There are no active potable water storage reservoirs at MCAGCC Twentynine Palms. There are 14 playa lakes that receive water from the ephemeral streams and washes. Water collects in these playa lakes after heavy rainstorm events and can remain in the lakes for as long as 2 months a year. There are also man-made water bodies, including storm water retention ponds, golf course ponds, and several sewage lagoons within the installation.

4.5. Groundwater Profile

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater basin(s)	The primary groundwater basins at MCAGCC Twentynine Palms include the Twentynine Palms basin, the Bristol Valley basin, and several smaller intramountain subbasins. **Twentynine Palms Basin:** The Twentynine Palms basin is located on the western part of MCAGCC Twentynine Palms and southwest of the Bullion Mountains. This basin is composed of five subbasins covering parts of MCAGCC Twentynine Palms: Bessemer Valley, Deadman Lake, Giant Rock, Surprise Spring, and Twentynine Palms Valley (**Figure 4-2**). These subbasins have independent groundwater flow systems, typically terminating just beneath playas scattered throughout the area (Izbicki and Michel, 2004). The subbasins are divided hydrogeologically by bedrock outcrops, faults, and folds (Riley et al., 2001; Londquist and Martin, 1991; MCAGCC Twentynine Palms, 2006). The water-bearing units within these subbasins comprise the Quaternary-Tertiary alluvial fan deposits and the Tertiary older sedimentary deposits. On the basis of lithologic and downhole geophysical logs, Li and Martin (2008) have divided the Quaternary-Tertiary alluvial fan deposits into two aquifers referred to as the “upper” and the “middle” aquifers. The older Tertiary sedimentary deposits have been designated as a single aquifer referred to as the “lower” aquifer (Li and Martin, 2008). The pre-Tertiary basement complex that consists of bedrock units forms the base of the aquifer system. This unit is essentially non-water-bearing and forms an effective groundwater barrier. Additionally, the Twentynine Palms groundwater basin contains thick clay deposits and perched groundwater tables beneath playas (Panacea, 2001a; Panacea, 2001b; ENSR, 1990). These perched aquifers are assumed to be limited in extent based on the available groundwater data and relatively small areal extent of the playas. It is unknown if these perched aquifers recharge the deeper aquifer system.

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FIGURE 4-3
MCAGCC TWENTYNINE PALMS WATERSHEDS ANDSURFACE WATER FEATURES

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA

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Lavic Lake
Lavic Lake I MC Loading Area
Lavic Lake II MC Loading Area
Gays Pass II MC Loading Area
Lower Sunshine Lake
Gays Pass I MC Loading Area
Galway Lake
Black Top I MC Loading Area
Black Top II MC Loading Area
Quackenbush MC Loading Area
Quackenbush Lake
Emerson Lake East
Emerson Lake
Range IV MC Loading Area
Ames Dry Lake
Range III MC Loading Area
Delta MC Loading Area
Range II MC Loading Area
Deadman Lake
Miller Dry Lake
South Miller Dry Lake
Range I MC Loading Area
Upper Mesquite Lake
Mesquite Lake
Lava MC Loading Area
Dry Lake
Bristol Dry Lake
Lead Mountain I MC Loading Area
Lead Mountain II / Bullion MC Loading Area
Cleghorn Pass I MC Loading Area
Cleghorn Pass II MC Loading Area
Prospect MC Loading Area

LEGEND

- INSTALLATION BOUNDARY
- MC LOADING AREA
- PLAYA LAKE (INTERMITTENT)
- STREAM/WASH (INTERMITTENT)
- SPRING

WATERSHED

- BRISTOL LAKE
- DRY LAKE
- EAST AND WEST SUNSHINE
- EMERSON LAKE
- GALWAY LAKE
- GOAT MOUNTAIN
- LAVIC LAKE
- MESQUITE LAKE
- QUACKENBUSH
- UPPER EMERSON
- DEADMAN LAKE
- DALE LAKE

0 1 2 4 6
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053

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Infrastructure Water Environment Buildings

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CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Groundwater basin(s) (continued)	However, the playa deposits, which mostly consist of clay, can have a thickness of approximately 50 ft (as estimated at the Deadman and Mesquite playa lakes by Li and Martin (2008)), indicating that recharge through the perched aquifer likely would be minimal. Groundwater from these perched aquifers is not suitable for potable use as it contains very high levels of total dissolved solids (TDS) that are orders of magnitude higher than the drinking water criteria. Groundwater for potable use within the installation is derived from the upper and middle aquifers (described below). Five of the production wells are screened in the upper and middle aquifers, and six of the wells are screened just in the middle aquifer. The estimated hydraulic conductivity near the five production wells screened in the upper and middle aquifers on the east end of the Surprise Spring subbasin ranges from 11 to 41 feet per day (ft/d)(Londquist and Martin, 1991). Hydraulic conductivities for the upper and middle aquifers were estimated higher near the three production wells located closest to the Surprise Spring fault (hydraulic conductivity values ranging from 39 to 41 ft/d versus 11 to 22 ft/d). *Upper Aquifer* The saturated part of the upper Quaternary-Tertiary alluvial fan deposits make up the upper unconfined aquifer. This aquifer mostly consists of sand and gravel, which is highly permeable and, where present, yields a large quantity of water to wells where it is saturated. Extent of this aquifer is limited to parts of the Surprise Spring and Twentynine Palms Valley subbasins. Outside these subbasins, the upper Quaternary-Tertiary alluvial fan depots are unsaturated, and an upper aquifer in these areas is absent. The saturated thickness is generally less than 50 ft; however, in 2002, Li and Martin (2008) determined that the aquifer had a maximum saturated thickness of 250 ft near the Surprise Spring. *Middle Aquifer* The middle aquifer includes the lower portion of the Quaternary-Tertiary alluvial fan deposits. It mostly consists of sand, silt, and clay and is less permeable than the upper aquifer. This aquifer is confined in areas where the upper aquifer is saturated and is unconfined where the upper aquifer is unsaturated. The thickness of this aquifer ranges from about 100 ft at the north part of the Surprise Spring subbasin to almost 500 ft east of the Mesquite Fault in the Deadman subbasin. As mentioned above, six of the installation production wells within the Surprise Spring subbasin are screened in the middle aquifer. All of these wells draw water from the unconfined portion of the aquifer. The estimated hydraulic conductivity in this aquifer near the six production wells ranges from 12 to 20 ft/d (Londquist and Martin, 1991). Specific yields for the upper and middle

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	aquifers in the Surprise Spring subbasin were estimated to range from 16% to 25% (Londquist and Martin, 1991). *Lower Aquifer* The lower aquifer consists of the Tertiary older sedimentary deposits. It contains poorly sorted sands, gravel, silt, and clay that become more consolidated with depth (Londquist and Martin, 1991). The overall permeability of this aquifer is very low. This aquifer is confined throughout the Twentynine Palms basin. The aquifer thickness varies greatly within the western area of MCAGCC Twentynine Palms, ranging from less than 100 ft near the Transverse Arch southwest of the installation boundary to more than 15,000 ft beneath the Deadman and Mesquite dry lakes (Li and Martin, 2008). Londquist and Martin (1991) estimated a horizontal hydraulic conductivity value of 1 ft/day and a specific yield of 5% for this lower aquifer in the Surprise Spring subbasin. **Bristol Valley Basin:** The Bristol Valley basin is located on the eastern part of MCAGCC Twentynine Palms and on the northeastern side of the Bullion Mountains (**Figure 4-2**). Similar to the Twentynine Palms basin, northwest-trending faults within the basin create independent groundwater subbasins. From the limited information available (Koehler, 1983), the water-bearing units in this basin are similar to the aquifer units described for the Twentynine Palms basin above. However, the areal extent and boundaries of the various aquifers within this basin have not been defined. Perched aquifers within the basin exist near Bristol Dry Lake and Dry Lake. As with those in the Twentynine Palms basin, the perched aquifers are assumed to be limited in extent. **Intramountain Basins:** Smaller intramountain basins are located on the central and northwestern parts of MCAGCC Twentynine Palms, within the Bullion and Lava Bed mountains (**Figure 4-2**). These basins are separated from the larger basins by bedrock outcrops and/or faults and include portions of the Dale Valley and Lavic Valley subbasins. Limited subsurface data are available for these basins, but subsurface conditions are expected to be similar to the Twentynine Palms basin described above, with two exceptions: 1) the water-bearing sedimentary deposits are expected to be thinner with proximity to the exposed bedrock outcrops and 2) the average grain size that composes the subbasins is expected to be coarser due to the proximal position of the basin with respect to the bedrock source, potentially affecting the average hydraulic conductivity (Malcolm Pirnie, 2007).
Designated beneficial uses	The CRWQCB Colorado River Basin Plan has designated the area covering MCAGCC Twentynine Palms as part of the Lucerne Valley planning area. Within this area, groundwater is designated to have existing beneficial uses for municipal and domestic supply, industrial service supply, and agriculture supply (CRWQCB, 2005).

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	Groundwater at MCAGCC Twentynine Palms, within the Twentynine Palms groundwater basin, is a primary source for private, agricultural, and municipal supply (Smith, 2003). Groundwater in the other basins, including the Bristol Valley and the intramountain basins, is not known to have any beneficial uses. Potable water at MCAGCC Twentynine Palms is provided by supply wells that pump groundwater from the Surprise Spring subbasin, which is a subbasin of the Twentynine Palms groundwater basin. There are no known nearby off-installation wells down gradient of identified primary MC loading areas.
Groundwater supply wells	Drinking water at MCAGCC Twentynine Palms is provided by 11 groundwater production wells that extract groundwater from the Surprise Springs subbasin, which is currently the sole source of potable water within MCAGCC Twentynine Palms (Battelle, 2007). The Surprise Spring subbasin is bounded by the Emerson and the Copper Mountain faults on the west, the Surprise Spring fault on the east, and an unnamed fault south of the Ames Dry Lake on the north. The southern boundary of the subbasin lies north of the Transverse Arch, an anticline that traverses the entire subbasin from northeast to southwest (MAGTFTC MCAGCC, 2003). The total production capacity of the wells is approximately 15.8 million gallons per day (MGD), but the maximum actual production from the wells is approximately 4.3 MGD (MCAGCC Twentynine Palms, 2011a). Water from these wells primarily is used for drinking but also includes other uses, such as fire fighting, irrigation, and equipment maintenance (Battelle, 2007). The wells are screened in the unconfined portion of the upper and middle aquifers. Locations of the wells are shown in **Figure 4-2**. The well field is located in an isolated and protected area of the installation known as the Restricted Area. The area is divided into an upper well field consisting of six wells and a lower well field consisting of five wells. There are no known potential sources of industrial or domestic contamination within 3 miles of any of the wells, and no groundwater contamination has been detected between the wells and the aquifer recharge area (Battelle, 2007). Water supply wells also have been drilled in the Deadman Lake subbasin near Deadman Lake playa within the Sand Hill RTA and in the Giant Rock subbasin near Emerson Lake within the Emerson Lake RTA (NREA, n.d.) (**Figure 4-2**). Two of these wells are inactive (the well near Emerson Lake and the one well near Deadman Lake). The well located on the southwest edge of Deadman Lake is an active production well for nonpotable water and reportedly is used by Marines in the field to wash vehicles and field equipment (Law Engineering, 1996). The screened interval of this well is shallow (depth to water is 25 ft), and it probably has high salinity due to its proximity to Deadman Lake. The installation is currently evaluating utilizing groundwater from the Deadman Lake subbasin as a supplemental potable supply source due to concerns with overdraft of the Surprise Spring groundwater subbasin (pers

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	comm, MCAGCC Twentynine Palms NREA staff, 2010). If pursued, the water withdrawn from this subbasin would be blended with water currently withdrawn from the Surprise Springs subbasin to augment potable water supplies.
Recharge source(s)	Groundwater recharge sources at MCAGCC Twentynine Palms include subsurface inflow from nearby subbasins, direct infiltration from precipitation, and infiltration from infrequent stream flow along streambeds and dry washes through the alluvium-filled basins. In many of the groundwater subbasins at MCAGCC Twentynine Palms, lateral subsurface inflow from adjacent subbasins is the principal source of groundwater. The Twentynine Palms groundwater basin is recharged by lateral groundwater inflow across the western and southwestern boundaries, and the Bristol Valley groundwater basin is recharged by groundwater inflow from the northwest (Li and Martin, 2008; Koehler, 1983). Recharge from direct infiltration of stream flow is comparatively low and occurs only during large storm events. With an average annual precipitation of about 4 to 6 inches, generally not enough to meet evapotranspiration and soil-moisture requirements (Li and Martin, 2008), recharge from direct precipitation is negligible. The approximate recharge rate is estimated at 0.1 to 0.14 inches/year (2% to 3% of the annual precipitation rate) based on the annual groundwater inflow rate into the Surprise Spring subbasin evaluated by Londquist and Martin (1991). The Surprise Spring groundwater subbasin, currently the only drinking water source at MCAGCC Twentynine Palms, is recharged by lateral groundwater inflow from the Giant Rock subbasin across the Emerson Fault, which is the western boundary of the subbasin. The source of the groundwater inflow to the Giant Rock subbasin is runoff from the San Bernardino Mountains that infiltrates the permeable deposits along intermittent streams (Li and Martin, 2008). It is unknown if perched groundwater beneath playas recharges the deeper aquifer system. However, the playa deposits, which mostly consist of clay at Deadman and Mesquite Lakes, are approximately 50 ft thick (Li and Martin, 2008), indicating that recharge through the perched groundwater beneath playas likely would be minimal. The recharge processes from the playas to more permeable quaternary deposits surrounding the playas are not well defined.
Porous or fracture flow	Groundwater flow through the water-bearing units at MCAGCC Twentynine Palms is generally porous-media flow. The water-bearing units contain alluvial deposits that are largely composed of loosely to well consolidated sand, gravel, silt, and clay. The Tertiary age volcanic rocks that outcrop in the Bullion Mountains are locally fractured and may contain small quantities of water but are generally considered to be non-water-bearing (Koehler, 1983).

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
Depth to groundwater	Depth to groundwater within the Twentynine Palms groundwater basin at the installation ranges from 5 to 400 ft below ground surface (bgs). However, the depth to groundwater within this groundwater basin near the installation water supply source (within the restricted area) and near Mainside is generally 185 to 260 ft bgs (Malcolm Pirnie, 2007). The depth to groundwater at perched zones that exist beneath playas ranges from 5 to 75 ft bgs (Malcolm Pirnie, 2007). Depth to groundwater within the Bristol Valley groundwater basin ranges from 125 to 300 ft bgs. Within this groundwater basin, groundwater at perched zones that exist near Bristol Dry Lake and Dry Lake occurs at depths of 14 to 90 ft bgs. The average groundwater elevation at the intramountain groundwater basins is likely shallower than the groundwater elevation at the Twentynine Palms and the Bristol Valley groundwater basins (Malcolm Pirnie, 2007). The presence of intermittent seeps in the area is one indication of shallower groundwater elevation. The limited data available from the Lava RTA indicate a depth to groundwater of 127 ft bgs (Almgren and Koptionak, 1993).
Gradient and flow velocity	The lateral movement of groundwater within the Twentynine Palms basin on the western part of MCAGCC Twentynine Palms is in a stair-step manner through successive groundwater subbasins (Li and Martin, 2008). The highest groundwater elevations are near areas of recharge on the western and southern parts of the groundwater basin, and the lowest elevations are near discharge areas on the eastern edge. Groundwater generally flows south to southeastward; however, local groundwater gradients may vary and are affected by faulting, folding, and pumping within the subbasins. General groundwater flow directions within the Twentynine Palms basin can be inferred from previous investigations and groundwater modeling investigations and are denoted by flow direction arrows in **Figure 4-2** (Izbicki and Michel, 2004; Riley et al., 2001; Londquist and Martin, 1989; Londquist and Martin, 1991; Schaefer, 1978; Stamos et al., 2004; Lewis, 1972). Water-level data show sharp discontinuities in water-level altitudes on opposite sides of the Surprise Spring fault (large drop in water-level altitude across the fault from the Surprise Spring subbasin to the Deadman Lake subbasin), indicating that the fault is a barrier to groundwater flow (Li and Martin, 2008). The Surprise Spring subbasin is separated from the adjacent Deadman Lake subbasin, and the pumping wells within the Surprise Spring subbasin have no significant influence in the Deadman Lake subbasin. Groundwater hydraulic gradients within the Surprise Spring and the Giant Rock subbasins have been estimated to range from 0.0003 to 0.03 and have a geometric mean value of 0.006 (Li and Martin, 2008). Using this estimated groundwater gradient for the subbasins within the Twentynine Palms groundwater basin, the hydraulic conductivity values presented by Li and Martin (2008), and the average effective porosity for mixed sand,

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	gravel, silt and clay, the average velocities in Surprise Spring, Deadman and Twentynine Palms Valley subbasins are estimated to be 0.027 ft/d, 0.013 ft/d, and 0.0026 ft/d, respectively. Groundwater within the Bristol Valley basin on the eastern part of MCAGCC Twentynine Palms flows away from the Bullion and Bristol Mountains and then southeast down the axis of the basin toward Bristol Dry Lake (Koehler, 1983) (**Figure 4-2**). The groundwater hydraulic gradients are estimated to range from 0.0009 to 0.008 and have a geometric mean value of 0.003 (Koehler, 1983). The groundwater velocity could not be estimated because there are no reported hydraulic conductivity values for this groundwater basin. Groundwater within the intramountain basins on the northwestern and central parts of MCAGCC Twentynine Palms is expected to flow according to surface topography, away from the bedrock uplands and toward the larger flanking basins and playas (Malcolm Pirnie, 2007) (**Figure 4-2**). There are no data available for estimating the groundwater velocity within this basin.
Known water quality characteristics	Groundwater quality data collected from wells installed within the aquifers of the Surprise Spring subbasin show that the groundwater is of a sodium bicarbonate type and generally meets water quality criteria established under the Safe Drinking Water Act (Law Engineering, 1996). Based on groundwater quality data collected by the installation from source water sample analysis for the period ranging from January 2008 through June 2011, concentrations of TDS, fluoride, arsenic, chromium, lead, and manganese are consistently below the federal Maximum Contaminant Levels (MCLs) in all of the installation production wells (MCAGCC Twentynine Palms, 2011b). Iron concentration has been measured to be above the secondary MCL of 0.3 milligrams per liter (mg/L) in two of the installation production wells (well 6A and 12A); however, the most recent samples in these wells (for sampling periods of April 2010–February 2011 and November 2010–May 2011) have been below detectable levels. Iron concentrations in all other installation production wells are below the secondary MCL. The pH in the production wells ranges from 8.1 to 9.4, and the average pH in the production wells is 8.56 (MCAGCC Twentynine Palms, 2011b). Perchlorate previously has been detected in six of the installation production wells at concentrations below the Range and Munitions Use Subcommittee (RMUS) screening value for drinking water (at a maximum concentration of 0.44 micrograms per liter [µg/L]) (Malcolm Pirnie, 2007). As indicated in the baseline REVA report for MCAGCC Twentynine Palms, the source for the perchlorate cannot be clearly identified but is a background source. Perchlorate is no longer monitored by the installation because the installation was approved for no further action regarding monitoring for perchlorate by the Environmental Protection Agency (EPA) as it received the second lowest rating (MCAGCC Twentynine Palms, 2011a). The National Water Information System (NWIS) data for the Deadman Lake subbasin, which is a potential water supply source for the installation,

CSM Information Profiles – Groundwater Profile	
Information Needs	**Preliminary Information**
	indicates that TDS and fluoride concentrations are generally above the federal MCLs and chromium concentrations are below the federal MCLs. About one-half the data in NWIS for this subbasin indicate arsenic concentrations above the federal MCL (Li and Martin, 2008). Under the installation contract, the USGS has conducted soil and groundwater sampling in the Camp Wilson area within the Deadman Lake subbasin (**Figure 4-4**) in order to determine potential MC contamination within the Deadman Lake subbasin. Their sampling results show that all explosives constituents are below detectable levels in soil and groundwater at all locations sampled (USGS, 2011). Perchlorate was detected in many of the groundwater samples but mostly at levels below the laboratory reporting limit. The maximum perchlorate concentration detected in groundwater was two orders of magnitude below the perchlorate RMUS screening value for drinking water. Perchlorate also was detected in all soil samples analyzed, but the perchlorate detects were estimated to be below the laboratory reporting limit in one-half of the soil samples analyzed (USGS, 2011). Groundwater from the Bristol Valley basin is considered nonpotable because of high mineral content (MCAGCC Twentynine Palms, 1996). Also, based on a study conducted by Koehler (1983), the groundwater quality for this basin does not appear to be suitable for human consumption without treatment. Analytical results for groundwater quality samples collected from exploratory wells indicated TDS ranges of 1,420 to 252,000 mg/L; chloride ranges of 140 to 11,000 mg/L; and arsenic ranges of 11 to 98 µg/L (Koehler, 1983). Groundwater from the Twentynine Palms Valley subbasin near Mainside is primarily of a sodium sulfate type. Fluoride and sulfate concentrations exceed drinking water standards (Panacea, 2001b).
Discharge location(s)	The dominant natural groundwater discharge at MCAGCC Twentynine Palms includes groundwater outflow across subbasin boundaries. Other minor natural groundwater discharges include flow to springs, evaporation of moisture from wet soil on the surrounding dry lake playas, and transpiration of phreatophytes in the subbasins. Man-made groundwater discharge includes groundwater flow to production wells mostly located within the Surprise Spring subbasin and one nonpotable production well located within the Deadman Lake subbasin.

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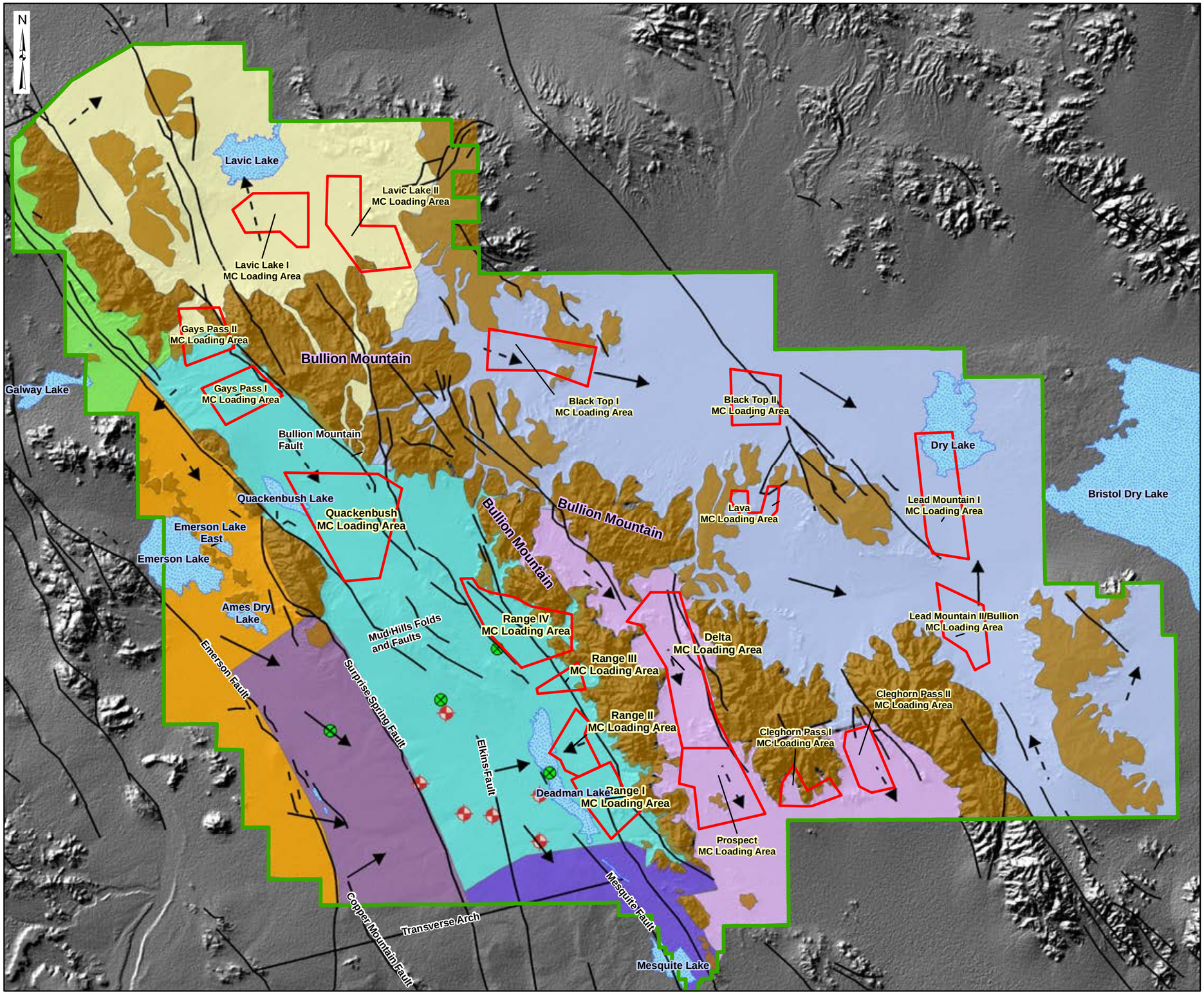
REVA
FIGURE 4-4
USGS SOIL AND GROUNDWATER SAMPLE LOCATIONS IN DEADMAN LAKE SUBBASIN

MCAGCC TWENTYNINE PALMS
TWENTYNINE PALMS, CA



LEGEND

- INSTALLATION BOUNDARY
- MC LOADING AREA
- PLAYA LAKE (INTERMITTENT)
- EXPOSED BEDROCK
- GEOLOGIC FAULT

TWENTYNINE PALMS BASIN

- BESSEMER VALLEY SUBBASIN
- DEADMAN LAKE SUBBASIN
- GIANT ROCK SUBBASIN
- SURPRISE SPRING SUBBASIN
- TWENTYNINE PALMS VALLEY SUBBASIN

BRISTOL VALLEY BASIN

INTRAMOUNTAIN BASIN

- DALE VALLEY SUBBASIN
- LAVIC VALLEY SUBBASIN
- USGS GROUNDWATER SAMPLING LOCATION
- USGS SOIL SAMPLING LOCATION
- GROUNDWATER FLOW (KNOWN)
- GROUNDWATER FLOW (INFERRED)

0 1 2 4 6
Miles

Coordinate System: UTM
Zone: 11N
Datum: WGS 1984
Units: Meters

Date: June 2012

Source: MCAGCC/NREA GIS Office 2010
GEOFIDELIS 2010
USGS Report 83-4053
Groundwater Flow Direction Based on: Schaefer, 1978; Koehler, 1983; Londquist & Martin, 1991; Izbicki & Michel, 2004, Stamos, 2004; Londquist & Martin, 1989; and Lewis, 1972.

ARCADIS MALCOLM PIRNIE

NOTE: GROUNDWATER FLOW DIRECTIONS BASED ON SOURCE INFORMATION LISTED BELOW AND

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4.6. Human Land Use and Exposure Profile

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
Land use	*Non-Live-Fire Range Training Areas* Mainside is the developed portion of the base that houses administrative, maintenance, housing areas, and community support facilities. Training activities in the other five non-live-fire RTAs consist of the use of blank ammunition, smoke grenades, and illumination rounds. 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 7,900-acre Restricted Area, which contains the installation's drinking water production wells as well as protected habitat for the threatened desert tortoise. Two additional restricted areas have been established in portions of two other RTAs (Lavic Lake and Lava). Many of these areas are limited in use due to their proximity to Mainside or surrounding communities. *Live-Fire Range Training Areas* The remaining 17 RTAs are designated for live-fire training activities. Live-fire training can be conducted anywhere within the RTA boundary with the exception of the zone 1,000 m from the installation boundary. Most firing is directed at designated target locations spread throughout the RTAs 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 the same RTAs identified in the baseline assessment as receiving the greatest amount of live-fire training continue to be the most utilized RTAs on the installation. These include Blacktop, Delta, Gays Pass, Lavic Lake, Lead Mountain, Prospect, Quackenbush, and Range RTAs.
Current human receptors	*Surface Water* Surface waters on the installation are not used as a potable water supply. MC transported to off-installation playas and evaporation ponds in the salt mining operations area are highly unlikely to cause food chain exposure. Based on the infrequency of potential exposure to surface water and the modeled low concentration of MC in surface water during the baseline assessment, significant exposures of MC in surface water to human receptors are not anticipated. *Drinking Water* With the exception of the water supply wells located within the Restricted Area, there are no exposure points to groundwater receptors at MCAGCC Twentynine Palms. The Restricted Area water supply wells are screened in the unconfined portions of the upper and middle aquifers within the Surprise Spring subbasin, which is unconnected to the subbasins containing primary MC loading areas. Furthermore, groundwater flow direction in the Surprise Spring subbasin is up gradient of the adjacent Deadman Lake subbasin containing primary MC loading areas. Therefore, there likely is no current complete pathway to potential groundwater receptors. However, in the

CSM Information Profiles – Human Land Use and Exposure Profile	
Information Needs	**Preliminary Information**
	future, groundwater from the Deadman Lake subbasin may be mixed with groundwater from Surprise Spring subbasin to fulfill increasing demand. *Sediment* Sediment containing MC may be transported to playas and evaporation ponds in the same manner as described for surface water. However, limited human contact with the deposited sediment is possible during the salt mining process at the salt mining operations.
Land use restrictions	No live-fire training is allowed in the restricted areas of the installation. The RTAs (or portions thereof) also may be subject to limitations or restrictions on the use for maneuvers, live fire, or other training activities.

4.7. Natural Resources Profile

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
Ecosystems	Krzysik and Trumbull (1996) described 10 ecosystems at MCAGCC Twentynine Palms, with species-ecosystem associations and management options for each ecosystem. Below is a brief summary of the ecosystems described. ***Creosote / Bursage Scrub Series*** - Creosote bush and white bursage are dominant species in the Creosote / Bursage Series. About 90% of MCAGCC Twentynine Palms is in this ecosystem. ***Yucca Woodlands: Joshua Trees and/or Mojave Yucca*** - This Joshua tree–dominated ecosystem is confined to the southwestern and northwestern corners of the Combat Center, covering only 0.4% of total land. This biodiversity-rich ecosystem supports 184 vertebrate species. ***Saltbush Scrub: Playa and Uplands*** - About 6% of the Combat Center (alkaline margins of dry lake beds) includes the saltbush ecosystem. This habitat supports 50 vertebrate species. ***Blackbrush Scrub*** - Blackbrush ecosystems are widespread on upper bajadas and rocky alluvial mountain slopes in the Mojave Desert, but they only comprise 0.7% of the Combat Center, primarily in the northwestern corner of the installation. A total of 154 vertebrate species may be found in this ecosystem. ***Desert Riparian (Xeroriparian)*** - These tree-dominated, desert wash ecosystems with ephemeral surface waters include less that 0.5% of the Combat Center. This biodiversity-rich ecosystem has up to 178 vertebrate species. ***Desert Wash with Ephemeral Flows*** - This smaller wash ecosystem can be considered a smaller scale xeroriparian ecosystem, similar to the desert riparian ecosystem, but dominated by shrubs instead of trees. This system is found on 2% to 4% of the Combat Center and supports 146

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
	species of vertebrates. ***Springs and Seeps*** - This ecosystem is poorly represented at the Combat Center. There are no permanent springs known. Only one intermittent spring has been identified (Sunshine Peak), and only one ephemeral spring (north of Lead Mountain) has been identified. Three "tinajas" or "highly ephemeral water pockets" have been identified. A total of 221 vertebrate species possibly inhabit this ecosystem. ***Dry Lake Beds (Playas)*** - Fourteen playas, 1.9% of the Combat Center, comprise this ecosystem. Surface water in playas is ephemeral and highly episodic. Fifty species of birds may use playas, and five species of fairy, clam, and tadpole shrimp have been found in some of the playas when water is present. ***Wet Areas / Ponds / Riparian: Perennial*** - This man-made habitat type covers less than 0.1% of the base within and near Mainside. The area is used heavily by migratory birds, and it is critical to a number of resident and breeding birds as well as other animals. This ecosystem is used by 88% of the potential avian fauna of the southern Mojave Desert. ***Caves, Mines, and Rock Crevices*** - These subterranean habitats are critical for bats and are used by other wildlife species for water, shelter, and protection from the heat. Yucca Woodlands, Desert Riparian, and Wet Areas / Ponds / Riparian: Perennial ecosystems, by far the richest in terms of wildlife biodiversity, include less than 1% of training land (MCAGCC Twentynine Palms, 2006).
Vegetation	MCAGCC Twentynine Palms supports a variety of plant and animal life, most of which are adapted to the desert environment. As of 1998, there were 387 native and naturalized vascular plant species recorded at the installation, including 66 plant families, 219 genera, and 381 species (Elvin, 2000). The predominant vegetation at the installation is desert annuals and creosote bush. Density and diversity of the vegetation tend to increase at higher elevations in the mountainous areas. The four major vegetation types present at the installation are creosote bush, mojave creosote bush scrub, desert saltbush scrub, mojave wash scrub, and blackbrush scrub (MCAGCC Twentynine Palms, 2006).
Fauna	A variety of reptile, bird, and mammal wildlife species are found at MCAGCC Twentynine Palms, including bats, bighorn sheep, coyote, bobcat, and desert tortoise. The wildlife species present at the installation are typical of Mojave Desert fauna with the exception of a wide variety of non-desert-adapted species inhabiting Mainside, particularly in man-made water areas. The availability of water is a key factor limiting the distribution of some species. Springs, seeps, and riparian areas support higher species diversity and constitute critical habitat for several resident and migratory birds as well as bat species. Rocky terrain provides habitat for many reptiles, rodent, and bird species.
Special status species	Sixteen resident and 19 nonresident species present at the installation are considered to have special status according the federal or state regulations. Birds represent the largest number of sensitive species at MCAGCC Twentynine Palms. Twenty-eight sensitive species have been

CSM Information Profiles – Natural Resources Profile	
Information Needs	**Preliminary Information**
	observed, primarily near Mainside due to the wet areas created by the golf course, sewage treatment systems, and the evaporation ponds. Sensitive birds also have been observed throughout the other RTAs. Deadman Lake, a playa located between Range RTA and the installation water supply system within Restricted Area, fills with surface water following precipitation events. Avian, reptilian, and mammalian populations are found near this playa, including several California special concern species. In addition, the playa provides habitat for the Mojave fringe-toed lizard (MFTL), a California special concern species. Other playas found within the installation also may serve the same habitat roles. The desert tortoise is a federally threatened species found throughout the Mojave Desert. The desert tortoise, an herbivore, spends much of the year underground in burrows to avoid the extreme desert temperatures. There may be several of the burrows within an individual tortoise's home range (MCAGCC Twentynine Palms, 2006). The tortoise is most active aboveground during the spring, summer, and fall when daytime temperature are below 90°F. MCAGCC Twentynine Palms is within the southern Mojave subdivision of the Western Recovery Unit for the desert tortoise. Critical habitat is not found on the installation; however, critical habitat is located near the installation. Desert tortoise populations on the installation are monitored and managed.

4.8. Potential Pathways and Receptors

MC accumulated in the MC loading areas can migrate to potential receptors via the following exposure pathways:

- Surface water runoff, including sediment transport
- Leaching to groundwater and subsequent groundwater flow

Exposure pathways considered in the REVA process include consumption of surface water and groundwater by off-range human receptors, as described in the *REVA Reference Manual* (HQMC, 2009). For groundwater, water supply wells located within the installation boundaries are considered an exposure source because the water is distributed to consumers within the installation cantonment area. Human receptor exposures to sediment through dermal contact are also considered. Exposure pathways for off-range ecological receptors (defined in the REVA analysis as any threatened or endangered species or species of concern) also are considered, including direct consumption of surface water and direct exposure to surface water. Ecological receptor exposure to sediment, including dermal contact and direction ingestion, is also considered. Other off-range exposure scenarios (e.g., soil ingestion, incidental dermal

contact, bioaccumulation and food chain exposure) are not considered in the REVA process. The potential points of exposure for receptors of MC at the MCAGCC Twentynine Palms installation include the following:

- Human receptors utilizing water from the 11 active water supply wells located in the Restricted Area
- Special status ecological receptors, such as the desert tortoise and the MFTL, that live near playas and may be exposed to MC in accumulated water and sediment
- Human receptors (through dermal contact) at salt mining activities east and southeast of the installation, which pump groundwater down gradient of MC loading areas and may be exposed to MC accumulated in sediment of playa lake beds

4.8.1. Surface Water and Sediment Pathway

Due to the low precipitation and limited natural leaching of soluble materials in soil at MCAGCC Twentynine Palms, MC potentially can accumulate in the soil at MC loading areas. The infrequent rainstorms can be torrential and often result in flash floods. Such flash flood events can mobilize and transport accumulated MC in soil through dissolution or erosion of soil and sediments. MC transport with sediment is dependent on the site erosion potential. The soil and site characteristics at MCAGCC Twentynine Palms generally indicate low potential for soil erosion throughout the installation. However, the soil erosion potential at a few of the identified MC loading areas is moderate due to the sparse vegetative cover, relatively steep slope, and soil/sediment disturbance from range activities and maintenance, indicating that this transport process can be an important mechanism for MC transport to surface water bodies.

The majority of the surface runoff drains to the interior of the installation and accumulates in playas. The fate of surface water in the playas is typically evaporation, although a small amount of infiltration may occur. The playas can be filled with water for up to 2 months per year. In an ecosystem where water is a limiting factor, playas and washes filled with storm water runoff can provide habitat for wildlife. For this reason, water accumulated in the playas may present a potential exposure pathway for ecological species, including the federally and state threatened desert tortoise and other California special concern species, including the MFTL. Ecological receptor are anticipated to have limited exposure to MC in surface water because the desert tortoise and MFTL are unlikely to consume water with high salinity levels (Malcolm Pirnie, 2007), which is the case in the playa lakes during a larger part of the year when there are no storm events. However, these receptors could consume water from the playa lakes immediately following rainstorm events when there is more water in the playa lakes and likely lower salinity levels. Furthermore, sediment accumulated in the playas may present a potential exposure pathway to ecological species through dermal contact.

A potential exposure pathway for human health has been identified in the salt mining activities in Bristol Dry Lake and Dale Lake, located down gradient of the Lead Mountain II / Bullion, Lava, Cleghorn Pass I, Cleghorn Pass II and Prospect MC loading areas (Malcolm Pirnie, 2007). However, interviews conducted with the owners of some of these operations during the baseline REVA assessment indicated that small areas of standing water form once or twice a year, but the water is not used in the salt mining operations and usually recedes within a few days or weeks. Therefore, surface water near the salt mining operations is not considered a potential exposure pathway for human receptors. MC from the installation are expected to be a negligible component of the mined salt, but there could be a potential human exposure pathway through dermal contact during the salt mining process from MC remaining in the sediments of the playa lake beds.

4.8.2. Groundwater Pathway

MC can migrate to groundwater by several different pathways at the installation. MC can be recharged with water percolating through the alluvial deposits along the stream beds and dry washes. MC in surface runoff washing from the flanks of the mountains can also infiltrate the Quaternary alluvial deposits along the alluvium-bedrock interface, although this MC migration pathway is likely to be very limited because most training activities at the installation are not focused on the upper and middle slopes of the mountain ranges. Water containing MC entering the vadose zone could migrate vertically into the phreatic zone, but the transport time is likely very slow, possibly lasting decades or more, due to the very low infiltration rate (a result of infrequent stream flow and high evaporation) and the deep water table.

The potential exists for surface water accumulating in the playas to recharge shallow, perched groundwater either by limited infiltration through the playa soils or by more rapid infiltration through more permeable alluvial soils surrounding the playas during flood events. Recharge directly through playa deposits is minimal due to the low permeability of these soils. However, during certain seasonal periods in which precipitation occurs, a limited hydraulic connection between shallow groundwater and surface water retained in playas is possible. As described in **Section 3.5**, the quantity of recharge to Quaternary deposits surrounding the playas is not well characterized.

The groundwater pathway from identified MC loading areas is currently not expected to impact human and ecological receptors. There is no potential groundwater pathway to ecological receptors. The installation drinking water production wells are located at significant distances from many of the MC loading areas and are in the Surprise Spring groundwater subbasin, which is not connected to the subbasins containing MC loading areas. The USGS water-level measurements have shown sharp discontinuity of water levels across faults bounding the Surprise Spring subbasin, like the Surprise Spring and

the Emerson faults (an approximate 250 ft of groundwater elevation drop across the faults), indicating that these faults act as groundwater barriers and, thus, hydraulically separate the Surprise Spring subbasin from adjacent subbasins, such as the Deadman Lake subbasin, which contains MC loading areas. Futhermore, groundwater in the Surprise Spring subbasin likely originates to the west of the installation in the San Bernardino Mountains (Li and Martin, 2008), and water-level measurements indicate that the groundwater flow direction from the Surprise Spring subbasin is up gradient of the MC loading areas located in the adjacent Deadman Lake subbasin. As a result, given the very slow MC migration to groundwater and the absence of potential pathways, training activities at MCAGCC Twentynine Palms are not expected to impact drinking water wells within the Surprise Spring subbasin. However, the installation has future plans to draw water from the Deadman Lake groundwater subbasin for drinking water use. Several of the identified MC loading areas are located within this groundwater subbasin and could have minimal impact to the water potentially utilized from this groundwater subbasin. Currently, the installation is conducting studies to identify potential contamination within the Deadman Lake subbasin; depending on the outcome of the investigation, the installation might move forward with utilizing water from this subbasin.

The salt mining operations in nearby Bristol Dry Lake and Dale Lake are not likely to be impacted by MC loading at MCAGCC Twentynine Palms. Groundwater is used as a brine source for salt production at the salt mine activities. However, only the Dale Lake salt mine activities could receive groundwater flow from the identified MC loading areas at MCAGCC Twentynine Palms, and these salt mine activities are located significant distances (16 to 22 miles) from the MC loading areas. Furthermore, many of the wells at the mining operations are screened in the deep groundwater zones and are not used for potable water. Although some pump shallow groundwater, they are unlikely to encounter high levels of MC due to limited MC groundwater transport potential, as described above.