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FINAL

Range Environmental Vulnerability Assessment Five-Year Review

MCB Camp Lejeune

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Acronym List

Acronym	Definition
µg/L	Microgram(s) per Liter
amsl	above mean sea level
ASR	Archive Search Report
BaB	Baymeade fine sand
bgs	below ground surface
BmB	Baymeade-Urban land complex
bmsl	below mean sea level
Bo	Bohicket silty clay loam
BZO	Battle Site Zero
cal	Caliber
CSM	Conceptual Site Model
Ct	Croatan muck
DO	Dissolved Oxygen
DoD	Department of Defense
DoDIC	Department of Defense Identification Code
DQO	Data Quality Objective
EMP	Enhanced Marksmanship Program
EOD	Explosive Ordnance Disposal
ETA	Engineering Training Area
f_{oc}	Organic Carbon Fraction
ft	Feet
ft/d	feet per day
ft/yr	feet per year
FY	Fiscal Year
GIS	Geographic Information System
GSRA	Greater Sandy Run Area
HE	High Explosive
HMX	Cyclotetramethylene Tetranitramine

Acronym	Definition
in/yr	Inch(es) per Year
kg/m^2	Kilogram(s) per Square Meter
$kg/m^2/yr$	Kilogram(s) per Square Meter per Year
kg/m^3	Kilogram(s) per Cubic Meter
K_{oc}	Organic Carbon Partition Coefficient
lb	Pound(s)
lb/yr	Pound(s) per Year
Illum	Illumination
IMAC	Interim Maximum Allowable Concentration
IR	Installation Restoration
IRP	Installation Restoration Program
KuB	Kureb fine sand
Ln	Leon fine sand
LZ	Landing Zone
m	Meter(s)
m^2	Square Meter(s)
MAC	Military Operations in Urban Terrain Assault Course
MaC	Marvyn loamy fine sand
Marine Corps	United States Marine Corps
MC	Munitions Constituents
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCICom	Marine Corps Installations Command
MCOLF	Marine Corps Outlying Field
mg/L	Milligram(s) per Liter
mgd	million gallons per day
MIT	Moving Infantry Target
Mk	Muckalee loam
mL/g	Milliliters per gram
mm	Millimeter(s)
MMRP	Military Munitions Response Program

Acronym	Definition
MOUT	Military Operations in Urban Terrain
MS	Matrix Spike
mS/cm	MilliSiemen(s)/centimeter
MSD	Matrix Spike Duplicate
msl	Mean Sea Level
Mu	Murville fine sand
mV	Millivolt(s)
NA	Not Applicable
NC	North Carolina
NCDENR	North Carolina Department of Environment and Natural Resources
NLW	Non-Lethal Weapon
NTU	Nephelometric Turbidity Unit
On	Onslow loamy fine sand
ORP	Oxidation Reduction Potential
Pa	Pactolus fine sand
PETN	Pentaerythritol tetranitrate
PITS	Portable Infantry Target System
PRA	Preliminary Range Assessment
QAPP	Quality Assurance Project Plan
RDX	Cyclotrimethylene Trinitramine
REVA	Range Environmental Vulnerability Assessment
RFMSS	Range Facility Management Support System
RL	Reporting Limit
RMUS	Range and Munitions Use Subcommittee
RTA	Range Training Area
RUSLE	Revised Universal Soil Loss Equation
SAP	Sampling and Analysis Plan
SAR	Small Arms Range
SARAP	Small Arms Range Assessment Protocol
SDZ	Surface Danger Zone
SIT	Stationary Infantry Target

Acronym	Definition
SOTG	Special Operations Training Group
T/E	Threatened and Endangered
TNT	Trinitrotoluene
To	Torhunta fine sandy loam
U.S.	United States
USGS	United States Geological Survey
UXO	Unexploded Ordnance
USEPA	United States Environmental Protection Agency
WaB	Wando fine sand
Wo	Woodington loamy fine sand

Executive Summary

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

The 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 REVA 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 Marine Corps Installations Command (MCICOM) 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. Sampling results are also compared to state protection standards obtained from the North Carolina Administrative Code for groundwater (North Carolina Department of Environment and Natural Resources Division of Water Quality, 2010).

This report presents the five-year review assessment results for the operational ranges and training areas at Marine Corps Base (MCB) Camp Lejeune, Marine Corps Air Station New River, and Marine Corps Outlying Field Oak Grove, all located in southeastern North Carolina. Collectively, these areas are referred to as MCB Camp Lejeune. This report serves as the first five-year review assessment documenting the period of munitions loading from October 2004 through September 2010. The baseline assessment conducted in 2007 documented munitions use through 2004 (Malcolm Pirnie, 2009).

Military Munitions Training and Operations

MCB Camp Lejeune is the world's most complete amphibious training base. The installation provides specialized training for those serving in the U.S. Marine Forces Command and is home to the Marine Corps Engineer School, the U.S. Coast Guard's Special Missions Training Center, the Marine Special Operations Command, the School of Infantry-East, the II Marine Expeditionary Force, and other Training and Education Command formal schools. Approximately 37,560 active military personnel are stationed at MCB Camp Lejeune. An additional 19,000 servicemen attend military training/schools at the installation each year (USACE, 2001a).

MCB Camp Lejeune contains approximately 153,439 acres. The REVA team identified 273 operational and historical use areas and training areas within MCB Camp Lejeune. The majority of the installation (approximately 107,263 acres) is designated for training purposes with fixed ranges positioned throughout the installation. A Conceptual Site Model (CSM) was developed for MCB Camp Lejeune using information collected during the REVA team's September 2010 site visit, information contained in the baseline REVA (Malcolm Pirnie, 2009), and information provided by the Environmental Management Division, Range Control, and other installation offices at MCB Camp Lejeune.

MC loading areas are where the majority of MC are deposited within an operational range. Thirty-three MC loading areas were identified and evaluated during the baseline assessment. Of these, 12 of the 33 were prioritized for modeling purposes based on use, receptors, and environmental characteristics. Due to overlapping uses over time, the 12 prioritized areas were grouped into 10 MC loading areas for fate and transport modeling. Twenty-three small arms ranges (SARs) were identified during the baseline and grouped into 21 SARs for qualitative evaluation based on proximity and use. 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.

Table ES-1: Summary of Baseline Assessment Results for MCB Camp Lejeune

MC Loading Area	Screening-Level Modeling Results REVA Trigger Values Predicted to Be Exceeded Off Range[a] Surface Water	 Groundwater	Samples Collected After Baseline Assessment	Samples Exceed RMUS Values	Historical Use Only	Assessing in Five-Year Review
G-10 Impact Area	Y	Y	Y	N	N	Y
K-2 Impact Area	Y	Y	Y	N	N	Y
F-5, F-2 Field Firing Range, Musketry Range A	Y	N	Y[b]	N	N	Y
F-14 Field Firing Range	N	N	Y[b]	N	Y	N

MC Loading Area	Screening-Level Modeling Results		Samples Collected After Baseline Assessment	Samples Exceed RMUS Values	Historical Use Only	Assessing in Five-Year Review
F-6	Y	N	Y [b]	N	N	Y
L-Impact Area	N	N	N	---	Y	N
L-Ranges	Y	N	N	---	N	Y
Combat Town	N	N	Y [b]	N	N	Y
M-10 Hand Grenade Range	N	N	N	---	Y	N
M-115 Hand Grenade Range	N	N	N	---	Y	N
Assessed Using SARAP	**Surface Water Concern**	**Groundwater Concern**	**Samples Collected**		**Assessing in Five-Year Review**	
A-1	Moderate	Moderate	N		Y	
B-12	Moderate	Moderate	N		Y	
D-29A and D-29B	Moderate	Moderate	N		Y	
D-30	Moderate	High	N		Y	
F-11A and F-11B	Moderate	Moderate	N		Y	
F-18	Moderate	High	N		Y	
I-1	Minimal	Moderate	N		Y	
MAC 1	Moderate	Moderate	N		Y	
MAC 2	Moderate	Moderate	N		Y	
MAC 3	Moderate	Moderate	N		N	
MAC 4	Moderate	Moderate	N		Y	
MAC 5	Moderate	Moderate	N		Y	
SR-11	Minimal	Moderate	N		Y	
Stones Bay Dodge City	Moderate	Moderate	N		Y	
Stones Bay Multi-Purpose	Moderate	Moderate	N		Y	
Stones Bay Mechanical	Moderate	Moderate	N		Y	
Stones Bay Non-Mechanical	Moderate	Moderate	N		Y	
Stones Bay Alpha Range	Moderate	Moderate	N		Y	
Stones Bay Bravo Range	Moderate	Moderate	N		Y	
Stones Bay Charlie Range	Moderate	Moderate	N		Y	
Stones Bay Hathcock Range	Moderate	Moderate	N		Y	

Note:
N = No, Y = Yes
MAC = Military Operations in Urban Terrain (MOUT) Assault Course
RMUS = Range and Munitions Use Subcommittee
SARAP = Small Arms Range Assessment Protocol

a Result is indicated for downstream receptor.
b Sample was collected at public supply well near MC loading area.

During the five-year review process, 31 MC loading areas were identified at MCB Camp Lejeune. These MC loading areas are distributed throughout the installation and are shown in **Figure ES-1**. Of the 10 MC loading areas modeled in the baseline assessment, 6 were reassessed in the five-year review. Those that were not reassessed were historical loading areas that showed no potential for MC release to off-range areas and have had no additional loading since the time of the baseline assessment.

Fourteen of the 31 identified MC loading areas identified in the five-year review were prioritized for fate and transport modeling based on use and potential for groundwater or surface water receptor exposure. Five of the prioritized MC loading areas were included in the 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.

Thirty-seven SARs were evaluated in the five-year review, but some of the SARs with similar characteristics that were in proximity to one another were grouped for the assessment; therefore, 27 SAR assessments were completed in the five-year review. Of the 21 SARs evaluated in the baseline assessment, all but one of these were evaluated in the five-year review. MAC-3 was not re-evaluated because it is an indoor range and, therefore, any potential impacts are assumed to be contained inside. Four SARs were identified in the five-year review that were not evaluated in the baseline assessment: MAC-6, Square Bay, SR-8, and SR-11. Ten ranges were evaluated as part of the K-Impact Area MC loading area in the baseline assessment that were determined to be SARs in the five-year review. These include K-302, K-309, K-317, K-319, K-321, K-321A, K-325, K-402, K-406A, and K-406B. All 14 of these ranges were evaluated with the SARAP for this five-year review.

The REVA assessment team estimated MC loading rates for identified MC loading areas and for lead deposition for MC loading areas and SARs at MCB Camp Lejeune. A CSM 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.

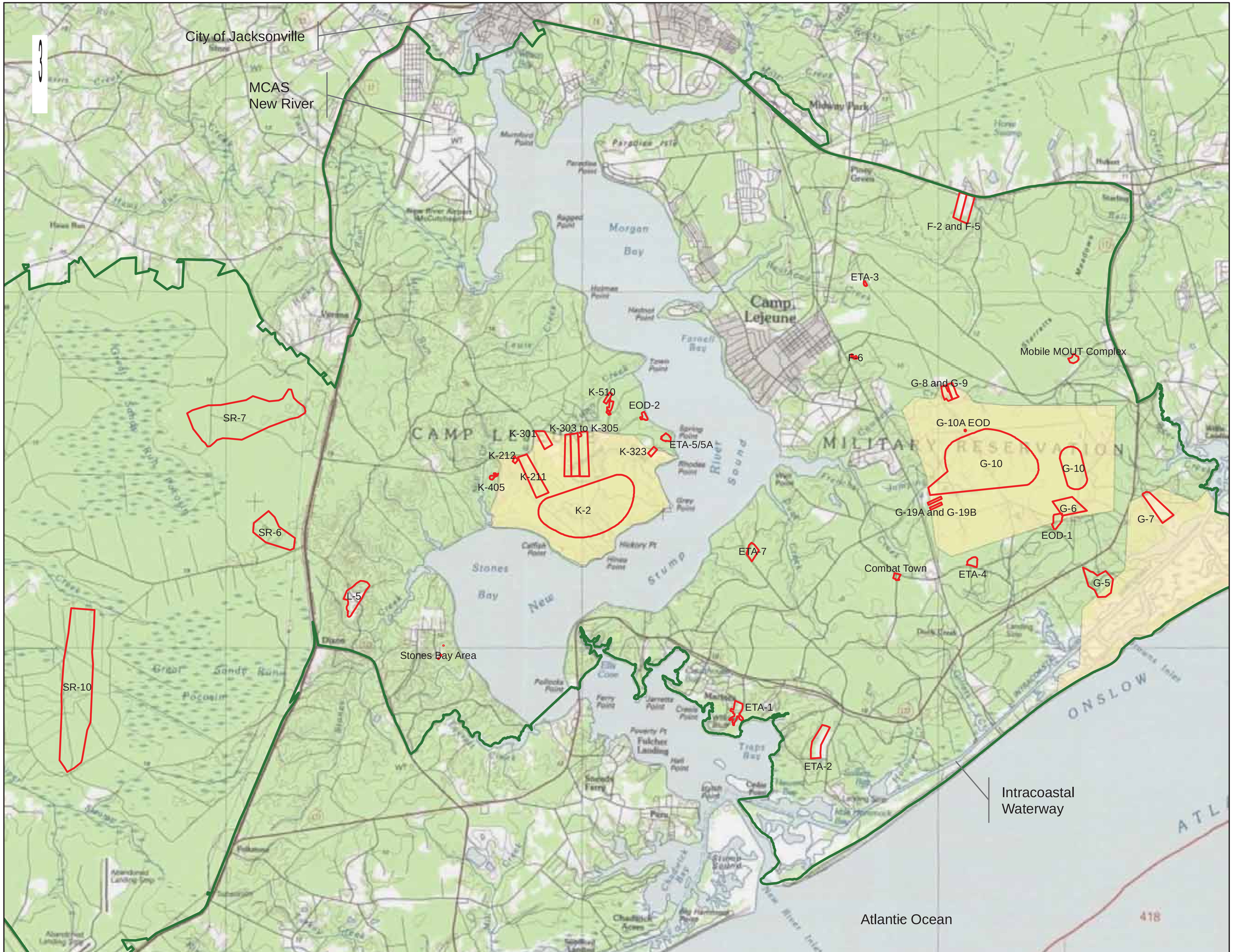
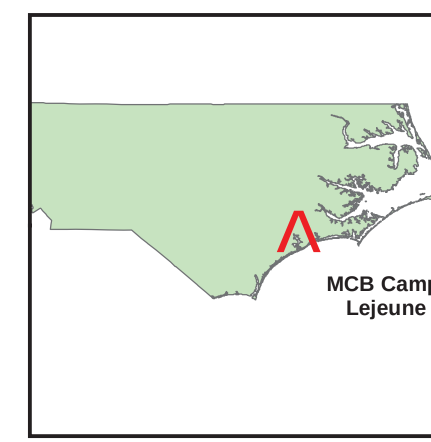


FIGURE ES-1
MCB Camp Lejeune
MC Loading Areas

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- Impact Area



0 0.45 0.9 1.8 2.7
Miles

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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Conceptual Site Model for MCB Camp Lejeune

MCB Camp Lejeune is located on the southeastern coast of North Carolina where the climate is warm and temperate, and winters are cool with occasional brief cold spells. Average annual precipitation is approximately 54 inches per year, with an average of 3 inches of snowfall per year (North Carolina State Climate Office, 2011). Hurricanes are not uncommon in the area and can cause severe flooding in low-lying areas. MCB Camp Lejeune is relatively flat, and elevation ranges from mean sea level (msl) to 72 feet (ft) above msl.

Soil erodibility factors of the predominant soil series at MCB Camp Lejeune are low to moderate (0.1 to 0.3 tons/acre) (USDA SCS, 1992). Even in areas of higher slope, such as stream valleys, the high vegetative cover causes the natural erosion potential to be low. The coastal barrier island complex is subject to erosion from wave action, particularly during storm surges, but serves to protect landward areas from such effects. Areas with moderate potential for erosion are those where the vegetation and soil have been disturbed by military operations. There are several MC loading areas that are vacant or sparsely vegetated; these areas have been estimated to have high erosion potential.

MCB Camp Lejeune is located within the Tidewater region of the Atlantic Coastal Plain physiographic province, in the lower Coastal Plain of North Carolina. It is underlain by an eastward-thickening wedge of marine and nonmarine sediments that vary from a thickness of near zero at the fall line to the west to more than 10,000 ft near and under the Atlantic Ocean (Winner and Coble, 1989). The several thousand ft of interlayered, unconsolidated sediment at the coastline consists of gravel, sand, silt, clay deposits, calcareous clays, shell beds, sandstone, and limestone. The sequence of unconsolidated sedimentary deposits at MCB Camp Lejeune is estimated to reach a thickness of 1,400 to 1,700 ft (O'Brien and Gere, 1988).

The unconsolidated sediment deposits that underlie MCB Camp Lejeune have been divided into seven hydrostratigraphic units or aquifer systems. The aquifer systems from shallow to deep are the surficial, Castle Hayne, Beaufort, Peedee, Black Creek, Upper Cape Fear, and Lower Cape Fear aquifer systems. The surficial aquifer is recharged by rainfall and is a source of recharge for the underlying Castle Hayne aquifer. It also is the source base flow to streams. The surficial aquifer ranges in depth from 0 ft in the channel of the New River and its tributaries to 75 ft in the southeastern portion of MCB Camp Lejeune. The bottom of the surficial aquifer is at or near msl throughout the majority of the installation. The Castle Hayne confining unit lies between the surficial and Castle Hayne aquifers and is a thin, discontinuous layer of clay to clayey sands and silts. The discontinuous nature of the confining unit results in vertical leakage (both upward and downward) throughout the Castle Hayne aquifer. The top of the Castle Hayne aquifer is between 0 and 75 ft below msl, and the aquifer ranges in thickness from 175 ft in the northern part of the installation to 375 ft along the coast. As of January 2012, there are 50 active water supply wells on the installation, which rely entirely on groundwater from the Castle Hayne aquifer. Most of these are located east of the New River along the northern boundary of the installation and on the western boundary of the G-10 Impact Area.

MCB Camp Lejeune is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The Atlantic Ocean forms the southeastern boundary, which contains approximately 14 miles of beachfront. The majority of MCB Camp Lejeune drains to the New River embayment and its tributaries; however, some southern areas drain directly to the Intracoastal Waterway, which flows into the Atlantic Ocean. Much of the interior area of the installation drains to intermittent and perennial streams that widen into tidal creeks in their downstream segments. Most perennial streams and tidal creeks occupy floodplains with extensive riparian wetlands. The flat terraces contain regions that drain to low areas with no surface water outlets, including pocosins.

Waters in and around MCB Camp Lejeune are used for human recreation, and there are no military restrictions in place for recreational use on the waters of MCB Camp Lejeune. Commercial oyster beds are located in the eastern and southern portions of the New River, and approximately 20 artificial reefs have been established in Onslow Bay to support offshore fishing and recreational diving. Surface waters on the installation are not a drinking water source.

Surface water runoff is a potential transport pathway of MC to surface water bodies, and MC transported to the shallow groundwater may discharge to surface water. Although soil erosion potential is relatively low, erosion potential is higher at many of the identified MC loading areas due to lower vegetative cover and disturbance from range activities. Thus, soil erosion at the identified MC loading areas is also a potential mechanism for MC transport to surface water bodies.

Due to the shallow water table depth and presence of sandy soils, MC have the potential to migrate toward the water table after dissolution in infiltrating rainwater. There are no known receptors for shallow groundwater, but there are potential receptors for surface water into which shallow groundwater discharges. Shallow groundwater is also a recharge source for the Castle Hayne aquifer.

Screening-Level Surface Water, Sediment, and Groundwater Transport Analyses

REVA screening-level modeling was completed for 14 MC loading areas to estimate potential MC concentrations in surface water, sediment, and groundwater at MCB Camp Lejeune. These MC loading areas were selected based on high explosives use and proximity to potential receptor locations. MC modeled included cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), trinitrotoluene (TNT), and perchlorate.

The initial surface water screening estimated annual average edge-of-loading-area MC concentrations in surface water runoff. The evaluation of transport of MC by surface water and sediment beyond the edge of the MC loading area was assisted by grouping MC loading areas into potential receptor locations (subwatershed outlet to the tidal waters).

Additional screening was carried out for those MC loading areas and MC where edge-of-loading-area concentrations were predicted to exceed REVA trigger values in order to estimate concentrations at the downstream receptor location. Results of this analysis are shown in **Table ES-2**. All MC concentrations in sediment entering downstream receptor locations were predicted to be below REVA trigger values.

Table ES-2: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering Downstream Receptor Locations

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	**0.110**	**0.113**	**0.114**	**0.021**
Surface Water Receptor Location	**Predicted Concentration at Nearest Surface Water Receptor Location (µg/L)**			
New River between Town Creek and Stones Bay	**0.761**	**0.568**	0.014	0.001
Bear Creek at the Confluence with Intracoastal Waterway	**0.914**	**0.711**	0.018	0.001
New River at Stones Bay	**0.598**	**0.215**	~0	0.001
New River between Stick Creek and Whitehurst Creek	**0.212**	**0.118**	~0	~0
Stones Creek at the confluence with Stones Bay	0.006	0.002	~0	~0
New River between Stones Bay and Intracoastal Waterway	**0.109**	**0.115**	~0	~0
Wallace Creek at the confluence with New River	**0.148**	0.048	~0	~0
Freeman Creek at the confluence with Intracoastal Waterway	0.018	0.013	~0	~0

Note:
µg/L = micrograms per liter
Bold indicates concentration exceeds the REVA trigger value.

A screening-level analysis was conducted on 14 MC loading areas to assess the potential for vertical migration of MC from the ground surface to the water table, the surficial aquifer, and the Castle Hayne aquifer, and from these points to move laterally to a receptor location (e.g., drinking water supply well). Only 10 of these MC loading areas were assessed further for the potential of MC to reach the Castle Hayne aquifer because four of the MC loading areas are not located near drinking water supply wells. Concentrations predicted to reach groundwater receptors are shown in **Table ES-3**.

Table ES-3: MC Concentrations Predicted to Reach Groundwater Receptors

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	**0.110**	**0.113**	**0.114**	**0.021**
MC Loading Area	**Predicted Concentration at Nearest Drinking Water Well (µg/L)**			
G-10 Impact	~0	~0	~0	**0.046**
F-6	~0	~0	N/A	**0.094**
G-8 and G-9	~0	N/A	~0	N/A
L-5	~0	~0	N/A	**0.431**
F-2 and F-5	**0.308**	~0	N/A	0.016
ETA-1	~0	~0	N/A	**0.105**
ETA-3	~0	~0	N/A	**0.021**
ETA-4	~0	~0	N/A	N/A
ETA-7	~0	~0	N/A	N/A
Stones Bay Area	~0	~0	N/A	N/A

Note:
ETA = Engineer Training Area
Bold indicates concentration exceeds the REVA trigger value.

Field Data Collection

Twenty-one groundwater, eight surface water, and nine public supply well samples were collected in September/December 2010 from around the G-10 and K-2 Impact Areas and analyzed for the full explosive suite, perchlorate, and total and dissolved lead. Collected from around the G-10 Impact Area were 14 groundwater samples, 4 surface water samples, and 9 public supply well samples. Collected from around the K-2 Impact Area were seven groundwater samples, three surface water samples, and zero public supply well samples. A monitoring well was installed into the Castle Hayne aquifer south of Range L-5 in October 2011. A groundwater sample was collected from this well and three additional surface water samples were collected in the New River and Wallace Creek in October 2011.

Explosives were not detected in any surface water samples. Perchlorate was detected at four surface water locations with the highest concentration detected in the background sample. Lead was detected at three surface water locations located around the K-2 Impact Area and in Wallace Creek. All surface water sample results were below RMUS screening values.

Explosives (including 2,4-dinitrotoluene and 2-amino-4,6-dinitrotoluene) were detected at estimated concentrations in one monitoring well near the G-10 Impact Area, and nitroglycerin was detected at an estimated concentration in one monitoring well near the K-2 Impact Area. Perchlorate was detected in eight wells near the G-10 Impact Area and in three wells near the K-2 Impact Area. All but two of the perchlorate detections were estimated concentrations and only one detection (estimated) was in the Castle Hayne aquifer. All explosives and perchlorate detections were below RMUS values, but one detection of 2,4-dinitrotoluene exceeded the interim maximum allowable concentration for the state of North Carolina. The monitoring well was resampled the following day, and this constituent was not detected.

Lead was detected at estimated concentrations around the G-10 Impact Area in four wells and around the K-2 Impact Area in five wells (two of the detections around the K-2 Impact Area were estimated). A total lead detection of 18 µg/L in one monitoring well at the K-2 Impact Area exceeded the RMUS and North Carolina screening value of 15 µg/L; dissolved lead was not detected in this well. The duplicate sample collected at this well contained a concentration of 14 µg/L. Total and dissolved lead results were well below the screening value at the wells and surface water location down-gradient of the exceedance. No dissolved lead results exceeded screening criteria, and dissolved concentrations were lower than total lead results, indicating that lead is largely immobilized by being bound to sediments. There were no detections in the sample collected from the newly installed well south of Range L-5.

Explosives and perchlorate were not detected in any public supply wells, but lead was detected in six public supply wells (two of these results were estimated concentrations). Total lead exceeded the RMUS and North Carolina screening value of 15 µg/L with a concentration of 38 µg/L in one public supply well located northwest of the G-10 Impact Area; however, total lead was not detected when this well was resampled in December 2010. No detections of dissolved lead exceeded RMUS screening values. Lead appears primarily to be bound to sediments in the surficial and Castle Hayne aquifers, as evidenced by the fact that dissolved lead results were consistently lower than total lead results.

Sampling results do not indicate a current release of MC to off-range areas at MCB Camp Lejeune.

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 generally are unavailable. Therefore, SARs are qualitatively assessed under the REVA program to identify factors that influence the potential for lead migration.

The 37 SARs evaluated at MCB Camp Lejeune are located throughout the installation. Some of these were grouped based on similar use and setting, resulting in assessments for 27 SARs or groups of SARs. Qualitative assessments were completed; 9 SARs were rated as a minimal concern for surface water receptors and 18 SARs as moderate concern. Lead was not detected in field samples near or above the screening value.

Assessments completed to determine concern for groundwater receptors from the SARs rated 3 SARs as a minimal concern to groundwater receptors, 23 as moderate concern, and 1 grouping of SARs as high concern. Only the grouping of Alpha, Bravo, and Charlie ranges received a rating of high concern to groundwater receptors. These were rated as high concern due to heavy use, the groundwater pathway, and nearby wetlands where shallow groundwater may discharge. No public supply wells or beneficial use for groundwater was identified near these ranges. Sediment near the Alpha, Bravo, and Charlie ranges was sampled in 2008 and 2010 in a study by the University of South Carolina – Beaufort and Georgia Institute of Technology – Savannah. Sediment samples were collected in uplands and within Stones Bay and were analyzed for lead, copper, antimony, manganese, iron, and zinc. Other parameters including bulk density, grain size distribution, total organic carbon, acid volatile sulfide, and simultaneously extracted metals were also analyzed. Results did not indicate metals in the sediment were bioavailable or migrating.

Total lead was detected in a groundwater monitoring well located on the northwest boundary of the K-2 Impact Area exceeding the RMUS and North Carolina screening value of 15 µg/L. Dissolved lead was not detected in this well, indicating that lead is bound to sediment and largely immobilized. It was not detected over or near the screening value at any wells located down-gradient of the exceedance.

One lead detection exceeded its screening value northwest of the G-10 Impact Area in a public supply well with a concentration of 38 µg/L; dissolved lead was detected at 1.7 µg/L. This well was resampled in December 2010 and neither total nor dissolved lead was detected. Other detections of lead were well below the screening value and many were qualified as estimated. Almost all dissolved results were well below total lead results, indicating lead is primarily bound to sediment and largely immobilized. PSWs are sampled semi-annually by MCB Camp Lejeune and analyzed for MC.

Conclusions

- One detection of total lead exceeded the RMUS and North Carolina screening value in a monitoring well on the northwest boundary of the K-2 Impact Area. This detection was slightly above the screening value and the duplicate sample result was just below the screening value. No groundwater receptors are in the vicinity and down-gradient results do not indicate migration.

- One detection of total lead exceeded the RMUS and North Carolina screening value in a public supply well northwest of the G-10 Impact Area. This well was resampled in December 2010, and lead was not detected. MCB Camp Lejeune conducts semi-annual sampling of public supply wells.

- One detection of 2,4-dinitrotoluene exceeded the North Carolina interim maximum allowable concentration for groundwater. This was an estimated concentration, and the constituent was not detected when the well was resampled.

- Sampling results do not indicate an off-range release of MC at MCB Camp Lejeune.

- Groundwater will be sampled annually from monitoring wells in which lead and 2,4-dinitrotoluene exceeded screening criteria. Analytical results will be used to determine if annual monitoring should be continued.

- Surface water and groundwater should be sampled in the next REVA five-year review for re-evaluation.

1. Introduction

1.1. Purpose

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

The REVA program is a proactive and comprehensive program designed to support the Marine Corps' 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, 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 Marine Corps Base (MCB) Camp Lejeune, Marine Corps Air Station (MCAS) New River, and Marine Corps Outlying Field (MCOLF) Oak Grove, all located in southeastern North Carolina (NC). These areas are collectively referred to as MCB Camp Lejeune throughout the remainder of this document. This report serves as the first five-year review assessment documenting the period of munitions loading from October 2004 through September 2010. The baseline assessment conducted in 2007 documented munitions use at MCB Camp Lejeune through 2004 (Malcolm Pirnie, 2009).

MCB Camp Lejeune maintains operational ranges and training areas within the installation boundaries and on the waters of the nearby New River and Atlantic Ocean. It encompasses approximately 246 square miles in Onslow County, NC and is located immediately southeast of Jacksonville, NC. The Atlantic Ocean forms the southeastern boundary of the facility, which has approximately 14 miles of beachfront. A site location map is provided as **Figure 1-1**.

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 Training and Education Command [TECOM]) purposely separates operational ranges and training areas. For this document, the term “operational range” includes both operational ranges and training areas.

A number of range types 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 (i.e., munitions-related activity). 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 and are being assessed separately from the REVA effort. 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 are 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 an off-range receptor location. 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, 2010). Exposure pathways for off-range ecological receptors include direct consumption of surface water and direct exposure to surface water and sediment. Other off-range exposures scenarios (e.g., soil ingestion, incidental dermal contact, bioaccumulation and food chain exposure) currently are not considered in the REVA process unless site-specific considerations warrant an evaluation.

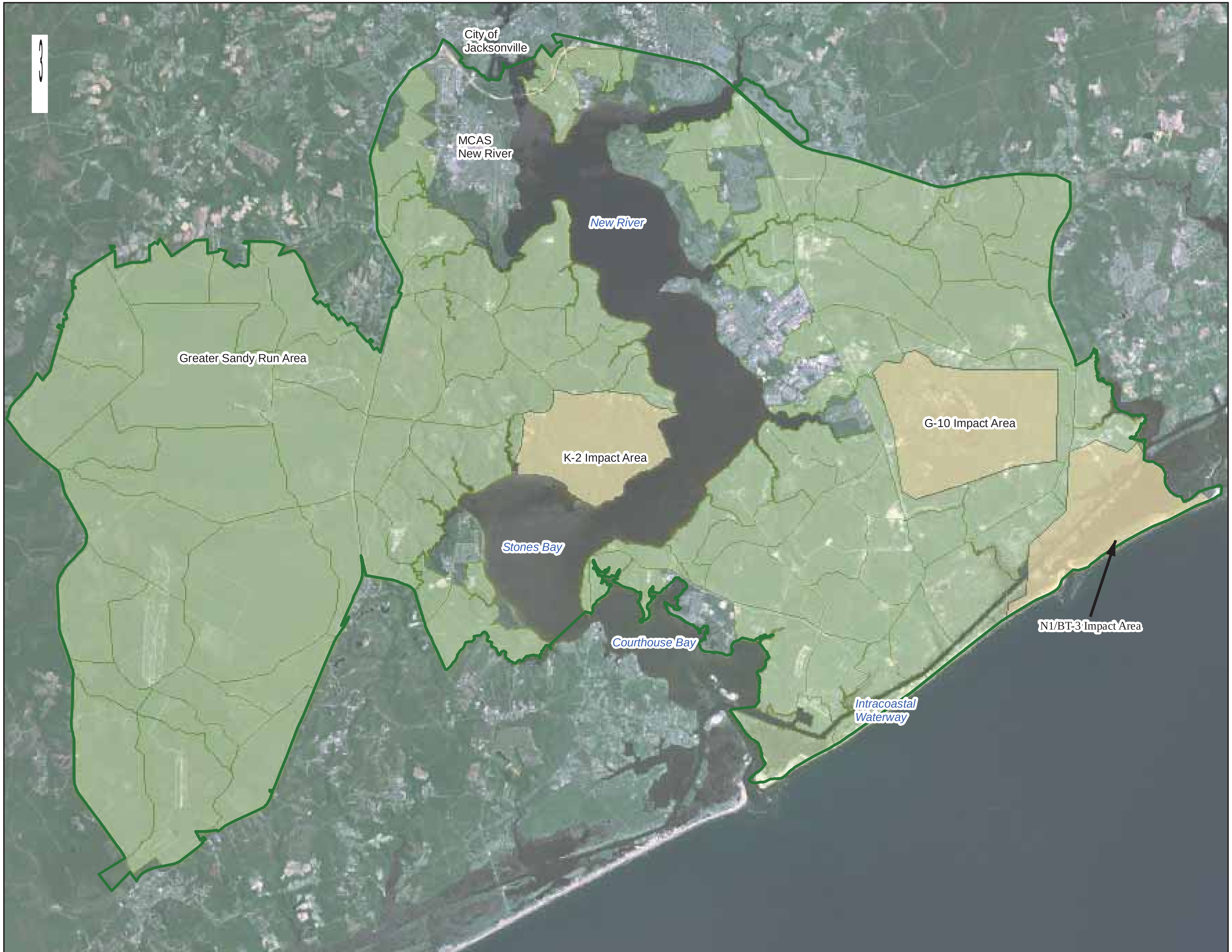
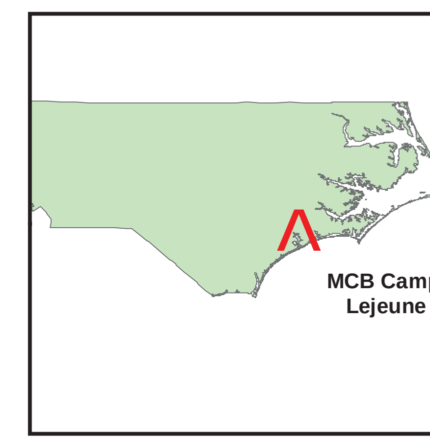


FIGURE 1-1
MCB Camp Lejeune Site Map

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- Impact Areas
- Training Area



0 0.5 1 2 3
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Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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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. The amount of lead that has been loaded to the operational ranges also has been estimated.

Lead loading associated with small arms and munitions components at HE ranges was estimated as part of the five-year review process. Lead is primarily present 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.

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 report presents the analysis of the data collected during site visits, the results of screening-level fate and transport modeling for MC loading areas, and the results of environmental sampling and analysis activities conducted at MCB Camp Lejeune. It 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 completed 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 Marine Corps Installations Command (MCICOM), 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 MCB Camp Lejeune from 20 to 24 September 2010. MCICOM 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:

- Environmental Affairs Department
  - Compliance
  - Cultural Resources
  - GIS
  - Natural Resources
  - Water Resources
- Explosive Ordnance Disposal (EOD)
- Facilities Systems Management Branch
- Range Control
  - Range Management
  - Range GIS

- Real Estate

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.

Several of the operational ranges at MCB Camp Lejeune were visited during the baseline assessment. During the five-year review installation visit, site visits were performed at 21 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 MCB Camp Lejeune is organized into the following sections:

Section 1 – Introduction

Section 2 – Baseline Results and Installation Changes

Section 3 – Munitions Constituents Loading Rates 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 – Field Data Collection Results

Section 9 – References

2. Baseline Results and Installation Changes

2.1. Summary of Baseline Results

At the time of the baseline assessment, all identified operational range areas were assessed using historical data and expenditure data from 2001 to 2004 to determine the impact of munitions loading on operational range lands. The results of the baseline assessment are documented in the *REVA Report for MCB Camp Lejeune* (Malcolm Pirnie, 2009). Specific details of the methodology for 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 results that provide a framework for the structure and areas of focus for the five-year review.

2.1.1. MC Loading Areas and Small Arms Ranges

A total of 33 MC loading areas and 23 SARs were identified in the baseline assessment. Of the 33 MC loading areas, 12 were prioritized for screening-level modeling based on MC loading and surface water and groundwater characteristics. Due to overlapping uses over time, the MC loading areas were grouped into 10 MC loading areas to perform screening-level modeling. These MC loading areas are summarized in **Table 2-1**. In general, the surface water and groundwater screening-level modeling at these MC loading areas indicated that MC were not likely to migrate off range at levels that would represent an exposure concern for receptors.

A Small Arms Range Assessment Protocol (SARAP) was completed for all operational 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, SARs are prioritized for possible further assessment or management practices. The military operations in urban terrain (MOUT) facilities at MCB Camp Lejeune were not evaluated during the baseline; however, these military training ranges are evaluated in this five-year review report, using the SARAP.

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

MC Loading Area	Screening-Level Modeling Results: MC Concentrations Predicted to Exceed REVA Trigger Values[a] Off Range		Historical Use Only	Assessing in Five-Year Review
	Surface Water	Groundwater		
G-10 Impact Area	Y	Y	N	Y
K-2 Impact Area	Y	Y	N	Y
F-5, F-2 Field Firing Range, Musketry Range A	Y	N	N [b]	Y
F-14 Field Firing Range	N	N	Y	N
F-6	Y	N	N	Y
L-Impact Area	N	N	Y	N
L-Ranges	Y	N	N	Y
Combat Town	N	N	N	Y
M-10 Hand Grenade Range	N	N	Y	N
M-115 Hand Grenade Range	N	N	Y	N
Assessed Using SARAP	**Surface Water Concern**	**Groundwater Concern**	**Historical Use Only**	**Assessing in Five-Year Review**
A-1	Moderate	Moderate	N	Y
B-12	Moderate	Moderate	N	Y
D-29A and D-29B	Moderate	Moderate	N	Y
D-30	Moderate	High	N	Y
F-11A and F-11B	Moderate	Moderate	N	Y
F-18	Moderate	High	N	Y
I-1	Minimal	Moderate	N	Y
MAC-1	Moderate	Moderate	N	Y
MAC-2	Moderate	Moderate	N	Y
MAC-3	Moderate	Moderate	N	N
MAC-4	Moderate	Moderate	N	Y
MAC-5	Moderate	Moderate	N	Y
SR-11	Minimal	Moderate	N	Y
Stones Bay Dodge City	Moderate	Moderate	N	Y
Stones Bay Multi-Purpose	Moderate	Moderate	N	Y
Stones Bay Mechanical	Moderate	Moderate	N	Y
Stones Bay Non-Mechanical	Moderate	Moderate	N	Y

Assessed Using SARAP	Surface Water Concern	Groundwater Concern	Historical Use Only	Assessing in Five-Year Review
Stones Bay Alpha Range	Moderate	Moderate	N	Y
Stones Bay Bravo Range	Moderate	Moderate	N	Y
Stones Bay Charlie Range	Moderate	Moderate	N	Y
Stones Bay Hathcock Range	Moderate	Moderate	N	Y

Note:
MAC = MOUT Assault Course
N = No, Y = Yes

[a] REVA trigger values used during the baseline assessment are documented in the *REVA Reference Manual* (HQMC, 2009).
[b] F-5 is operational; others are historical use only.

2.1.2. Historical Use Areas

Historical use areas are those areas that lie within a designated operational range area but no longer are used for the original designated purpose. There were four historical use only areas evaluated in the baseline assessment, and two additional historical use areas were modeled in grouping with an operational range (**Table 2-1**). Because no further loading has occurred at any of these MC loading areas since the baseline assessment, they were not considered in the five-year review. Training has ceased since the baseline assessment at three MC loading areas evaluated in the five-year review; these areas are now designated as historical use areas at MCB Camp Lejeune.

A number of factors were considered to determine whether historical use areas would be evaluated through modeling in the five-year review. One factor is that these historical use areas have experienced only historical loading; no additional loading has occurred in these locations since the baseline assessment. The following sections detail the results of the baseline assessment for the historical MC loading areas and site-specific considerations that aided in the determination to not evaluate them as part of the five-year review.

Historical MC Loading Areas Designated But Not Modeled in the Baseline Assessment – These MC loading areas include the F-1 Field Firing Range, F-12 Field Firing Range, M-Impact Area, Unexploded Ordnance (UXO) Area, Rocket Range 2, M-8 Assault of a Fortified Position Range, and M-113 Hand Grenade Range. The F-1 Field Firing Range, M-Impact Area, and UXO Area received a medium prioritization, and the Rocket Range 2 received a low prioritization. These were not modeled because the modeling results of higher priority MC loading areas did not indicate a potential for off-range MC migration. The F-12 Field Firing Range initially received a high prioritization; however, it later was determined to contain no REVA indicator MC and was withdrawn from the modeling process. The M-8 Assault of a Fortified Position Range and the M-113 Hand Grenade Range were considered represented by the assessment of the M-10 Range because of proximity and similar site conditions. Because these were determined in the baseline assessment to have no current impact and no additional loading has occurred since the baseline assessment, they were not evaluated as part of the five-year review.

F-2 Field Firing Range and Musketry Range A – The footprints of the F-2 Field Firing Range and the Musketry Range A overlapped the current F-5 range located east of the New River along the northern boundary of the installation and, therefore, were included in the operational F-5 MC loading area in the baseline assessment. The MC loading area was delineated using pre-existing GIS shapefiles and aerial photography and resulted in a 19-acre MC loading area.

The F-2 Field Firing Range was used from 1950 through 1976, and the Musketry Range was used from 1942 until 1947. Although the predominant use of this area since 1976 has been for small arms, the historical ranges were used for artillery activities. Military munitions expended included small arms ammunition, large caliber ammunition, and mortars. Use at the F-2 Field Firing Range included TNT, while use at the Musketry Range A included RDX, TNT, and perchlorate. Model results indicated that MC concentrations from the historical ranges would not exceed REVA trigger values at the water table, and MC concentrations in surface water runoff were predicted to be negligible at the time of the baseline assessment. Confirming these results, a water supply well located near these ranges was sampled, and results indicated that MC were not migrating off range at the time of the assessment. These historical ranges were not considered in the five-year review because the baseline assessment indicated no exceedances of REVA trigger values, and no additional MC loading has occurred at these ranges since the baseline assessment.

F-14 Field Firing Range – This range was located within Training Areas FA, FB, and FE and was in use from 1950 until 1961. The designated MC loading area was delineated based on Archive Search Report (ASR) and Preliminary Range Assessment (PRA) maps, resulting in a 63-acre area. Munitions used at this historical range contained HMX, RDX, and TNT. Although groundwater is encountered within 10 ft below ground surface (bgs), modeling predicted no indicator MC concentrations to exceed REVA trigger values at the water table, and surface water runoff was predicted to contain negligible MC at the time of the baseline assessment. Because modeling in the baseline assessment did not predict REVA trigger value exceedances and no additional loading has occurred since that time, the F-14 Field Firing Range was not evaluated further during the five-year review.

L-Impact Area – The L-Impact Area was located near the northeast point of Stones Bay and was in use from 1951 until 1962. The MC loading area was delineated based on maps in the ASR and PRA, resulting in a 66-acre area. This historical use area is located on an upland with stream valleys to the north and south. Munitions used at the L-Impact Area contained HMX, RDX, and TNT. Modeling predicted no indicator MC concentrations to exceed REVA trigger values at the water table, and MC concentrations in surface water runoff were predicted to be negligible. Because modeling in the baseline assessment did not predict REVA trigger value exceedances and no additional loading has occurred since that time, the L-Impact Area was not evaluated further during the five-year review.

M-10 Range (also representative of MC loading areas M-8 Assault of a Fortified Position Range and the M-113 Hand Grenade Range) – The historical M-10 Range was located within Training Area MA and was in use from 1958 until 1961. The MC loading area was delineated based on maps in the ASR and PRA and consists of a 0.3-acre area located in a flat, swampy area of less than 5 feet (ft) elevation above mean sea level (amsl). Because of proximity and similar site conditions, the M-10 Range was considered representative of the M-8 Assault of a Fortified Position Range and the M-113 Hand Grenade Range; therefore, further evaluation of the M-8 and M-113 ranges was not completed. Munitions used at the M-10 Range contained RDX and TNT. Modeling the M-10 Range predicted no indicator MC concentrations to exceed REVA trigger values at the water table or in runoff at the edge of the MC loading area. Because modeling in the baseline assessment did not predict REVA trigger value exceedances, and no additional loading has occurred since that time, the M-10 Range was not evaluated further during the five-year review. Based on this conclusion, the M-8 and M-113 ranges also were not evaluated further.

M-115 Range – The historical M-115 Range was located within Training Area MA, just south of MCAS New River, and was in use from 1970 until 1977. The MC loading area was delineated based on maps in the ASR and PRA reports, which resulted in a 0.3-acre MC loading area located on a gently sloping upland with an elevation of 15–20 ft amsl. Munitions used at the M-115 range contained RDX, TNT, and perchlorate. Modeling predicted no indicator MC concentrations to exceed REVA trigger values at the water table or in runoff at the edge of the MC loading area. Because modeling in the baseline assessment did not predict REVA trigger value exceedances and no additional loading has occurred since that time, the M-115 Range was not evaluated further during the five-year review.

2.2. Installation Changes

A number of changes have occurred at the installation since the baseline assessment. Three historical MC loading areas (K-301, K-303 through K-305, and K-405) that were operational ranges areas during the baseline assessment are historical use areas in the five-year review. All of these ranges were included in the K-2 Impact Area MC loading area in the baseline assessment but have been designated as separate MC loading areas in the five-year review in order to more accurately reflect MC loading. Additionally, training ceased at Ranges G-8 and G-9 in 2008 with no current plan for training at the two ranges; these were evaluated as a single MC loading area for the five-year review because they are adjacent to one another. It is expected that a non-dudded Combat Town will be opened at some point in the future on the footprint of the G-8 and G-9 ranges.

Range K-301 was in use from approximately 1970 through 2006. Ranges K-501 and K-501A were built to replace training activities at K-301, and they occupy much of the footprint of the former K-301; however, K-501 and K-501A had not opened at the time of the five-year review and therefore were not assessed in this review. Ranges K-303, K-304, and K-305 were consolidated into one MC loading area for the five-year review because of their proximity to one another. The ranges were in use from approximately 1970 through 2008. New ranges K-503, K-503A, and K-504 now occupy a portion of the footprints of the former K-303 to K-305 ranges; however, these new ranges had not opened at the time of the five-year review and, therefore, were not assessed. Range K-405 was in use from approximately 1970 until 2008. Range K-510 opened in 2008 to replace training at Range K-405; however, it is in a different location and therefore, these two MC loading areas were assessed separately. As previously noted, training is no longer conducted at Ranges G-8 and G-9, and a non-dudded Combat Town will be located on the footprint of these two ranges in the future.

Range E-1 and H-Range are water ranges because the targets and impact areas for these ranges are located in the Atlantic Ocean. At the time of the baseline assessment, water ranges were not considered within the purview of the REVA program. Programmatically, water ranges are now included; therefore, a thorough review of all historical loading at these sites was conducted in the five-year review effort. Expenditures from these ranges were not significant and/or contained negligible amounts of indicator MC, and it was determined that the level of use did not warrant designating these as MC loading areas. They were thus eliminated from further evaluation.

Since the baseline assessment, five new ranges have opened; these were consolidated into three MC loading areas for the five-year review. Ranges G-19A and G-19B opened in 2010 to replace training activities at Ranges G-8 and G-9. The G-19 ranges and Ranges G-8 and G-9 are at different locations and, therefore, were assessed as two separate MC loading areas. As discussed above, Range K-510 opened in 2008 to replace historical Range K-405. Engineer Training Area (ETA)-7 opened in 2009 as an additional engineer demolition training area, and MAC-6 opened in 2005. MAC-7 opened after the baseline assessment, but it contained no expenditure data and therefore, will not be further assessed in this five-year review.

Prioritization of MC loading areas for further evaluation with regards to munitions use in the baseline assessment was determined by evaluating the level of use, duration of MC loading, expected presence of REVA indicator MC, size, and current status for each MC loading area. Each of these categories was rated 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, loading rates were calculated in the five-year review. Prioritization of MC loading areas for the five-year review with regards to munitions use was determined based on MC loading rate (pound [lb]/area). The MC loading was determined using expenditure data obtained from Range Control and EOD commitment sheets. EOD commitment sheets were available for only a 5-month period; these sums were adjusted proportionally to represent a 12-month (1-year) span.

Lead was considered only for SARs in the baseline assessment; however, lead loading was estimated for all ranges, including non-SARs, in the five-year review. Because fate and transport parameters for lead are dependent on site-specific geochemical properties, potential for lead migration was not quantitatively assessed. A qualitative recommendation was determined based on loading and known site characteristics.

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

2.3. Summary of Areas Addressed

The baseline assessment report identified 33 MC loading areas and 23 SARs. Based on the results of the baseline assessment as detailed above and additional data collected for the five-year review effort, 31 MC loading areas and 37 SARs were evaluated during the five-year review effort. Some of these were grouped based on proximity and similar use and environmental characteristics, as summarized in the following:

- G-10 Impact Area *(included in baseline assessment)*
- K-2 Impact Area *(included in baseline assessment)*
- F-2 and F-5 *(included in baseline assessment)*
- F-6 *(included in baseline assessment)*

- G-5 *(included in baseline assessment as part of G-10 Impact Area MC loading area)*
- G-6 *(included in baseline assessment as part of G-10 Impact Area MC loading area)*
- G-7 *(included in baseline assessment as part of G-10 Impact Area MC loading area)*
- G-8 and G-9 *(included in baseline assessment as part of G-10 Impact Area MC loading area)*
- G-19A and G-19B
- K-211 and K-212 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- K-301 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- K-303 to K-305 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- K-323 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- K-405 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- K-510 *(included in baseline assessment as part of K-2 Impact Area MC loading area)*
- L-5 *(included in baseline assessment as part of L-Ranges)*
- Mobile MOUT Complex *(included in baseline assessment)*
- SR-6
- SR-7
- SR-10
- Combat Town *(included in baseline assessment)*
- EOD-1 *(included in baseline assessment)*
- EOD-2 *(included in baseline assessment)*
- ETA-1 *(included in baseline assessment)*
- ETA-2 *(included in baseline assessment)*
- ETA-3 *(included in baseline assessment)*
- ETA-4 *(included in baseline assessment)*
- ETA-5 *(included in baseline assessment)*
- ETA-7
- G-10A EOD *(included in baseline assessment as part of G-10 Impact Area MC loading area)*
- Stones Bay Area *(included in baseline assessment as Special Operations Training Group (SOTG) North and SOTG South)*

The following SARs were evaluated in the five-year review:

- A-1 *(included in the baseline assessment)*
- B-12 *(included in the baseline assessment)*
- D-29A and D-29B *(included in the baseline assessment)*
- D-30 *(included in the baseline assessment)*
- F-4 *(included in the baseline assessment but not assessed by SARAP)*
- F-11A and F-11B *(included in the baseline assessment)*
- F-18 *(included in the baseline assessment)*
- I-1 *(included in the baseline assessment)*
- K-302 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-309 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-315 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-317 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-319 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-321 and K-321A *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-325 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-402 *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- K-406A and K-406B *(included in the baseline assessment as part of the K-2 Impact Area MC loading area)*
- MAC-1, MAC-2, MAC-4, MAC-5, and MAC-6 *(all but MAC-6 were included in the baseline assessment)*
- Alpha, Bravo, and Charlie Ranges *(included in the baseline assessment)*
- Dodge City *(included in the baseline assessment)*
- Hathcock Range *(included in the baseline assessment)*
- Mechanical Pistol *(included in the baseline assessment)*

- Multi-Purpose *(included in the baseline assessment)*
- Walk-Down Pistol *(included in the baseline assessment)*
- Square Bay
- SR-8
- SR-11

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 (2005 to 2010). At MCB Camp Lejeune, MC loading was conducted for the first time for 12 operational ranges that were not assessed in the baseline assessment; therefore, all historical loading was completed for these areas. Since historical loading was completed for the other MC loading areas in the baseline assessment, it was not completed in the five-year review. Generally, explosives HMX, RDX, and TNT tend to degrade relatively quickly and not accumulate in the environment; however, in order to maintain a conservative approach, degradation was not factored into the historical loading.

The MC loading process for a baseline assessment is outlined in the *REVA Reference Manual* (HQMC, 2009), whereas specifics pertaining to MCB Camp Lejeune are discussed in its baseline REVA Report (Malcolm Pirnie, 2009). 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 MCB Camp Lejeune and defines the specific MC loading areas identified for the installation, and **Section 3.6** provides 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 Web site (DoD, n.d.) and ORDATA database (2008).

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 UXO. MC loading estimates are based upon the sum of the MC deposition associated with each outcome for a given MC loading area. Details on this process are included in the *REVA Reference Manual* (HQMC, 2009).

When calculating MC loading for an area that is determined to be regularly and intensely managed for explosive hazards (e.g., demolition or engineering range), these rates were set to zero. In addition, for the purposes of the REVA program, it was assumed that the amount of residual explosives remaining after a low-order detonation and a high-order detonation was 50% and 0.1%, respectively. Given the nature of metals, lead deposition estimates for the SARAP assumed no consumption from impact of this REVA indicator MC.

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 MCB Camp Lejeune (HQMC, 2009; Malcolm Pirnie, 2009).

3.2. Expenditure Data

The Base S-3 Department is responsible for the administration and oversight of the training operations conducted at MCB Camp Lejeune, as well as coordinating recordkeeping for munitions expenditures at the installation's operational ranges. Summaries of current munitions expenditures were based upon data produced by Range Control. The dates of the records incorporated into this assessment range from October 2004 to September 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 MCB Camp Lejeune:

- The expenditure summaries contain a few instances in which data regarding MC content were not available for the provided DoDICs; there were also instances where no DoDICs were provided. The installation provided a general description of the munitions types used in these cases. These were reviewed, along with available information regarding the associated range, its design, and its regulations. Professional judgment then was used to select surrogate MC loading factors from available data for similar munitions for use in MC loading calculations.
- The expenditure summaries also include entries where the DoDIC and munitions type are not specified (e.g., the munitions title is blank even though some number of expenditures is listed), although these expenditures are tied to a particular range for a given year. Because no other information was available regarding these listings, the unknown expenditures were distributed proportionally per year based on the known expenditures for the respective ranges.

Given these considerations, 6 years of data (October 2004 through September 2010) were used for MC loading calculations associated with current MC loading areas at MCB Camp Lejeune, as well as to determine lead loading estimates at SARs and MC loading areas. Other general assumptions regarding application of these expenditure data to calculating MC loading are discussed in **Section 3.6**. Assumptions specific to individual MC loading areas or ranges are discussed as appropriate in **Section 3.5, Section 3.6**, and **Section 6**.

Additionally, there are cases where expenditure data were not maintained for the entire time the range was in use, yet assessment of the entire period of use is warranted because an operational range was newly identified for the REVA process during this five-year review. In these cases, the amount of military munitions expended over time was estimated through use of the REVA MC Loading Rate Calculator (**Section 3.3**). Generally, historical expenditures were estimated based on extrapolation of the fiscal year (FY)2004–FY2010 expenditure data, as applicable, to documented initial use dates.

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 and 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 put into the MC Loading Rate Calculator for each operational range area assessed are documented in **Section 3.5**, **Seciton 3.6**, and **Section 6**.

3.4. Training Factor

Historically, the level of military training operations has been affected strongly by conflicts and wars, typically fluctuating in association with the start and cessation of a conflict or war. Because of its potential influence on estimation of MC loading during periods where expenditure data are not available, the REVA program assessed this impact by developing a training timeline of significant military conflicts and wars from 1914 to the baseline REVA assessment. Subject matter experts within the Marine Corps were queried to establish time periods of increased training throughout history. This inquiry resulted in the establishment of a baseline training level period, as well as the development of four periods that increase the MC loading rate by a training factor. The periods identified and their associated training factors are as follows:

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

When needed, the MC Loading Rate Calculator automatically applies the training factor adjustments according to the time period so that MC loading rates are estimated for each year the operational range is known or suspected to have been in use. Additionally, 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. As MCB Camp Lejeune opened in 1941, only time periods B through F were assessed for this installation. MC loading was estimated for ranges that were not identified during the baseline; however, only loading from Period F was completed for most MC loading areas since historical loading was accounted for during the baseline assessment.

3.5. Munitions Constituents Loading at MCB Camp Lejeune

3.5.1. Operational Range Profiles

MCB Camp Lejeune is known as the world's most complete amphibious training base. The installation provides specialized training for those serving in U.S. Marine Forces Command and is home to the Marine Corps Engineer School, the II Marine Expeditionary Force, the U.S. Coast Guard's Special Missions Training Center, the Marine Special Operations Command, the School of Infantry-East, and other TECOM formal schools.

As of September 2010, the installation covers approximately 153,439 acres with 107,263 acres dedicated to maneuver, live-fire, amphibious, and tactical training, with fixed ranges located throughout the training area. Approximately 37,560 active military personnel are stationed at MCB Camp Lejeune, with an additional 19,000 servicemen attending military training/schools at the installation each year. Approximately one-quarter of the individual training standards for riflemen, all infantry specialties, and proficiency and sustainment training require live-fire range time; therefore, the live-fire ranges at MCB Camp Lejeune are heavily used as an essential element for training. Demolition training is also a critical component of training at the installation. The demolition training course requires the use of explosive charges to destroy, breach, or create obstacles (MCB Camp Lejeune, 2009a). No munitions use was recorded for MCAS New River or MCOLF Oak Grove; therefore, no further evaluation was conducted at these areas.

The REVA team identified 85 operational range training areas (RTAs) (AA through SW) at MCB Camp Lejeune; 79 are dedicated to tactical maneuver training and 6 are dedicated to amphibious exercises. RTAs cover the majority of the installation, with the exception of the Morgan Bay sector, Farnell Bay area, Courthouse Bay area, Stones Bay Complex, MCAS New River, G-10 Impact Area, K-2 Impact Area, and the N1/BT-3 Impact Area. Five impact areas were identified, of which two are historical use only. Historical and operational fixed ranges, including both small arms and high explosives, are located throughout these training areas and impact areas. There are also 35 gun positions, of which 5 are historical use only, and 8 mortar positions, of which 1 is historical use only. All range and training areas and corresponding details are provided in **Table 3-1**.

During the five-year review, 31 MC loading areas were identified and 14 of these were evaluated using screening-level models. Those MC loading areas not further evaluated have lower MC loading rates, incomplete pathways, and/or lack of surface water or groundwater receptors. MC loading areas are shown in **Figure 3-1**. MC loading areas that were evaluated with screening-level modeling are described in greater detail below.

3.5.1.1. G-10 Impact Area

The G-10 Impact Area is a bombing and target range encompassing 4,995 acres. The impact area has been used since at least 1953, with potential use dating to 1941 (USACE, 2001b). It is located southeast of the main cantonment area and east of Sneads Ferry Road and the New River. There are 55 hard targets within the G-10 Impact Area, and it serves primarily as a familiarization range but has several alternate uses as well. These include air-to-ground weapons fire, helicopter and tiltrotor gunnery, mortar fire, field artillery indirect fire, infantry weapons fire, machine gun fire, guided missile fire, and naval gunfire.

3.5.1.2. F-6

Range F-6 is a hand grenade range encompassing 2.3 acres located in the interior of MCB Camp Lejeune east of Sneads Ferry Road, south of Lyman Road, and northeast of the G-10 Impact Area. F-6 has been operational since 1972. The range contains two open grenade fragmentation impact areas with two throwing pits in each area, which is divided by an earthen berm and contains aiming stakes in each lane/pit area (for a total of eight stakes in the pit area); one practice throwing area with four practice pit structures and aiming stakes; a hand grenade distance and accuracy course with all targets; and a hand grenade assault course with all targets. Public supply wells are located in the immediate vicinity of F-6.

3.5.1.3. G-8 and G-9

Training has not been conducted at Ranges G-8 and G-9 since 2008, but the ranges previously served as a grenade launcher range and a light anti-armor/antitank weapons range, respectively. A base order issued in 1970 indicates that these ranges were in use at that time (USACE, 2001b). They are located immediately beside each other in the northwestern corner of the G-10 Impact Area. G-8 contained 17.9 acres, and G-9 contained 16.81 acres. UXO clearances occurred at G-8 and G-9 in 2005, 2006, and 2008. Public supply wells are located to the northwest, west, and southwest of the ranges. They are located just north of one of the tributaries of French’s Creek, which feeds into the New River.

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
AC	A-1	1958	present	278	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range	
BC	B-12	1960	present	278	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range	
DF	D-9	1960s	present	478	Operational			Skeet Range	Skeet/Trap Firing Range	Shotgun Familiarization Range	Not evaulated as part of REVA
EB	GP-20 (no name)		present	2	Operational			Gun Position			
FA	F-2	1950	present	1152	Operational			Machinegun Field Firing and Multipurpose BZO Range	Squad Automatic Rifle, Transition Range	Squad Live Fire Range, Multipurpose BZO Range, Combat Marksmanship Range	Plans to move range south of G-10 Impact Area in 2015
	F2 Field Firing Range	1950	1976	19	Historical Use						
	F-5	1972	present	1086	Operational			Squad/Fire Team Live Fire Maneuver Course	Squad/Fire Team Live Fire Maneuver Course	Rifle Familiarization Range, Squad Battle Drill Range, Unknown Distance Range, Night Firing Range, CMP Range, Moving Target Range	Plans to move range south of G-10 Impact Area in 2015
	F-25T		present	1826	Operational						
	GP-1 (no name)		present	22	Operational			Gun Position			
	Musketry Range A	1942	1947	19	Historical Use						
FB	F-1 Field Firing Range	1950	1961	48	Historical Use						
	F-4		present	1237	Operational	X		Fire Team/Squad Attack Range	Rifle Familiarization Range	Pistol Familiarizaiton Range, Rifle Marksmanship Range, Shotgun Range	Plans to move range south of G-10 Impact Area in 2015
	F-14 Field Firing Range	1950	1976	63	Historical Use						
FC	MAC-1	1990	present	752	Operational	X	X	Urban Quick Kill Range for Fire Team/Squad Size Units	Urban Quick Kill Range, Basic Room/Building Entry and Clearing Range	Urban Battle Drill Range	
	MAC-2	1990	present	753	Operational	X	X	Search and Kill Range	Search and Kill Range, Basic Room Entry and Clearing Range	Urban Battle Drill Range	
	MAC-3	1990	present	744	Operational/ Indoors	X	X	Live Fire Grenade House	Close Quarters Battle, Live Fire Grenade House	Urban Battle Drill Range, SESAMS Shoot House (mock-up only)	
	MAC-4	1990	present	705	Operational	X	X	Cover and Clear	Fire Team MOUT	Urban Battle Drill Range, CQB Range	
	MAC-5	1990	present	811	Operational	X	X	Dodge City	Basic Squad MOUT Range	Urban Battle Drill Range, Stairwell/Room Clearing Range	
FC	MAC-6	2005	present	766	Operational	X	X	Enhanced Marksmanship Range	Enhanced Marksmanship Range, NBC Field Firing Range, Quick Kill Range, Non-Lethal Range	Urban Battle Drill Range, Rifle BZO Range, Pistol FAM Firing Range, Shotgun Range, Combat Pistol Course Range, Night Firing Range	
	MAC-7		present	25	Operational		X	MOUT M203 Grenadier Gunnery Range	MOUT M203 Grenadier Gunnery Range	M203/M32 Battle Drill Range	
	MOUT Lejeune BIV			4			X	MOUT Facility			
	MOUT Lejeune UTF -2 ST -3 ST		present	27	Operational		X	MOUT complex, shoothouse, 2 story urban training facility with moveable walls/doors, elevator shaft, internal/external ladder walls	MOUT	Room Clearing Operations, Non-Combatant Evacuation Operations, Embassy Reinforcement, Firm Base Operations, Law Enforcement/Emergency Response, MOUT Raid Operations, MOUT Force on Force Events	
	Mobile MOUT Complex		present	20	Operational		X	Mobile MOUT Facility with 71 total Buildings/Containers, 66 non-live fire and 5 live fire containers with roads, 11 tracked vehicle pads, courtyard walls, and tunnels and many more training enhancements	MOUT	Non-Combatant Evacuation Operations, Embassy Reinforcement, Mechanized Raid, Firm Base Operations, Urban Patrolling, COC Operations, Law Enforcement/Emergency Response, Civil Disturbance Operations	
	Mobile MOUT Live Fire Buildings # 2, 24, 36, 40, 67		present	9	Operational/ Indoor		X	Five Separate Live Fire Houses within the Mobile MOUT Complex	Small Arms Live Fire Training, Dynamic Entry Drills, Live Fire Room Clearing, Combat in Built-up Area	Raid Operations	
	MOUT Sniper Tower		present	<1	Operational		X	MOUT Facility			Not shown on figures.
FD	N/A	1941	present	1065	Operational			Maneuver Training Area	Tactical Maneuver Training	mechanized assault training; multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; mechanized combined arms maneuver area	
	F-6	1972	present	31	Operational			Hand Grenade Range	Hand Grenade Range	Hand Grenade Distance and Accuracy Course (non-live fire), Hand Grenade Assault Course (non-live fire)	
	Gas Chamber		present	4	Operational			M40 Series Field Protective Mask Qualification Area	M40 Series FPM Qualification, CBRN Defense Refresher Classes	Decontamination Training Area, CBRN Confidence Course, CBRN Annual Training	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
FE	N/A	1941	present	922	Operational			Maneuver Training Area	Tactical Maneuver Training	mechanized assault training; multipurpose exercise training area; small unit training; infantry tactics maneuver area; command post exercise training	
	GP-2 (Swan)		present	18	Operational			Gun Position			
FF	N/A	1941	present	1021	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; infantry tactics maneuver area; command post exercise training; small dismounted unit training; small unit training	
FG	N/A	1941	present	2173	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; infantry tactics maneuver area; command post exercise training; small dismounted unit training; small unit training; mechanized assault training	
	ETA-3	1994	present	67	Operational			Engineering Training Area	Engineer Demolition Training	Infiltration Course, Obstacle Course, Breaching Course, IED Course	
	F-11A	1950	present	733	Operational	X		Baffled Rifle BZO/Pistol Range	Basic 30 meter firing range (ZERO)	Shotgun Familiarization Range, Modified Table 3 and 4 CMP (Limited)	
	F-11B	1950	present	250	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range, Combat Pistol Course	
	F-12 Field Firing Range	1950	1985	44	Historical Use						
	F-18	1970	present	4160	Operational	X		Machinegun Field Firing Range	Machinegun Field Firing Range	Infantry BZO/Zero Range, Night Vision Firing Range, Sniper Range (7.62mm), Pistol Familiarization Range, Shotgun Familiarization Range, Non-Lethal Ammunition Range, CMP Range	Plans to close this range in 2011.
G-10 Impact Area											
G-10 Impact Area	N/A	1953	present	4995	Operational						
	G-3A			33	Historical Use			M257 Smoke Grenade Launcher	Vehicle Mounted Smoke Grenade Launcher Range	None	
	G-8		2008		Historical Use						Currently not used and plan to replace. Replaced by G-19A and B. Had UXO clearance conducted. A non-dudded Combat Town will eventually be located here.
	G-9		2008		Historical Use				Rocket Range		Currently not used and plan to replace. Replaced by G-19A and B. Had UXO clearance conducted. A non-dudded Combat Town will eventually be located here.
	G-10A EOD		2010	<1	Operational/ Not in Use						No longer in use
	G-10 Urban Close Air Support Facility (UCAS) Lego City		present	11	Operational			G-10 Urban CAS Training Facility (UCAS)	Urban Close Air Support, FAC/JTAC Training	Air to Ground Weapons, Rotary Wing Door Gunnery Range, Aerial Sniper Range (SRR Only)	
GA	N/A	1941	present	767	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; forward observer training; multipurpose exercise training; tactical air control party	
	ETA-4	1994	present	87	Operational			Engineering Training Area	Engineer Demolition Training	Live Fire Breaching Exercises, APOBE Operations	
	G-3		present	9236	Operational			Infantry Weapons Range	Infantry Weapons Range	Mortar Range, Guided Missile Range, Rocket Launcher Range, Grenade Launcher Range, Field Firing Machinegun Range, Sniper Range (Limited), LAR (25mm) Weapons Range, AAV Weapon System Range, Tank (MG Firing Range only)	
	G-19A	2010	present	737	Operational			Light Anti-Armor Weapons and Shoulder Launched Multipurpose Assault Weapon Range	Light Anti-Armor/Anti-Tank Weapons Range, Shoulder-Launched Multipurpose Assault Weapon Range	Light Anti-armor (9mm and 21mm sub-caliber) Weapons FAM Range, SMAW Field Firing Range	
	G-19B	2010	present	73	Operational			Grenade Launcher Range	Grenade Launcher Range	M203/M32 FAM Fire Range, M203/M32 Zeroing Range, M203/M32 Qualification Range	
	MP-7		present		Operational			Mortar Position			
GB	N/A	1941	present	535	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; forward observer training; multipurpose exercise training	
	GP-4 (Penguin)				Historical Use			Gun Position			
	MP-1		present		Operational			Mortar Position			
	MP-2		present		Operational			Mortar Position			
	MP-3		present		Operational			Mortar Position			
GC	N/A	1941	present	623	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; forward observer training	
	GP-5 (Tern)		present		Operational			Gun Position			
	GP-6 (no name)		present		Operational			Gun Position			
	GP-8 (no name)		present		Operational			Gun Position			
	MP-4		present		Operational			Mortar Position			
	MP-5		present		Operational			Mortar Position			
	MP-6		present		Operational			Mortar Position			

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
GD	N/A	1941	present	1102	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; multipurpose exercise training	
	EOD-1	1994	present	45	Operational			Explosive Ordnance Disposal Range (G-10 Impact Area)	EOD Range	None	
	G-6/CBC	estimated 1951	present	3204	Operational			Infantry Company Battle Course	Infantry Company Battle Course, (Company Live Fire and Maneuver)	Basic Techniques of Fire Range, Squad/Platoon, Live Fire and Maneuver Range, Combined Arms Deliberate Attack Range, Machinegun Field Firing Range	
	G-10 Live Fire Convoy Range -Site 3 -Site 4	2004	present	3654	Operational			G-10 Convoy Operations Course	Live Fire/Non-Live Fire Convoy Range	Convoy Battle Drill Range, Convoy Quick Reaction Range, Convoy Counter Ambush Range, Convoy IED Reaction Course, Damaged Vehicle Recovery Operations, Vehicle Check Point Operations, Vehicle Escorting Operations, Blocked/Unblocked Convoy Ambush	
	GP-11 (no name)				Historical Use			Gun Position			
	MP-8				Historical Use			Mortar Position			
GE	N/A	1941	present	527	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; forward observer training; multipurpose exercise training	
	GP-7 (Crane)		present	23	Operational			Gun Position			
GF	N/A	1941	present	643	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; fire support coordinator training; command post exercise training; forward observer training; multipurpose exercise training	
	Machine Gun Range	2011	under construction	132	Future Use			Machine Gun Range			Currently under construction. Expected to open 2011 to replace F-18. Not shown on figures.
GG	N/A	1941	present	1412	Operational			Maneuver Training Area	Tactical Maneuver Training	amphibious support exercises; mechanized combined arms maneuver area; multipurpose exercise training area; tractical maneuver training; mechanized assault training	
	GP-10 (Goose)		present	22	Operational			Gun Position			
	GP-13 (Falcon)		present	32	Operational			Gun Position			
GH	N/A	1941	present	855	Operational			Maneuver Training Area	Tactical Maneuver Training	amphibious support exercises; mechanized combined arms maneuver area; multipurpose exercise training area; tractical maneuver training; mechanized assault training	
	G-5		present	4109	Operational			Vehicle Convoy Range, Infantry Weapons Range, AAV/LAV Gunnery Range	Vehicle Convoy Range, Infantry Weapons Range, AAV/LAV Gunnery Range	Inert Line Charge Range	
	GP-12 (no name)		present	17	Operational			Gun Position			
GI	N/A	1941	present	560	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; mechanized assault training; mechanized combined arms maneuver area; infantry tactics maneuver area	Historical files shows no demo in this training area
	G-7	~1947	present	1946	Operational			Infantry Weapons Range, Field Artillery Direct Fire Range	Infantry Weapons Range/Artillery Direct Fire Range, Direct Fire Range	AAV Gunnery Range, MK-19 40mm Range, .50 cal Machinegun Range	
	GP-9 (Gull)		present	21	Operational			Gun Position			
HA	N/A	1941	present	899	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; small unit training; small dismounted unit training	
	ETA-7	2009	present	770	Operational			Engineering Training Area	Engineer Demolition Training	Steel Cutting Range, Field Expedient Charge Range	Built on footprint of former GP-28
	GP-28 (no name)				Historical Use			Gun Position			
HB	N/A	1941	present	1542	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; small unit training	
	GP-16 (Dodo)		present	19	Operational			Gun Position			
	GP-24 (no name)				Historical Use			Gun Position			
	GP-25 (Dove)		present	10	Operational			Gun Position			
HC	N/A	1941	present	891	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; small unit training	
	GP-29 (Plover)		present	33	Operational			Gun Position			
HD	N/A	1941	present	947	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; small unit training	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
HE	N/A	1941	present	633	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; small unit training; small dismounted unit training; mechanized combined arms maneuver area	
HF	N/A	1941	present	1067	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small dismounted unit training; small unit training	
	Combat Town	1976	present	192	Operational		X	62 Buildings with Compound Walls/Gates	Combat in Built-up Areas, MOUT	Non-combatant evacuation operations (NEO), embassy reinforcement, mechanized raid, helicopter raid	
	GP-14 (no name)		present	19	Operational			Gun Position			
	MOUT Hawk FOB			3			X	MOUT Facility			This is a landing zone within a FOB, not a range
HG	N/A	1941	present	589	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small dismounted unit training; small unit training	
	GP-35 (Finch)		present	18	Operational			Gun Position			
HH	N/A	1941	present	744	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small dismounted unit training; small unit training	
	GP-23 (Jaybird)		present	49	Operational			Gun Position			
IA	N/A	1941	present	1067	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training; command post exercise training; engineer maneuver/training area; mechanized assault training	
	GP-17 (Osprey)		present	21	Operational			Gun Position			
	GP-21 (Heron)		present	18	Operational			Gun Position			
IB	N/A	1941	present	861	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; large unit training; command post exercise training; engineer maneuver/training area; mechanized assault training	
	GP-15 (Quail)		present	27	Operational			Gun Position			
IC	N/A	1941	present	905	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; command post exercise training; engineer maneuver/training area; mechanized assault training	Historical files show no demo in this training area.
	GP-19 (no name)		present	12	Operational			Gun Position			
ID	N/A	1941	present	293	Operational			Maneuver Training Area	Tactical Maneuver Training	amphibious support exercises; assault aircraft landing strip; engineer maneuver/training area; helicopter rappelling; infantry tractics maneuver; mechanized combined arms maneuver area; unmanned aerial system maneuver area; drone maneuver area; boat ramp/launch area	
	GP-22 (Bluebird)		present	72	Operational			Gun Position			
IE	N/A	1941	present	1438	Operational			Maneuver Training Area	Tactical Maneuver Training	command post exercise training; infantry tactics maneuver area; small unit training	
	GP-26 (no name)		present	17	Operational			Gun Position			
	GP-30 (Egret)		present	22	Operational			Gun Position			
IF	N/A	1941	present	1445	Operational			Maneuver Training Area	Tactical Maneuver Training	engineer maneuver/training area; infantry tactics maneuver area; command post exercise training; small unit training	
	ETA-1 -ETA-1 OBST -ETA-1 BRID -ETA-1 FIEL	1994	present	154	Operational			Engineering Training Area	Engineer Demolition Training	Urban Mobility Breachers Course	
	ETA-2	1994	present	1150	Operational			Engineering Training Area	Engineer Demolition Training	Mechanized Assault Course, Breaching Operations, Constructing Tank Traps, ABV Operations and Operator Training	
	GP-27 (Canary)		present	21	Operational			Gun Position			
IG	N/A	1941	present	530	Operational			Maneuver Training Area	Tactical Maneuver Training	engineer maneuver/training area; infantry tactics maneuver area; command post exercise training; small unit training	
	GP-18 (Albatross)		present	17	Operational			Gun Position			
JA	N/A		present	357	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; engineer maneuver/training area; infantry tactics maneuver area	
	GP-31 (Sandpiper)		present	15	Operational			Gun Position			
	GP-33 (Oriole)		present	16	Operational			Gun Position			
JB	N/A		present	194	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; engineer maneuver/training area; amphibious training	Amphibious Support Exercise Area
JC	N/A		present	356	Operational			Maneuver Training Area	Tactical Maneuver Training	swim site/vehicular water crossing; small unit training; tactical maneuver training; engineer maneuver/training area; small boat launch operating area	Amphibious Support Exercise Area
	GP-32 (Kite)		present	17	Operational			Gun Position			
JD	N/A		present	108	Operational			Maneuver Training Area	Tactical Maneuver Training	swim site/vehicular water crossing; small unit training; infantry tactics maneuver area; amphibious training area	
JE	N/A		present	128	Operational			Maneuver Training Area			

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
K-2 Impact Area											
K-2 Impact Area	N/A	1950	present	3237	Operational						
	K-211	estimated 1970	present	388	Operational			Grenade Launcher Range	MK-19 Grenade Launcher Range	M203/M32 FAM Fire Range, M240B/G Medium Machinegun Range, Rocket Range, 81mm/60mm Mortar Range	
	K-212	estimated 1970	present	1158	Operational			Temporary Light Anit-Armor Weapon and Shoulder-Launcher Multipurpose Assault Weapon Range	Temporary AT-4/M72A7 Anti-Tank/Anti-Armor Weapon/MK-153 SMAW Range	MK153 SMAW Field Firing Range, AT-4 Field Firing Range, M72A7 Field Firing Range, M203 (TP Only) Fam-Fire Range	
	K-301	estimated 1970	2006		Historical Use			Light Anti-armor Weapon and Shoulder-Launcher Multipurpose Assault Weapon Range	AT-4 Light Antitank/Anti-armor Weapon Range	MK153 SMAW Field Firing Range; M203 Fam-Firing Range	
	K-302		present	1004		X		Battle Sight Zero/10 meter Qualification Range	Battle Sight Zero and SAW/IAR 10 meter Qualification Range	Rifle Familiarization Range, Pistol Familiarization Range, Shotgun Familiarization Range, SAW/IAR 10 Meter Qualficiation, Non-Lethal Weapons Range, CMP Range (Limited)	
	K-303	estimated 1970	2008	48.8	Historical Use			Basic Techniques of Fire and Mortar Field Firing Range			Berms re-used for K-503
	K-304	estimated 1970	2010	65.1	Historical Use			Helicopter Door Gunnery Range			
	K-305	estimated 1970	2008	78.2	Historical Use			Infantry Weapons Demonstration Range			
K-2 Impact Area	K-309		present	55	Operational	X					
	K-315		present	1232	Operational	X		Day/Night and Combat Field Firing Range	Infantry Familiarization Range	Shotgun Familiarization Range, Pistol Familiarization Range, CMP Range, Night Field Firing Range	
	K-317		present	1576	Operational	X		Close Combat Pistol Rifle and CMP Range	Close Combat/CMP Range	Shotgun Range, Rifle Quick Kill Range, Combat Pistol Range, Rifle BZO Range, Night Live Fire Range	
	K-319		present	1007	Operational	X		Field Firing Range	Fire and Movement Range	Day/Night Live Fire Range, Shotgun/Pistol Fam Firing Range, BZO/Zero Weapon Range, CMP Range	
	K-321		present	1517	Operational	X		M249 Squad Automatic Rifle Transition Range (K-321)	Squad Automatic Weapon (SAW) and Infantry Automatic Rifle (IAR) Transition Range	BZO/Zero Range, Night Live Fire Range, Military Shotgun Range	
	K-321A		present	1514	Operational	X		M249 Squad Automatic Rifle Transition Range (K-321)	Squad Automatic Weapon (SAW) and Infantry Automatic Rifle (IAR) Transition Range	Squad Fire/Movement Range, CMP Range, Night Live Fire Range, Military Shotgun Range	
	K-323		present	74	Operational			Grenade Launcher Range	Grenade Launcher Range	M203/M32 Non-Lethal Range	
	K-325		present	972	Operational	X		Combat Marksmanship Program Range	CMP Range	Shotgun Familiarization Range, Pistol Familiarization Range, Night Vision Device Range	
	K-402		present	990	Operational	X		Fire and Maneuver Range	Individual Tactical Training Range	Infantry Moving Target Range, M249 SAW Transition Range, CMP Range (existing targets only), Squad Battle Drill Range, Uknown Distance Range, Night Firing Range, Weapon/LASER Range	
	K-402A		present	18	Operational/ Indoors	X		House/Room Clearing Range	MOUT	Live-Fire Shooting House	
	K-405		2008		Historical Use						
	K-406A		present	948	Operational	X		CMP Range	CMP Range	M249/M27 Qualification Range, Combat Pistol Range, Shotgun Range	
	K-406B		present	1177	Operational	X		Friend/Foe Reaction Range	Close Combat Range/CMP Range (Behind the Structure)	Small Arms (Quick Kill) Range	
	K-407		present	1177	Operational			Live Fire Ambush Range (Day/Night)	Live Fire Ambush Range	Night Vision Device Firing Range, Quick Reaction Range	
	K-408		present	1173	Operational		X	Urban Obstacle Course	MOUT	Urban Obstacle Course, Close Quarter Battle Firing Range, Night Target Engagement Firing Range	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
	K-501	2010	present	770	Operational			M16/M4/M249 SAW Range	M16/M249 SAW Static Live Fire Range	Rifle familiarization range, SAW/IAR Familiarization Range, SAW/IAR Transition Range, Unknown Distance Range, Night Firing Range, LASER Pointer Range	
	K-501A	2010	present	719	Operational	X		M16/M4/M249 SAW BZO/Zero Range	M16/M249 SAW Static Live Fire Range	Rifle familiarization range, SAW/IAR Familiarization Range, SAW/IAR Transition Range, Unknown Distance Range, Night Firing Range, LASER Pointer Range	
	K-503	2009	present	770	Operational	X		M16/M4 Rifle	M16/M4 Static Live Fire Range	Rifle Familiarization Range, Rifle Unknown Distance Range, Rifle Night Firing Range, Rifle/LASER Pointer Range	
	K-503A		present	719	Operational	X		M16/M4 Rifle BZO/Zero Range	M16/M4 Static Live Fire Range	Rifle Familiarization Range, Rifle Unknown Distance Range, Rifle Night Firing Range, Rifle/LASER Pointer Range	
	K-504A		present	69	Operational			M203/M32 Grenade Launcher Range	M203/M32 Grenade Launcher Range	M203/M32 Non-Lethal Range	
	K-504B		present	15	Operational			M203/M32 Grenade Launcher Range	M203/M32 Grenade Launcher Range	M203/M32 Non-Lethal Range	
KA	N/A	1941	present	617	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; command post exercise training; infantry tactics maneuver area	
KB	N/A	1941	present	1092	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; bivouac sites for live fire ranges; infantry tactics maneuver area	
	K-510	2008	present	52	Operational		X	Live Hand Grenade Range	Live Hand Grenade Range	Hand Grenade Distance and Accuracy Course (non-live fire), Hand Grenade Assault Course (non-live fire)	
	GP-34 (Cardinal)				Historical Use			Gun Position			
KC	N/A	1941	present	1009	Operational			Maneuver Training Area	Tactical Maneuver Training	command post exercise training; infantry tactics maneuver area	
KD	N/A	1941	present	425	Operational			Maneuver Training Area	Tactical Maneuver Training	command post exercise training; infantry tactics maneuver area	
	EOD-2	1970	present	68	Operational			Explosive Ordnance Disposal Range (Verona Loop Area)	EOD Range	None	Receives anything too dangerous to blow up in K-2.
	ETA-5	1994	present	16	Operational			Engineering Training Area	Engineer Demolition Training	Field Expedient Demo Range	
	ETA-5A	1994	present	189	Operational			Urban Breaching House	Breaching Operations	Close Quarters Battle, Room Clearing Operations	
Stone Bay											
Stone Bay Complex	Alpha	mid-1980s	present	1101	Operational	X		Known Distance Ranges (25 yards - 600 yards)	Rifle Marksmanship Training	Unit Rifle Training CMP Ranges	
	Bravo	mid-1980s	present	1081	Operational	X		Known Distance Ranges (25 yards - 600 yards)	Rifle Marksmanship Training	Unit Rifle Training CMP Ranges	
	Charlie	mid-1980s	present	1029	Operational	X		Known Distance Ranges (25 yards - 600 yards)	Rifle Marksmanship Training	Unit Rifle Training CMP Ranges	
	Claymore			1	Operational						
	Dodge City	mid-1980s	present	1591	Operational	X		200 meter multiple supported and elevated shooting positions	urban sniper training	special operations urban training	
	Hathcock Range	mid-1980s	present	1683	Operational	X		50 thru 1000 yard Rifle/Sniper Range	Sniper Live Fire Range	Unknown Distance Range, Moving Target Range	
	Mechanical Pistol	mid-1980s	present	232	Operational	X		50 meter, 50 firing point pistol range	Pistol Marksmanship Range	Combat Pistol Range	
	Multi-Purpose	mid-1980s	present	1109	Operational	X		100 meter small arms range	Rifle Marksmanship Range, CMP/CQB Range, Pistol Rifle Range, Shotgun Range	Combat Live Fire Range	
	Walk Down Pistol		present	379	Operational	X		50 meters, 50 firing point range	Pistol Marksmanship Range	Static Small Arms Training, Combat Pistol Range	
LA	N/A	1941	present	1438	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	
	L-5	1957	present	2329	Operational			Infantry Live Fire Maneuver Range	Infantry Live Fire Maneuver Range	Multi-Purpose Medium Machinegun Range, CMP Range, Field Firing Range, M249 SAW Range, Weapon/LASER Range	
LB	N/A	1941	present	723	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	
LC	N/A	1941	present	1262	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	Size reduced for MARSOC in 2006
LD	N/A	1941	present	349	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	Size reduced for MARSOC in 2006
LE	N/A	1941	present	818	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	
LF	N/A	1941	present	1576	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	
	L-Impact Area	1951	1962	66	Historical Use						
LG	N/A	1941	present	214	Operational			Maneuver Training Area	Tactical Maneuver Training	infantry tactics maneuver area; small unit training	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
	Breacher Pit UTF		present	5	Operational			Breacher Pit	Explosive and Thermal Breaching	None	
	Breacher Training Facility (RR-215)		present	5	Operational			Breacher Training Buildings with Crib Wall	Breaching: Explosive/ballistic thermal and mechanical	None	
	Demo Pit		present		Operational						Not shown on figures
	Demo Facility		present		Operataional						Not shown on figures
	Non-Lethal Weapons (NLW) Range 1		present	5	Operational			Non-Lethal Weapons (NLW) Range (SOTG Only)	NLW Small Caliber Live Fire Range	None	
	Non-Lethal Weapons (NLW) Range 2		present	5	Operational			Non-Lethal Weapons (NLW) Range (SOTG Only) Large Caliber Weapons/Devices	NLW Large Caliber Live Fire Range	NLW Maneuver Range	
LG	Square Bay (RR-227)			252	Operational	X		Live Fire Pistol/Rifle Range	Live Fire Combat Drills with the Pistols/Rifles	CMP Range	
	SOTG Stone Bay Indoor Shoothouse (RR-249)		present	5	Operational			Single Story Building	Close Quarters Battle (CQB) Facility	Explosve/Ballistic/Thermal Breaching	
	Urban Training Facility/RR-243		present	5	Operational			3 Story Training Facility	Close Quarters Battle	Explosive Breaching, Urban Climbing	
MA	N/A	1941	present	1042	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver training	
	M-8 Assault of a Fortified Position Range	1958	1961	0.3	Historical Use						
	M-10 Hand Grenade Range	1958	1961	0.3	Historical Use						
	M-113 Hand Grenade Range	1970	1977	0.3	Historical Use						
	M-115 Hand Grenade Range	1970	1977	0.3	Historical Use						
	MOUT Devil Dog		present	18	Operational		X	MOUT			
MB	N/A	1941	present	1115	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area; helicopter and tiltrotor operations	
MC	N/A	1941	present	1297	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area; helicopter and tiltrotor operations	
MD	N/A	1941	present	1333	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area	
ME	N/A	1941	present	1726	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area; command post exercise training; small dismounted unit training	
MF	N/A	1941	present	1412	Operational			Maneuver Training Area	Tactical Maneuver Training	tactical maneuver training; small unit training; infantry tactics maneuver area; drop zone, para-ops	
QA	N/A	1941	present	1166	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area; command post exercises training	
	GP-3 (Woodpecker)		present	18	Operational			Gun Position			
QB	N/A	1941	present	512	Operational			Maneuver Training Area	Tactical Maneuver Training	mechanized assault training; cross country vehicle maneuver area; small dismounted unit training; wheeled vehicle driving course	
RA	N/A	1941	present	1034	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area	Size reduced for cantonment in 2004
	New Skeet Range	2011	under construction		Future Use			Skeet Range	Skeet/Trap Firing Range		Not evaulated as part of REVA
RB	N/A	1941	present	779	Operational			Maneuver Training Area	Tactical Maneuver Training	small unit training; infantry tactics maneuver area	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
Greater Sandy Run Area (GSRA)											
SA	N/A	1992	present	1248	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SB	N/A	1992	present	1130	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SC	N/A	1992	present	1202	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SD	N/A	1992	present	1456	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
	SR-7	1997	present	11568	Operational			Multi-Purpose Training Range (MPTR)	LAR Crew Qualification Firing Range	LAR/AAV/Mounted Weapons Multipurpose Mechanized Assault Range, Basic Techniques of LAV/MG Gunnery, Armor Moving Target Range, Moving Vehicle Live Fire Range, Helicopter Gunnery Firing Range, Ground/Aerial Sniper Range, Machinegun Range (limited), Convoy Live Fire (limited), TOW live fire range (inert TOW only)	
SE	N/A	1992	present	1686	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SF	N/A	1992	present	4178	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SG	N/A	1992	present	1743	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SH	N/A	1992	present	1076	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SI	N/A	1992	present	3294	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SJ	N/A	1992	present	2292	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
	SR-6	1995	present	6323	Operational			Infantry Platoon Battle Course	Infantry Platoon Battle Course (Fire and Manuever/Movement Range)	Basic Techniques of Fire, Fire and Movement Range, Platoon Battle Drill Range, Vehicle Mounted Weapons Range, Night Attack Range (non-illum)	
SK	N/A	1992	present	2563	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SL	N/A	1992	present	5312	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
	SR-8	2009	present	6042	Operational			Multipurpose Machinegun Range (MPMG)	Machinegun Qualification Firing Range	Sniper Live Fire Range, Basic Techniques MG Gunnery, Vehicle Mounted Weapons Range (stationary, moving), M249 SAW/IAR M27 Transition Range, M240B/G MG Transition Range, Machinegun Table Firing Range, M16/M4 Rifle Range (static fire only)	
	SR-8A	2009	present		Operational			Multipurpose Machinegun Range (MPMG)	Machinegun 10 meter Zero/Qualification Firing Range	Sniper Live Fire Range, Basic Techniques MG Gunnery, Vehicle Mounted Weapons Range (stationary, moving), M249 SAW/IAR M27 Transition Range, M240B/G MG Transition Range, Machinegun Table Firing Range, M16/M4 Rifle Range (static fire only)	Not shown on figures.
SM	N/A	1992	present	1107	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SN	N/A	1992	present	1584	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	

Training Area	Fixed Range	Start Date	End Date	Size (acres)	Status	Small Arms Range	MOUT Facility	Description	Primary Use	Alternate Use	Notes
SO	N/A	1992	present	1658	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SO	SR-10	1997	present	9902	Operational			Multi-purpose range complex	tank crew qualification firing range	LAV/AAV Multi-purpose Mechanized Assault Range, Basic Techniques of Gunnery, Moving Armor Target Range, Mechanized/Convoy Range, Mech Infantry Assault Range, Helicopter Aerial Gunnery, Sniper Live Fire Range	
	SR-11	2001	present	254	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Firing Range	
SP	N/A	1992	present	982	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
SQ	N/A	1992	present	560	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; infantry tactics maneuver area	
SR	N/A	1992	present	990	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
ST	N/A	1992	present	2421	Operational			Maneuver Training Area	Tactical Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training	
	SR-12	2010	present		Operational			JIEDDO Site; Driving Course on IED's			Opened October 2010; not shown on figures. Per Dave Lynch: this is not a range but rather a home station driving course.
SU	N/A	1992	present	1447	Operational			Maneuver Training Area	Tactical Maneuver Training	mechanized assault training; multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training; mechanized combined arms maneuver area	
SV	N/A	1992	present	2459	Operational			Maneuver Training Area	Tactical Aviation and Ground Maneuver Training	multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; mechanized combined arms maneuver area; airfield seizure facility	
	Camp Davis, Airfield Seizure Facilities -Davis TOW		present	369	Operational			Mock Airfield Structures for Joint/Combined Training/Exercises	Tactical Airfield Assault and Seizure	Multi-purpose Maneuver Area, Infantry Dismounted Training, Helicopter Assault/Seizure, Mechanized Assault/Seizure	
SW	N/A	1992	present	658	Operational			Maneuver Training Area	Tactical Maneuver Training	mechanized asault training; multipurpose exercise training area; small unit training; small dismounted unit training; infantry tactics maneuver area; command post exercise training; mechanized combined arms maneuver area	
	D-29A	1958	present	278	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range/Combat Pistol Course	
	D-29B	1958	present	278	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range/Combat Pistol Course	
	D-30	1958	present	278	Operational	X		Baffled Pistol Range	Pistol qualification/requalification	Pistol Familiarization Range/Combat Pistol Course	
	I-1	1960	present	1203	Operational	X		Baffled Small Arms Range, Pistols, Rifle, Shotgun Range	Small Arms Qualification/Requalification Range, Non-Lethal Weapons Range, Shotgun (non-lethal only)	Small Arms Familiarization	Fires toward water
	M-Impact Area	1941	1945	135	Historical Use						
Bear Island, Brown's Island Bombing Target	Rocket Range 2	1945	1947	14	Historical Use						
MCOLF Oak Grove	Small Arms Range	1950	1970	1	Historical Use						Not shown on figures.
	Skeet Range	circa 1944		15	Historical Use						Not shown on figures.
N1/BT-3 Impact Area	Brown's Island	1945	1976	1038	Operational						
	E-1		present	9502	Operational/ Fires to Sea			Air Defense Firing Range	Anti-aircraft range	.50 machine gun range	Fires toward water
	H-Range		present	7095	Operational/Water Range			Waterborne Live Fire Range	Riverine Assault Range, Waterborne Gunnery Range, Oceanside Gunnery Range	Rotary Wing Aerial Gunnery Range	Fires toward water
	Naval Gunfire		present	33478	Operational/Water Range						Range located in Onslow Bay and fires into G-10 Impact Area
New River	MOUT Geiger FOB		present	18	Operational		X	MOUT			
UXO Area	UXO Area			127	Historical Use						Per Dave Lynch: this is a chemical dumping ground that Bob Lowder is currently working to clean up as MARSOC is hoping to use the area.

Notes

Data not available
N/A: data not applicable
New Range
Not evaluated in Reva

Training Area acreage and Fixed Range acreage is not additive
Acreage is combined SDZ and fixed range area

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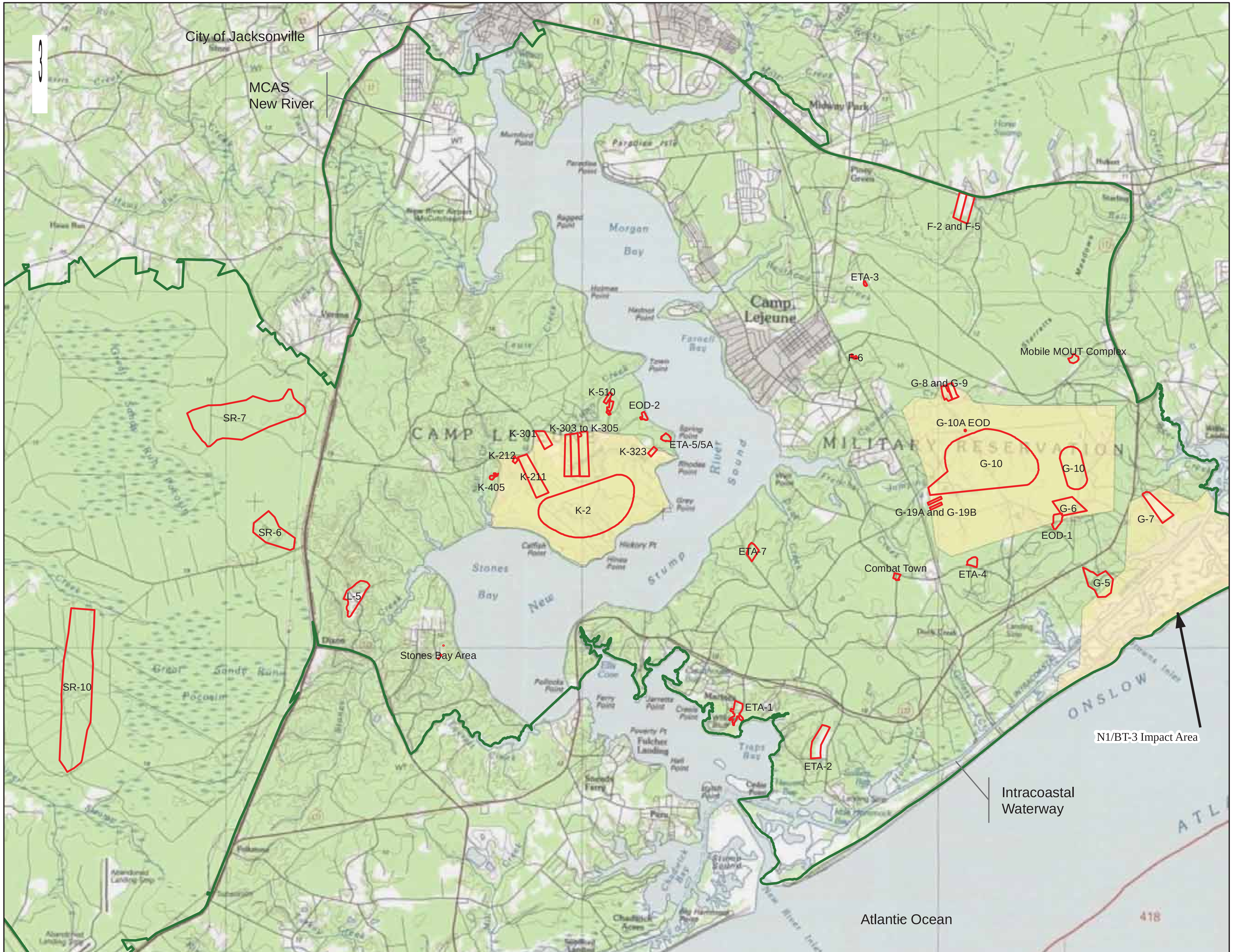
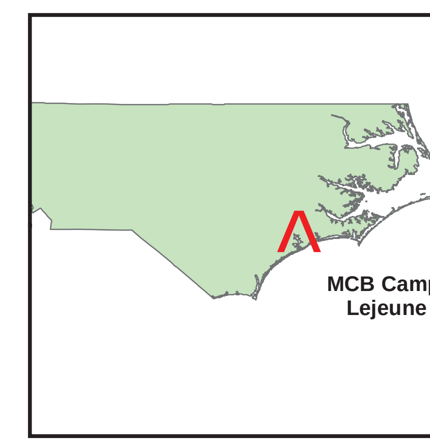


FIGURE 3-1
MCB Camp Lejeune
MC Loading Areas

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- Impact Area



0 0.45 0.9 1.8 2.7
Miles

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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3.5.1.4. K-211 and K-212

K-211 and K-212 encompass 97.3 acres and 3.8 acres, respectively. A base order issued in February 1970 indicates the ranges were in use at that time (USACE, 2001b), and they continue to be used today. These ranges are located on the northwestern side of the K-2 Impact Area. K-211 is a grenade launcher range, and K-212 is a temporary light anti-tank weapon and shoulder-launched multipurpose assault weapon range.

3.5.1.5. K-405

Range K-405 encompassed 4.2 acres. Based on expenditure data and discussions with Range Control personnel, training at the range is estimated to have been suspended in 2008. The PRA indicates use of small arms at this range (same approximate location) from 1970 to 1974. More recent use of this range includes practice hand grenades, smoke grenades, and fragmentation hand grenades. A UXO clearance was completed at K-405 in 2009. This range is located just east of Mill Creek, which empties into Stones Bay.

3.5.1.6. K-510

Range K-510 encompasses 16.5 acres and has been in use since 2008 as a live hand grenade range, replacing Range K-405. Authorized ammunition includes practice, HE, and fragmentation hand grenades. It is located approximately one-half mile north of the K-2 Impact Area and one-half mile west of the New River. It is located along Town Creek, which empties into the New River. Range K-510 opened in 2008, and therefore, it was not assessed in the baseline.

3.5.1.7. L-5

Range L-5 is an 85-acre range located northwest of Stones Bay and west of the K-2 Impact Area; it is used primarily as an infantry live-fire maneuver range. L-5 was first used in 1957 and continues to be used today. L-5 is located along intermittent streams west of Stones Creek.

3.5.1.8. F-2 and F-5

Range F-2 is a 64-acre machine gun field firing and multipurpose battle site zero (BZO) range with no permanent targets. It has been operational since 1940. Range F-5 has been operational since 1972 and is used as a 65-acre squad/fire team live-fire maneuver course. F-2 has no permanent targets, but units can place silhouette targets or arrange for portable infantry target systems (PITS). F-5 has 43 pop-up targets and 2 moving infantry targets (MITs). Although there is no impact berm downrange, an incline berm is located behind the 500-yard line.

3.5.1.9. ETA-1

ETA-1 is a 30.6-acre engineer training area dedicated to engineer demolition training. Alternate uses of the range include an infiltration course and urban mobility breacher course. This area includes a multi-training area, two demolition pits, and one urban mobility breacher course. ETA-1 is located east of the New River between Courthouse Bay and Traps Bay. It has been in use since 1994.

3.5.1.10. ETA-3

ETA-3 opened in 1994 as a 2-acre engineer training area dedicated to engineer demolition training. Alternate uses of the range include an infiltration course, obstacle course, breaching course, and improvised explosive device course (MCB Camp Lejeune, 2010b). This area includes a night infiltration course, land navigation course, ropes course, combat obstacle course, and a field fortification and trench complex (USACE, 2001b). ETA-3 is located east of the New River in the northern part of the installation.

3.5.1.11. ETA-4

ETA-4 opened in 1994 as a 14.5-acre engineer training area dedicated to engineer demolition training. Alternate uses of the range include live-fire breaching exercises and anti-personnel obstacle breaching exercise operations (MCB Camp Lejeune, 2010b). There is an open demolition area, and no targets are present. This ETA is located south of the G-10 Impact Area and east of Snead's Ferry Road. It lies northwest of Freeman Creek, which empties into the Intracoastal Waterway.

3.5.1.12. ETA-7

ETA-7 is a 25-acre engineer training area dedicated to engineer demolition training. Alternate uses of the range include a steel cutting range as well as a field expedient charge range (MCB Camp Lejeune, 2010b). This ETA is located east of the New River across from Stones Bay and west of Snead's Ferry Road. ETA-7 opened in 2009 and, therefore, was not evaluated in the baseline assessment.

3.5.1.13. Stones Bay Area

Training facilities/ranges located immediately south of the Stones Bay Complex were designated as the Stones Bay Area MC loading area. These ranges were combined into one MC loading area because of proximity to one another. The Stones Bay Area MC loading area includes the following training facilities:

- RR-NLW (Non-lethal Weapons) Grenade 1
- RR-NLW Grenade 2
- RR-Urban Training Facility Breacher Pit

RR-NLW Grenade 1 and Grenade 2 opened in 1998 and 1999 as NLW ranges, and the Breacher Pit is used for breacher training. Targets at the Breacher Pit include doors, windows, walls, and a roof façade. Thermal and explosive breaching devices are used at the Breacher Pit, while small caliber NLW systems, non-lethal grenades, and non-lethal devices are used at the NLW ranges. These ranges are located less than one-half mile west of Stones Bay.

3.5.1.14. EOD-2

EOD-2 consists of approximately 6.6 acres and is located northeast of the K-2 Impact Area on the west bank of the New River. Standard procedures for the demolition of ammunition include 4-foot deep pits with 2 ft of soil over top. General types of ammunition used at the range include dynamite, C-4 and TNT demolition charges, detonation cord, shape and cratering charges, and small arms ammunition.

3.5.2. Small Arms Range Profiles

Thirty-seven SARs, five of which are considered MOUT ranges (MAC ranges), were qualitatively evaluated as part of the five-year review using the SARAP. Due to similar use and location, they were grouped into a total of 27 evaluations, which are provided in **Appendix A**. SARs are distributed throughout the installation at MCB Camp Lejeune, as seen in **Figure 3-2**. The SARs are presented in **Table 3-2** and are described in detail in **Section 7**.

Table 3-2: SARs at MCB Camp Lejeune

Range Name	Size (acres)	Type of Range
A-1	0.39	Pistol qualification range
B-12	0.25	Pistol qualification range
D-29A and D-29B	D-29A: 0.2 D-29B: 0.16	Pistol qualification ranges
D-30	0.26	Pistol qualification range
F-4	34.5	Rifle familiarization range
F-11A and F-11B	1.72 (total)	F-11A: Rifle BZO/Pistol range F-11B: Pistol qualification range
F-18	67.30	Machine gun field firing range
I-1	0.51	Small arms qualification range
K-302	19.26	BZO and machine gun 10-meter qualification range

Range Name	Size (acres)	Type of Range
K-309	54.75	Machine gun zeroing and live fire qualification range
K-315	13.59	Infantry familiarization firing range
K-317	13.40	Close combat pistol/rifle and Enhanced Marksmanship Program (EMP) range
K-319	6.33	Fire and movement range
K-321 and K-321A	33.27	Squad automatic weapon transition range
K-325	12.36	EMP range
K-402	15.99	Individual tactic training range
K-406A and K-406B	K-406A: 5.12 K-406B: 5.75	Basic room clearing range Close combat/EMP range
MAC-1 (grouped with other MAC ranges for SARAP)	12.63	Urban quick kill range, basic room entry and clearing range, EMP
MAC-2 (grouped with other MAC ranges for SARAP)	12.63	Search and kill range, basic room entry and clearing range
MAC-4 (grouped with other MAC ranges for SARAP)	12.63	Fire team MOUT
MAC-5 (grouped with other MAC ranges for SARAP)	12.63	Basic squad MOUT range
MAC-6 (grouped with other MAC ranges for SARAP)	12.63	EMP range
Alpha, Bravo, Charlie Ranges	Alpha: 29.40 Bravo: 34.11 Charlie: 37.01	Rifle marksmanship range
Dodge City	1.86	Urban sniper training
Hathcock Range	42.81	Sniper training
Mechanical Pistol	1.43	Pistol marksmanship
Multi-Purpose	1.64	Rifle marksmanship, special operations rifle, pistol, and shotgun training
Walk-Down Pistol	1.26	Pistol marksmanship

Range Name	Size (acres)	Type of Range
Square Bay (RR-227)	0.22	Five fire pistol/rifle range
SR-8	186.98	Machinegun qualification firing range
SR-11	0.90	Pistol qualification range

Note:
TP = target practice

3.6. MC Loading Assumptions

3.6.1. 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.

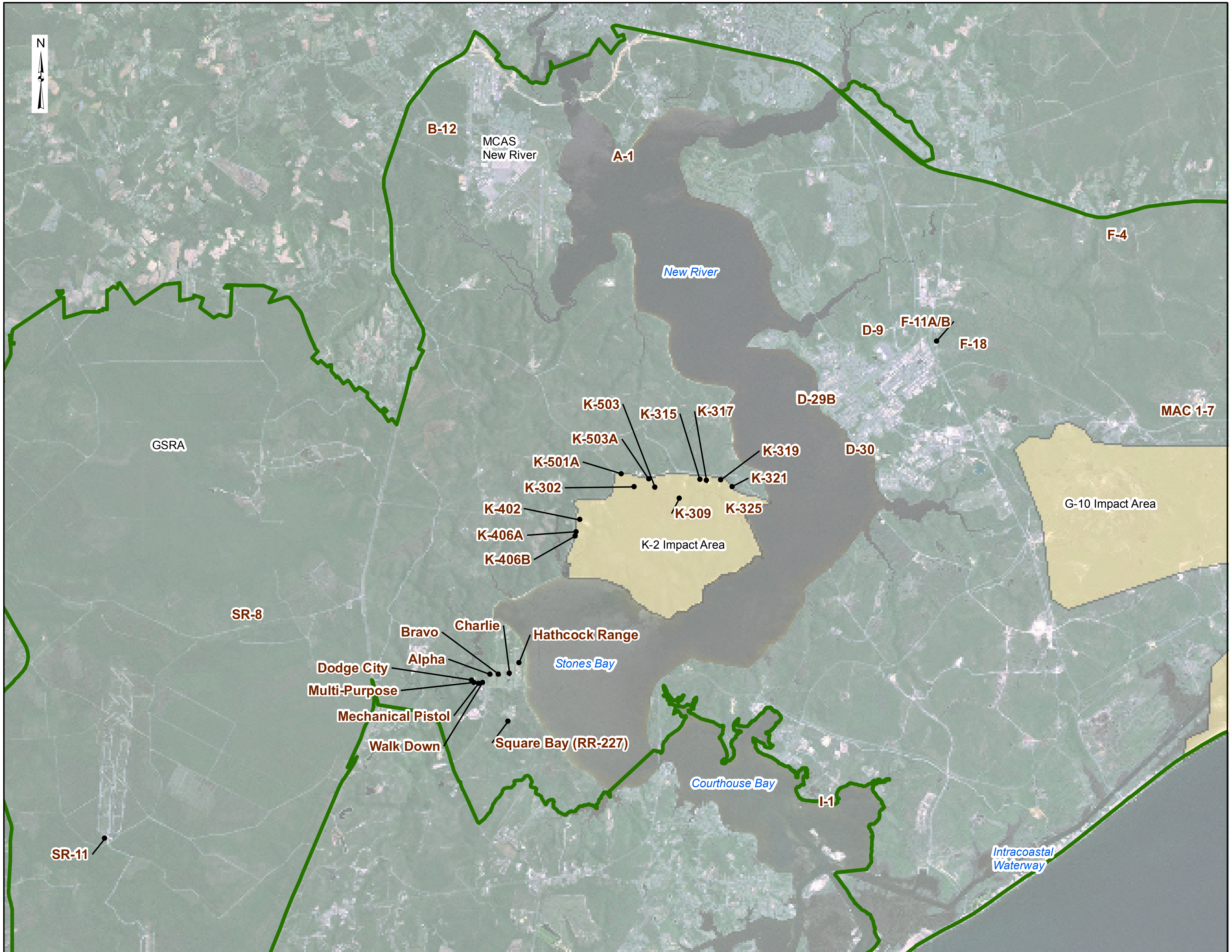
- Only the main fillers and perchlorate components (REVA indicator MC) are included in the estimates. The amount of MC in fuzes, boosters, and other components is not considered significant enough, by comparison, to impact the MC loading amounts.
- All REVA indicator MC are considered 100% pure and, 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, predefined rates will be implemented. The source of the rates used will be included in the installation-specific assumptions.
- 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.
- In the event that data are unavailable for the entire training period identified, methods for estimating those MC loading periods will be implemented.

HE and perchlorate were evaluated at MC loading areas where significant HE use has been documented; lead was evaluated at all MC loading areas, operational SARs, and live-fire MOUTs. Calculation of representative annual values of expenditures at the ranges was performed to help characterize 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. Due to the limited data available, the MC and lead loading analysis processes for areas in which historical loading was estimated required various assumptions pertaining to the quantities of expenditures over time. As noted in Section 3.2, conservative extrapolations of expenditure totals were made from existing data for current MC loading areas and ranges in order to account for missing years.

The specific methodologies and assumptions used to conduct the MC loading at each MC loading area are detailed in **Section 6**.

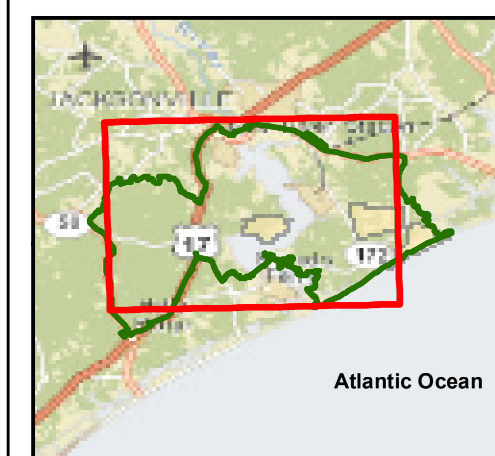
FIGURE 3-2
SARs at MCB Camp Lejeune

MCB Camp Lejeune
Jacksonville, NC



Legend

- Installation Boundary
- Impact Area



0 0.45 0.9 1.8
Miles

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

ARCADIS MALCOLM PIRNIE

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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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 MCB Camp Lejeune 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 MCB Camp Lejeune. Key information sources used in the development of the CSM include the following:

- Military munitions expenditure data
- MCB Camp Lejeune GIS shapefiles
- MCB Camp Lejeune map room files
- Resource management plans
- Environmental site assessments
- Topographic maps and regional groundwater resources report
- MCB Camp Lejeune Integrated Natural and Cultural Resources Management Plan
- U.S. Geological Survey (USGS) Military Geology Branch
- Climate data

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 a generalized MC loading area, the range boundary, and potential receptors (e.g., drinking water reservoirs/wells, ecological receptors).

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

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Notes:

Surface features shown are not intended to be exact locations but rather are representative of those present on the installation.

Possible MC Migration Pathways:
- Most surface water drains into the New River either directly or via its tributaries, with some southern areas draining into the Intracoastal Waterway before discharging into the Atlantic Ocean.
- Potential transport from the surficial aquifer to the Castle Hayne Aquifer in areas where the Castle Hayne Confining Unit is thinned or missing.
- Shallow groundwater discharges to the New River, all its tributaries (including swamps, wetlands, and streams), and the Atlantic Ocean.
- Surface water is used for fishing, boating, swimming, and training.
- The Castle Hayne Aquifer is a drinking water source.

T & E species present in surface waters at the installation include the Atlantic Loggerhead sea turtle, the green sea turtle, and the American alligator.

Not to Scale

FIGURE 4-1
Graphical Conceptual Site Model of MCB Camp Lejeune

ARCADIS MALCOLM PIRNIE
Infrastructure · Water · Environment · Buildings

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4.1. Installation Profile

CSM Information Profiles – Facility Profile – MCB Camp Lejeune	
Information Needs	**Information**
Installation location	MCB Camp Lejeune is located in Onslow County, NC. The installation consists of 246 square miles (153,439 acres) and is bisected by the New River. The Atlantic Ocean forms the southeastern boundary, providing approximately 14 miles of beachfront, and the city of Jacksonville, NC is located immediately northwest of the primary cantonment area east of the New River.
Date of establishment	The first surveys of the installation area were completed in 1940, and by April 1941, construction for the new Marine Corps Base began. The training center was formally organized at Camp Lejeune by the end of 1941. In the early 1970s, the installation covered 110,000 acres, and an additional 44,000 acres (GSRA) were added in 1992 to alleviate deficiencies in operational land training areas and available operational firing ranges. Additional details pertaining to the history of the installation are provided in the baseline REVA report (Malcolm Pirnie, 2009).
Installation mission	The mission of MCB Camp Lejeune is to aid, assist, facilitate, and expedite the training of the operational forces of the United States of America so they are prepared to fight anywhere around the globe. The installation also aims to provide support and services that enhance operational readiness and quality of life for the operating forces and Camp Lejeune community. As of 2010, MCB Camp Lejeune provides deployment support to warfighting commands and resident formal school training to approximately 42,000 Marines per year in the School of Infantry-East, Marine Corps Combat Service Support Schools, Marine Corps Engineer School, Field Medical Support School, and the U.S. Coast Guard's Joint Maritime Training Center.
Installation area and layout	MCB Camp Lejeune covers approximately 246 square miles and is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean. The Atlantic Ocean forms the southeastern boundary of the facility, which contains approximately 14 miles of beachfront. MCAS New River is located in the northern part of the installation on the eastern bank of the New River. The city of Jacksonville is located immediately northwest of the primary cantonment area. MCOLF Oak Grove is operated by and considered part of MCB

CSM Information Profiles – Facility Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Camp Lejeune and is located northwest of MCB Camp Lejeune in southeast Jones County, west of the town of Pollocksville, NC. It is approximately 956 acres and is bordered to the south and west by the Trent River. MCB Camp Lejeune is in the adjacent county of Onslow, NC.

4.2. Operational Range Profile

CSM Information Profiles – Operational Range Profile – MCB Camp Lejeune	
Information Needs	**Information**
Range locations	MCB Camp Lejeune maintains numerous operational ranges within its boundaries (and extending into the waters of the Atlantic Ocean). Operational ranges are located throughout the installation, as seen in **Figure 1-1**. The installation is divided into approximately 85 training areas, with each training area divided into subtraining areas. Training areas cover the majority of the installation, with the exception of the Morgan Bay Sector, Farnell Bay Area, Courthouse Bay Area, Stones Bay Complex, MCAS New River, G-10 Impact Area, and K-2 Impact Area. Several ranges are concentrated around the G-10 Impact Area and the K-2 Impact Area, which receive the majority of loading, and several SARs are located at the Stones Bay Complex near Stones Bay.
Ranges	In September, 2010, the REVA team identified 85 operational training areas and three operational impact areas, and 101 operational ranges. Of the 101 operational ranges, 44 are SARs, 14 are MOUT areas, 7 are ETAs, and 3 are EOD areas (one of which is no longer used). Seven SARs were identified in addition to the 37 SARs evaluated in the five-year review (total of 44 SARs). These seven SARs were not evaluated because five had no expenditure data and two are contained indoors. There are also 30 operational gun positions and 7 operational mortar positions. Details on these RTAs, impact areas, and ranges are provided in **Table 3-1**. Operational impact areas include G-10 Impact Area, K-2 Impact Area, and N1/BT-3 Impact Area. All mortar positions surround and fire to the G-10 Impact Area, which is located on the eastern side of the installation. Seven of the gun positions fire to both the K-2 and G-10 Impact Areas, and the remaining gun positions fire only to the

CSM Information Profiles – Operational Range Profile – MCB Camp Lejeune	
Information Needs	**Information**
	G-10 Impact Area. The K-2 Impact Area is located on the western side of the installation, and the N1/BT-3 Impact Area is located in the southeastern corner of the installation extending into the Atlantic Ocean. Few expenditures were recorded for the N1/BT-3 Impact Area; therefore, it was not designated as an MC loading area.
Date of establishment	The first training areas were established at the installation in 1941, and N1/BT-3 Impact Area became operational in 1945. The K-2 Impact Area and the first F ranges opened in 1950, and the G-10 Impact Area opened in 1953. The Stones Bay Complex was established in the 1980s, MACs 1–5 opened in 1990, and the ETAs opened in 1994 (except for ETA-7, which opened in 2007). The GSRA was acquired in 1992, and training areas became operational that same year, with the first fixed range in the GSRA opening in 1995. It is currently unknown when many of the fixed ranges were established at MCB Camp Lejeune, and new ranges are continuing to be built.
Range area	As of September 2010, the G-10 and K-2 Impact Areas are 4,995 and 3,237 acres, respectively. Operational fixed ranges total approximately 12,000 acres, whereas range fans total approximately 80,500 acres.
Range design	Ranges are positioned around the perimeter of the G-10 Impact Area inward toward the impact area. These currently include G-3, G-8 (training no longer conducted), G-9 (training no longer conducted), G-6, G-10, G-19A, and G-19B. Ranges located in the northeastern part of the installation fire toward the same area in the northeast. Firing south to southwest are F-2, F-4, and F-5; firing in a northwestern direction are the MAC ranges; and firing to the east are F-11A, F-11B, and F-18. Ranges in the southeastern part of the installation fire in a southeastern direction toward the Atlantic Ocean. These include G-5, G-7, and H-Range. K-Ranges are position along the northern boundary of the K-2 Impact Area and fire south into the impact area. GSRA ranges generally fire to the north, west, or northwest.

CSM Information Profiles – Operational Range Profile – MCB Camp Lejeune	
Information Needs	**Information**
	SARs located along the eastern bank of the New River fire west toward the New River. These include D-29A, D-29B, and D-30. SARs A-1 and B-12, located in the northernmost part of the installation, fire south. SARs included in the Stones Bay Complex fire in a northern direction. Other ranges are designed to maintain SDZs inside the installation boundary.
Other features	There are five live-fire buildings/indoor ranges at the MOUT Lejeune Complex. Fixed range K-402A is also an indoor range; as such, these contained ranges are not assessed as part of REVA. Ranges H-1 and E-1 fire at targets located on the Atlantic Ocean. The installation contains 48 tactical landing zones (LZs), 12 ground and 5 water drop zones, eight observation posts, and a landing helicopter dock training site for helicopter and tilt rotor pilot training. There are 200 square miles of special use airspace, restricted for military use from sea level to 17,999 ft. MCB Camp Lejeune also controls MCOLF Oak Grove, which includes seven training areas, three runways, and two tactical LZs. No munitions are used at MCOLF Oak Grove.
Military munitions usage	A wide variety of munitions is used at the ranges and training areas distributed across MCB Camp Lejeune. The extensive list of military munitions usage can be found in the Final Range Summary for MCB Camp Lejeune, in **Table 3-1**.
MC loading areas	The REVA team delineated 31 MC loading areas within the MCB Camp Lejeune: • G-10 Impact Area MC loading area • K-2 Impact Area MC loading area • Ranges F-2 and F-5 MC loading area • Range F-6 MC loading area • Range G-5 MC loading area • Range G-6 MC loading area • Range G-7 MC loading area • Ranges G-8 and G-9 MC loading areas • Ranges G-19A and G-19B MC loading areas • Ranges K-211 and K-212 MC loading areas

CSM Information Profiles – Operational Range Profile – MCB Camp Lejeune	
Information Needs	**Information**
	• Range K-301 MC loading area • Range K-303 to K-305 MC loading area • Range K-323 MC loading area • Range K-405 MC loading area • Range K-510 MC loading area • Range L-5 MC loading area • Mobile MOUT Complex MC loading area • Range SR-6 MC loading area • Range SR-7 MC loading area • Range SR-10 MC loading area • Combat Town MC loading area • EOD-1 MC loading area • EOD-2 MC loading area • ETA-1 MC loading area • ETA-2 MC loading area • ETA-3 MC loading area • ETA-4 MC loading area • ETA-5 MC loading area • ETA-7 MC loading area • G-10A EOD MC loading area • Stones Bay Area MC loading area
Range maintenance	Regular maintenance activities of the ranges generally include maintenance of vegetation to prevent overgrowth on the ranges. Sweeps of the fire and maneuver areas are conducted in order to maintain safe working conditions. Operations and Training is responsible for this type of maintenance of ranges, training areas, and training facilities. Impact areas are swept periodically by EOD to remove UXO and in conjunction with semiannual retargeting operations. High frequency use ranges are swept as often as scheduling allows (MCB Camp Lejeune, 2010b). UXO clearance activities include surface and subsurface clearance to depths as great as 8 ft bgs. From 2004 - 2010, 36 ranges were cleared of UXO. Some of these are historical use areas/ranges, and some are ranges that continue to be used today. As of September 2010, six additional ranges were identified for clearance as soon as funds become available.

CSM Information Profiles – Operational Range Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Range berms have been mined for lead on an as-needed basis or as berms are pulled out of service. Ranges with heavy small arms use where spent bullets are left on the ground have been maintained by sifting soil as needed and as scheduling allows. Bullet traps located at SARs are on a regular maintenance schedule to maintain the traps and remove lead debris. Bullet traps are inspected monthly and cleaned every quarter. Cleanings include changing the high-efficiency particulate air filter and grease fittings and inspecting the traps and steel. Targets are inspected monthly.
Range security	All of the operational ranges are located within the MCB Camp Lejeune boundary. Access is gained only through secured gates, which require screening by a security officer in order to pass through the gate. Access to the installation is limited to installation personnel (military and nonmilitary) and contractors with escorts. The entire installation is fenced along its perimeter, with various access points with locked gates present around the facilities.

4.3. Physical Profile

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
Climate	MCB Camp Lejeune has a warm, temperate climate. Winters are cool with occasional brief cold spells. Annual precipitation data from the State Climate Office of North Carolina for 1971–2001 estimate an average annual precipitation of 54 inches per year (in/yr). The average snowfall is about 3 in/yr. Hurricanes are not unusual near MCB Camp Lejeune and have caused severe flooding and damage in low-lying areas near the ocean, sounds, bays, river, and creeks. According to U.S. Department of Agriculture Soil Conservation Service (1992), 56 hurricanes passed across or close by the North Carolina coast between 1900 and 1986.

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
Elevation	The elevation of MCB Camp Lejeune ranges from mean sea level (msl) to 72 ft amsl. The majority of the land area occupies a geomorphic terrace at an elevation ranging from 24 to 42 ft amsl (USDA SCS, 1992). A thin narrow strip of land near the coast of MCB Camp Lejeune occupies a lower terrace at an elevation ranging from sea level to 24 ft amsl.
Topography and geologic features	MCB Camp Lejeune is located within the Tidewater region of the Atlantic Coastal Plain physiographic province, in the lower Coastal Plain of North Carolina. The topography at MCB Camp Lejeune consists of flat terraces underlain by unconsolidated sediments. Although most of the installation is relatively flat with slopes of less than 2%, steeper topography with slopes of 2% to 15% is present in the valleys of the dendritic stream systems that dissect the terraces. The land at MCB Camp Lejeune can be categorized as upland, floodplains and riparian wetlands, barrier islands, and low-lying pocosin areas. The MCB Camp Lejeune area is underlain by an eastward-thickening wedge of marine and nonmarine sediments ranging in age from early Cretaceous to Holocene (CH2M Hill, 2008). The eastward-thickening wedge of sediment varies from a thickness of zero near the Fall Line, which is at the western boundary of the Atlantic Coastal Plain physiographic province to more than 10,000 ft near and under the Atlantic Ocean (Winner and Coble, 1989). The several thousand feet of interlayered, unconsolidated sediment that is present at the coastline consists of gravel, sand, silt, clay deposits, calcareous clays, shell beds, sandstone, and limestone. This unconsolidated sediment was deposited over pre-Cretaceous crystalline basement rock. Minor amounts of detrital carbonate shells and secondary minerals, such as glauconite, siderite, and chlorite, often distinguish these sedimentary units (CH2M Hill, 2008). The sequence of the unconsolidated sedimentary deposits at MCB Camp Lejeune is estimated to reach a thickness of 1,400 to 1,700 ft (O'Brien and Gere, 1988).
Hydrostratigraphy/ aquifers	The unconsolidated sediment deposits that underlie MCB Camp Lejeune have been divided into seven hydrostratigraphic units or aquifer systems. The aquifer systems from shallow to deep are the surficial, Castle Hayne, Beaufort, Peedee, Black Creek,

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
	upper Cape Fear, and lower Cape Fear aquifer systems. The two most important aquifer systems near MCB Camp Lejeune are the surficial and the Castle Hayne aquifers. The Castle Hayne aquifer is used for potable water at the installation and the surrounding areas, and the surficial aquifer that overlies the Castle Hayne aquifer is a source of recharge for the Castle Hayne aquifer. As a result, the surficial and the Castle Hayne aquifers are discussed in greater detail here. The surficial aquifer at MCB Camp Lejeune is composed of Pleistocene deposits and recent deposits of sand and silts and the upper portion of the Belgrade Formation. It is the first-encountered aquifer beneath MCB Camp Lejeune. This unconfined aquifer is recharged from rainfall and is the source of recharge to the underlying confined aquifers as well as the source of base flow to streams. The surficial aquifer ranges in thickness from 0 ft in the channel of the New River and its tributaries to 75 ft in the southeastern portion of MCB Camp Lejeune (Harden et al., 1989). The bottom of the surficial aquifer is at or near msl throughout the majority of the installation. The hydraulic conductivity of the surficial aquifer on the installation has been measured by rising/falling head tests and pumping tests conducted during various remedial investigations. The average hydraulic conductivity of the surficial aquifer at two Installation Restoration Program (IRP) sites was 3 feet/day (ft/d) (Baker Environmental, 1998a). The aquifer is not used as a potable water supply by MCB Camp Lejeune or neighboring public water supplies, and its potential future use as a public water supply source is limited due to its relatively low yield, inconsistent quality, susceptibility to groundwater contamination, and the potential for saltwater intrusion within the aquifer. While there are some individual domestic wells using the surficial aquifer within the county, use is limited due the relatively low yield. The Castle Hayne confining unit underlies the surficial aquifer and overlies the Castle Hayne aquifer. This unit is a thin, discontinuous clay to clayey sands and silts from one or more of

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
	the following lithologic units: the lower portion of the Belgrade Formation, the River Bend Formation, or the Castle Hayne Formation (Cardinell, Berg, and Lloyd, 1993). The thickness of this confining unit is generally 5 to 9 ft near MCB Camp Lejeune and has an estimated vertical hydraulic conductivity ranging from 0.0014 to 0.41 ft/d (Baker Environmental, 1998a; Cardinell, Berg, and Lloyd, 1993). It is not present in the area of New River and some of its larger tributaries (Geophex, 1994; Baker Environmental, 1998a). It is also absent in localized areas containing buried paleochannel deposits (Geophex, 1994). Additionally, it may be absent in areas of the installation where there are solution features and sink holes (Harden et al., 2004). Because of the limited thickness and the discontinuous nature of the confining unit, the underlying Castle Hayne aquifer is best characterized as semiconfined and is unconfined in some areas of the installation. The Castle Hayne aquifer lies beneath the Castle Hayne confining unit and is currently the source of potable water supply at MCB Camp Lejeune, Onslow County, and the city of Jacksonville. Near MCB Camp Lejeune, the Castle Hayne aquifer consists mainly of fine sand, shell rock, and limestone. The upper portion of the aquifer consists of calcareous sand with discontinuous silt and clay beds. The calcareous sand generally grades to limestone with depth (Cardinell, Berg, and Lloyd, 1993). The top of the aquifer is between 0 and 75 ft below msl (bmsl). The aquifer ranges in thickness from 175 ft in the northern part of the installation to 375 ft along the coast. In general, the Castle Hayne is complex and heterogeneous with varying vertical and horizontal lithology, which significantly affects its hydraulic properties. For example, the transmissivity of the aquifer has been estimated to be greater on the west side of the New River than that on the east side (Triangle, 1999). Because the Castle Hayne aquifer is generally thicker to the east of the New River, it is evident that aquifer thickness is not the main factor controlling transmissivity in the area. Rather, the hydraulic conductivity appears to be the main factor. Limestones, which comprise part of the Castle Hayne aquifer,

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
	are heterogeneous. Because the Castle Hayne aquifer in the MCB Camp Lejeune area is semiconfined, vertical leakage (both upward and downward) occurs throughout the overlying Castle Hayne confining unit. Recharge to the Castle Hayne aquifer occurs along its outcropping area, located to the west-northwest of MCB Camp Lejeune. In this area, the aquifer is unconfined, and infiltration directly recharges the aquifer. Recharge also occurs through the Castle Hayne confining unit in areas where the water level in the surficial aquifer is higher than the potentiometric surface in the Castle Hayne aquifer. When the water table drops below the Castle Hayne potentiometric surface, groundwater will flow upward through the semiconfining layer. The absence of the confining unit below the New River allows the discharge of groundwater flow from the Castle Hayne aquifer to the New River (Triangle, 1999). The Beaufort aquifer underlies the Beaufort confining unit, which separates the Beaufort aquifer from the Castle Hayne aquifer. The Beaufort confining unit consists of clay, silt, and sandy clay (ATSDR, 2007). This confining unit impedes groundwater into and out of the Beaufort aquifer. The Beaufort aquifer is composed of fine to medium glauconitic sand, clays sand, shell and limestone, and interbedded clay (Lyke and Winner, 1990). This aquifer is relatively unused in Onslow County. The Peedee aquifer underlies the Peedee confining unit, which separates the Peedee aquifer from the Beaufort aquifer. The Pedee confining unit is composed of clay, silt, and sandy clay beds. It has an average thickness of about 33 ft and is less than 25 ft thick in a few scattered areas of Onslow County. The Peedee aquifer is composed primarily of sand with interbedded clay and silt layers, but limestone and partially consolidated calcareous sandstone are layered within the sands of the aquifer in some areas (Lyke and Winner, 1990). In most areas, the aquifer has high levels of iron; because of this and the presence of saltwater, the aquifer is not used for water supply in the southern part of Onslow County (USGS, 2010).

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
	The Black Creek aquifer underlies the Black Creek confining unit, which separates the Black Creek aquifer from the Peedee aquifer. The Black Creek confining unit consists of beds of clay, silty clay, and sandy clay. The thickness of this confining unit can range from 23 ft in northern and central Onslow county to over 100 ft in other areas. The aquifer is composed of interbedded sand and clay layers, which contain shells, glauconite, and large amounts of organic matter (Lyke and Winner, 1990). The aquifer is a source of high quality drinking water in most areas of Onslow County, but the presence of salt water prevents the aquifer from being used for water supply in the southern half of Onslow County (USGS, 2010). The upper and lower Cape Fear aquifers are composed of sand with minor amounts of clay, gravel, and limestone of the Cape Fear Formation. The upper Cape Fear confining unit separates the upper Cape Fear aquifer from the Black Creek aquifer, and the lower Cape Fear confining unit separates the upper Cape Fear aquifer from the lower Cape Fear aquifer. The upper and lower Cape Fear confining units are composed of clay and silt beds, and local beds of thin fine sand. The thickness of the upper Cape Fear confining unit averages about 59 ft and ranges from about 38 ft to about 112 ft. The thickness of the Lower Cape Fear confining unit averages about 43 ft and has been identified to have a thickness of 74 ft in the north central part of MCB Camp Lejeune (Lyke and Winner, 1990). The lower Cape Fear aquifer is underlain by crystalline bedrock. The upper and lower Cape Fear aquifers are not used for water supply within the Onslow County because of their depth and the presence of salt water (USGS, 2010).
Soil and vadose zone characteristics	The flat, upland regions of MCB Camp Lejeune are underlain by a variety of sandy and loamy soils of highly variable drainage characteristics (USDA SCS, 1992). The loamy Baymeade-Foreston-Stallings association or the sandy Leon-Murville-Kureb association underlies most upland areas that are designated as MC loading areas at MCB Camp Lejeune. These soils have an organic content of 0.5% to 2%. The floodplains and riparian wetlands of MCB Camp Lejeune are underlain by soils of the

CSM Information Profiles – Physical Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Muckalee-Dorovan association, which consist of loam, sandy loam, and muck. The barrier island complex on the coast is underlain by tidal marsh and dune soils of the Bohick-Newhan association. Low-lying pocosin areas at MCB Camp Lejeune are underlain by poorly drained, mucky soils of the Croatan series, which have a very high organic content (25% to 60%).
Erosion potential	Soil erodibility factors of the predominant soil series at MCB Camp Lejeune are low to moderate (0.1 to 0.3 tons/acre) (USDA SCS, 1992). Most of the loamy sands that underlie the flat, upland portions of the facility have low erodibility factors of 0.1 to 0.15 tons/acre. Even in areas of higher slope, such as stream valleys, the high vegetative cover causes the natural erosion potential to be slight. Undisturbed upland forest, forested bottomlands, and pocosins have very low rates of erosion. The coastal barrier island complex is subject to erosion from wave action, particularly during storm surges, but serves to protect landward areas from such effects. Areas with a moderate potential for erosion are those where the vegetation and soil have been disturbed by military operations. There are several MC loading areas that are vacant or sparsely vegetated, and these areas have been estimated to have high erosion potential.

4.4. Surface Water Profile

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
General surface water characteristics	The largest surface water feature at MCB Camp Lejeune is the New River embayment, which bisects the installation. The river is relatively short, with a course of approximately 50 miles on the central Coastal Plain of North Carolina. It is confined to a relatively narrow channel over most of its length upstream of MCB Camp Lejeune but widens into a large tidal embayment south of Jacksonville (Baker Environmental, 1998a). At MCB Camp Lejeune, the New River flows in a southerly direction into the Atlantic Ocean through the New River Inlet. This inlet is relatively narrow compared to the embayment and restricts the rate of tidal flushing of

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
	the embayment. The majority of MCB Camp Lejeune drains to the New River embayment and its tributaries. However, some southern areas of MCB Camp Lejeune drain directly to the Intracoastal Waterway, which is connected to the Atlantic Ocean by Bear Inlet, Brown's Inlet, and the New River Inlet. The New River, the Intracoastal Waterway, and the Atlantic Ocean converge at the New River Inlet. Much of the interior of MCB Camp Lejeune drains to intermittent and perennial streams that widen into tidal creeks in their downstream segments. Most perennial streams and tidal creeks occupy floodplains with extensive riparian wetlands. The flat terraces of the facility interior also contain regions that drain to low areas with no surface water outlets, including pocosins. Surface water features are displayed in **Figure 4-2**.
Watershed areas	According to data obtained from MCB Camp Lejeune (2005), 23 subwatershed areas have been delineated within the MCB Camp Lejeune installation boundary at a 10-digit hydrologic unit code level. These subwatershed areas mostly drain to streams and tidal creeks, which in turn drain to the New River embayment or the Intracoastal Waterway. The subwatershed areas range in size from 2,760 to 31,746 acres. A majority of these subwatershed areas extend beyond the MCB Camp Lejeune installation boundary; only 5 out of the 23 subwatershed areas are currently located entirely within the installation boundary. MC loading areas occupy portions of 14 of the existing 23 subwatersheds within MCB Camp Lejeune's installation boundary. These include subwatersheds of the different segments of the New River and the Intracoastal Waterway, tributary streams of the New River and the Intracoastal Waterway, and two swamps located west of the New River.
Subwatershed of Shelter Swamp Creek	This 31,746-acre subwatershed is the largest drainage at MCB Camp Lejeune and is located on the western part of MCB Camp Lejeune, within the GSRA area of MCB Camp Lejeune. Riparian wetlands fringe much of the stream length and tidal creeks within this subwatershed. Approximately 40% of the subwatershed lies outside the installation boundary. Federal endangered species, including the red-cockaded woodpecker and the rough-leaved loosestrife, have been documented to exist

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
	within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). All of SR-6, approximately 60% of SR-7, and approximately 40% of SR-10 MC loading areas are located within this watershed.
Subwatershed of Southwest Creek	This 28,830-acre subwatershed is located on the northwest part of MCB Camp Lejeune. Southwest Creek originates northwest of the New River embayment and flows perennially for approximately 5 miles before it widens into a tidal creek and ultimately discharges into the New River embayment. Riparian wetlands fringe much of the stream length and tidal creeks in the subwatershed. Tributaries of Southwest Creek include Harris Creek, Haws Run, Hicks Run, Mill Run, and Tank Creek. Federal threatened and endangered (T/E) species, including the red-cockaded woodpecker and the American alligator, have been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). Approximately 40% of the SR-7 MC loading area is located within this subwatershed.
Subwatershed of the New River between Town Creek and Stones Bay	This 21,123-acre subwatershed is located in the central part of MCB Camp Lejeune. It is located entirely within the boundaries of MCB Camp Lejeune and drains to the New River embayment. Streams within this subwatershed include Whitehurst Creek, Cowhead Creek, Jumping Run, Frenchs Creek, Duck Creek, Goose Creek, Two Pole Branch, and Cogdels Creek. Riparian wetlands fringe much of the stream length and tidal creeks in the subwatershed. Federal T/E species, including the red-cockaded woodpecker, the rough-leaved loosestrife and the American alligator, have been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). This subwatershed contains the largest number of MC loading areas of any subwatershed at MCB Camp Lejeune. It contains all of F-6, G-8 and G-9, G-10A EOD, G-19A, G-19B, Combat Town, ETA-7, and K-323 MC loading areas. In addition, approximately 70% of G-10 Impact, half of ETA-4, 90% of K-2 Impact, 85% of ETA-5, 97% of K-303 to K-305, 15% of K-211 and K-212, and 10% of K-301 MC loading areas are contained within this subwatershed.
Subwatershed of Juniper	This 20,127-acre subwatershed is located on the southwestern part of MCB Camp Lejeune. It contains Juniper Swamp, which originates

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
Swamp	within MCB Camp Lejeune and drains northwestward off the installation boundary into Holly Shelter Swamp, which is a large riparian wetland area located southwest of MCB Camp Lejeune. The subwatershed also includes Big Shakey Swamp, a tributary of Juniper Swamp. Riparian wetlands fringe stream segments throughout the subwatershed. The federal endangered rough-leaved loosestrife species has been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). Approximately 60% of the SR-10 MC loading area is located within this subwatershed.
Subwatershed of the New River between Stick Creek and Whitehurst Creek	This 14,544-acre subwatershed is located on the north-central part of MCB Camp Lejeune. It is located entirely within the installation boundary. It includes the northern section of the New River embayment within MCB Camp Lejeune and its tributary streams, including Town Creek, Lewis Creek, and other smaller unnamed streams that drain through riparian wetland areas. The federal endangered red-cockaded woodpecker species has been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). This subwatershed contains all of K-510 and EOD-2 MC loading areas. It also contains approximately 90% of K-301, 15% of ETA-5, and 3% of K-303 to K-305 MC loading areas.
Subwatershed of Wallace Creek	This subwatershed is located on the east part of MCB Camp Lejeune. A small portion of this subwatershed lies outside of the installation boundary. This 12,868-acre subwatershed contains Wallace Creek and its tributaries. Wallace Creek originates approximately 4.6 miles east of the New River embayment, flows through riparian wetland areas, and widens into a tidal creek before discharging into the New River embayment. Major tributaries of Wallace Creek include Bearhead Creek and Beaverdam Creek. Federal T/E species, including the red-cockaded woodpecker and the American alligator, have been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains all of the F range and ETA-3 MC loading areas.
Subwatershed	This subwatershed is located in the south-central part of MCB Camp

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
of the New River at Stones Bay	Lejeune. A small southern portion of this subwatershed lies outside of the installation boundary. This 12,294-acre subwatershed includes streams that drain southward and northeastward and discharge into Stones Bay. Some of these streams include Everett Creek, Mill Creek, and Muddy Creek. The federal T/E red-cockaded woodpecker species has been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains all of K-405 and Stones Bay Area MC loading areas. It also contains approximately 85% of the K-211 and K-212 MC loading areas.
Subwatershed of the Intracoastal Waterway between Alligator Bay and Freeman Creek	This subwatershed is located on the south-central tip of MCB Camp Lejeune. Approximately one-half of the subwatershed area lies outside of the installation boundary. This 11,749-acre subwatershed includes a significant portion of the Intracoastal Waterway, four bays just north of the Intracoastal Waterway (Salliers Bay, Mile Hammock Bay, Haward Bay, and Chardwick Bay), portions of the New River just upstream of the New River Inlet, Fullard Creek, and four other tributary streams of the Intracoastal Waterway. Many of the tributary streams of the Intracoastal Waterway within this widen into tidal creeks before discharging into the Intracoastal Waterway. Federal T/E species, including the red-cockaded woodpecker, the rough-leaved loosestrife, the green sea turtle, the loggerhead sea turtle, the leatherback sea turtle, the seabeach amaranth, and the piping plover, have been documented to exist within this subwatershed or in areas such as the Onslow Beach that receive drainage from this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). Approximately 70% of the ETA-2 MC loading area is contained within this subwatershed.
Subwatershed of the New River between Stones Bay and Intracoastal Waterway	This subwatershed is located on the southern part of MCB Camp Lejeune. A larger portion of the subwatershed lies outside of the installation boundary. This 7,810-acre subwatershed includes portions of the New River, two bays (Courthouse and Traps Bays) just upstream of the New River embayment, and six tributary streams of the New River. Most of the tributary streams within the subwatershed widen into tidal creeks before discharging into the New River. Snead North and Snead South Creeks, which are two of the tributary streams, flow through riparian wetland areas.

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Federal T/E species, including the red-cockaded woodpecker, the rough-leaved loosestrife, and the bald eagle, have been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains all of ETA-1 MC loading area. It also contains approximately 30% of ETA-2 MC loading area.
Subwatershed of Stones Creek	This subwatershed is located in the southwestern part of MCB Camp Lejeune. Almost one-half the area of this subwatershed lies outside of the installation boundary. This 7,587-acre subwatershed includes Stones Creek and its tributary Millstone Creek. Stones Creek originates approximately 5 miles southwest of Stones Bay and widens into a tidal creek before discharging into Stones Bay. Both Stones Creek and Millstone Creek flow through riparian wetland areas. The federal T/E red-cockaded woodpecker species has been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). This subwatershed contains all of L-5 MC loading area.
Subwatershed of Bear Creek	This subwatershed is located in the southeastern part of MCB Camp Lejeune. Some portion of this subwatershed extends beyond the installation boundary. This 6,886-acre subwatershed includes Bear Creek and its tributary Mill Creek. Bear Creek originates approximately 3.8 miles north of the Intracoastal Waterway and widens into a tidal creek before discharging into the Intracoastal Waterway. Bear Creek drains through riparian wetland areas. Federal T/E species, including the red-cockaded woodpecker and the rough-leaved loosestrife, are located within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). This subwatershed contains all of the Mobile MOUT complex MC loading area. It also contains approximately 95% of G-6, 30% of G-10 Impact Area, 2% of EOD-1, and 2% of G-7 MC loading areas.
Subwatershed of Intracoastal Waterway between Browns Inlet	This subwatershed is located on the southeastern corner of MCB Camp Lejeune. A little more than half of the subwatershed area lies outside the installation boundary. This 6,247-acre subwatershed includes approximately 4 miles of the Intracoastal Waterway, two tributary streams of the Intracoastal Waterway (Goose Creek and

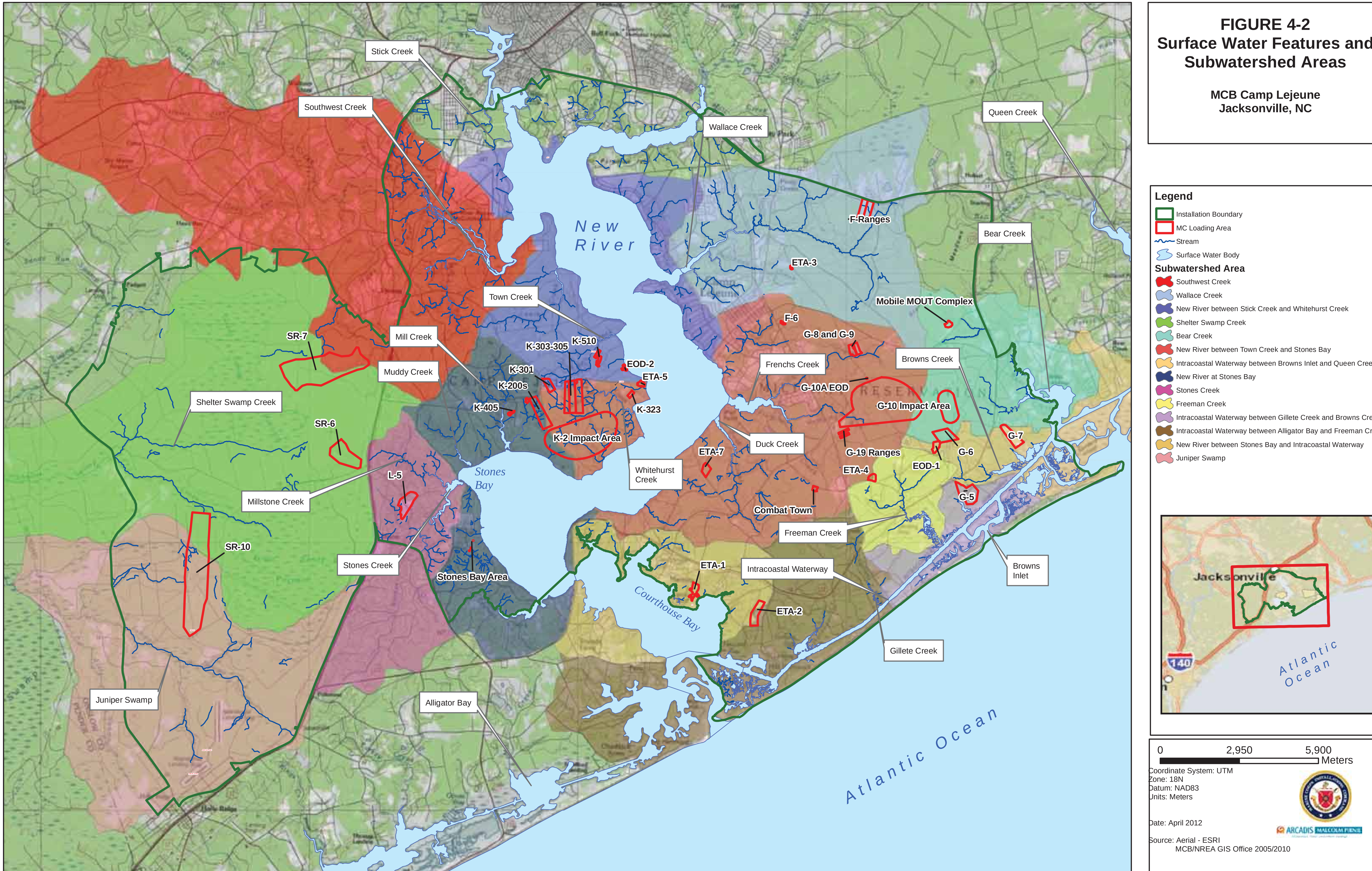
CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
and Queen Creek	Browns Creek), a network of tidal creeks draining from the Intracoastal waterway, and the upper portion of Bear Inlet. Hydrologic features within this subwatershed include Sanders Island (a large riparian wetland) and a network of tidal creeks that drain from the Intracoastal Waterway into Bear Inlet. Federal T/E species, including the red-cockaded woodpecker, the rough-leaved loosestrife, the green sea turtle, the loggerhead sea turtle, the leatherback sea turtle, the seabeach amaranth, and the piping plover, have been documented to exist within this subwatershed or in areas such as parts of the Onslow Bay that receive drainage from this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains approximately 98% of the G-7, 5% of the G-6, 98% of the EOD-1, and 3% of the G-5 MC loading areas.
Subwatershed of Freeman Creek	This subwatershed is located on the southern part of MCB Camp Lejeune. The entire subwatershed area is within the boundaries of the installation. This 2,789-acre subwatershed contains the tidal Freeman Creek and its tributary streams, including Browns Swamp, Bank Branch and Mirely Branch. Extensive riparian wetland areas fringe Freeman Creek and many of its tributaries. Federal T/E species, including the red-cockaded woodpecker and the rough-leaved loosestrife, have been documented to exist within this subwatershed (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains approximately one-half of the ETA-4 MC loading area.
Subwatershed of Intracoastal Waterway between Gillete Creek and Browns Creek	This subwatershed is located on the southeastern part of MCB Camp Lejeune. The entire subwatershed is located within the MCB Camp Lejeune installation boundary. This 2,760-acre subwatershed contains approximately 4 miles of the Intracoastal Waterway and Banks Channel, which flows from the Intracoastal Waterway into Browns Inlet. This subwatershed contains extensive riparian wetland areas. Federal T/E species, including the green sea turtle, the loggerhead sea turtle, the leatherback sea turtle, the seabeach amaranth, and the piping plover, have been documented to exist in parts of the Onslow Bay that receive drainage from this subwatershed (MCB Camp

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Lejeune, 2007; MCB Camp Lejeune, 2010a). The subwatershed contains approximately 97% of the G-5 MC loading area.
Designated beneficial uses	Most tidal surface waters at MCB Camp Lejeune are classified by the State of North Carolina as high quality waters, nutrient sensitive waters, and waters that have an existing and potential use for market shellfishing and secondary recreation. Some waters in and around MCB Camp Lejeune, including Wallace Creek, the New River, and the Atlantic Ocean, are classified as waters that have an existing and potential use for primary recreation (NCDENR, 2010). Waters in and around MCB Camp Lejeune generally are used for human recreation, and there are no military restrictions in place for recreational use on the waters of MCB Camp Lejeune. Surface water is not a drinking water source for MCB Camp Lejeune.
Supported habitats/ ecosystems	A variety of wildlife species, including amphibians, reptiles, mammals, and birds, inhabit MCB Camp Lejeune (MCB Camp Lejeune, 2007). MCB Camp Lejeune provides habitat and open space for a variety of migratory birds. There are various designated wildlife management areas throughout MCB Camp Lejeune. The vegetation at MCB Camp Lejeune largely consists of forest (including bottomland hardwood, hardwood, mixed pine, pine and upland hardwood), followed by scrub and shrub and wetlands (mostly including wet pine flatwoods, blackwater bottomland hardwoods, pocosins, vernal pools, and coastal salt marshes) (MCB Camp Lejeune, 2007; MCB Camp Lejeune, 2010a). Federal T/E species that are known to occur at MCB Camp Lejeune include the red-cockaded woodpecker, the green sea turtle, the loggerhead sea turtle, the leatherback sea turtle, the rough-leaved loosestrife, the seabeach amaranth, the piping plover, the bald eagle, and the American alligator. Further description of T/E species is provided in the Natural Resources Profile.
Gaining or losing streams	The larger streams, creeks, and rivers at MCB Camp Lejeune, including the New River and all of its tributaries (including swamps, wetlands, and streams), and the Atlantic Ocean are groundwater discharge locations. Shallow groundwater may discharge locally into smaller streams and other surface water features. As a result, streams at MCB Camp Lejeune generally are gaining.
Lakes, ponds,	There are no actively used potable water storage reservoirs at MCB

CSM Information Profiles – Surface Water Profile – MCB Camp Lejeune	
Information Needs	**Information**
and reservoirs	Camp Lejeune. There are various small ponds, including golf course ponds, vernal pools, and small depression ponds at various areas of MCB Camp Lejeune.

FIGURE 4-2
Surface Water Features and Subwatershed Areas

MCB Camp Lejeune
Jacksonville, NC



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4.5. Groundwater Profile

CSM Information Profiles – Groundwater Profile – MCB Camp Lejeune	
Information Needs	**Information**
Groundwater basin(s)	The North Carolina Department of Environment and Natural Resources (NCDENR) designates aquifers but not groundwater basins. As discussed in the Physical Profile section, there are seven aquifers at MCB Camp Lejeune and its vicinity. The Castle Hayne aquifer is the primary water-supply source at MCB Camp Lejeune. The primary water-supply source in Onslow County and other areas of the Coastal Plain historically has been the Black Creek aquifer (Harden et al., 2004). However, due to excessive groundwater withdrawals that have lowered the potentiometric head in the Black Creek aquifer, the NCDENR has reduced withdrawals from the Black Creek aquifer as part of the Central Coastal Plain Capacity Use Area. For this reason, the Castle Hayne aquifer has become an increasingly important source of water supply for Onslow County with groundwater withdrawals by the County exceeding 4.5 million gallons per day (mgd) near the installation (Harden et al., 2004).
Designated beneficial uses	Potable water to MCB Camp Lejeune and the surrounding residential area is provided by water supply wells that pump groundwater from the Castle Hayne aquifer (CH2M Hill, 2008). Although fresh water is present within the surficial, Castle Hayne, Beaufort, and Peedee aquifers, all of which underlie MCB Camp Lejeune, only the Castle Hayne aquifer is used by the installation as a water supply source (Cardinell, Berg, and Lloyd, 1993). Regionally in southeastern North Carolina, the Castle Hayne aquifer is used as a potable source of domestic water supply, public water supply, commercial water supply, and industrial water supply (CH2M Hill, 2008).
Groundwater supply wells	Based on the information provided by installation personnel at MCB Camp Lejeune, as of January 2012, there are 50 active water supply wells on the installation, which rely entirely on groundwater from the Castle Hayne aquifer as the supply source (pers comm MCB Camp Lejeune, 2010a). There are about 51 additional water supply wells that have been installed at MCB Camp Lejeune that are currently inactive or abandoned. Some of the inactive wells have been abandoned due to contamination or failure issues, and others are temporarily out of service. As of September 2010, ten water supply wells have been proposed for installation within the boundaries of MCB Camp Lejeune (pers comm MCB Camp

CSM Information Profiles – Groundwater Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Lejeune, 2010a). Many of the water supply wells are located along the north and northeastern boundary of the installation, and some are in the eastern and southeastern parts of the installation. The supply wells are included in the installation's annual wellhead monitoring program to ensure compliance with drinking water standards (Geophex, 1991). MCB Camp Lejeune tests all wells semi-annually for munitions constituents. The installation is permitted to withdraw approximately 22.5 mgd of water, but the actual water usage is approximately 15 mgd from the 64 active water supply wells (pers comm MCB Camp Lejeune, 2010a). In addition to water supply wells located at MCB Camp Lejeune, there are 10 county public water supply wells and two unidentified potential supply wells located near MCB Camp Lejeune on the east, southwest, and north. The supply wells on the southeast withdrew approximately 4.5 mgd in 2002; current use is expected to be higher. Additionally, off-installation domestic wells likely exist close to the installation.
Recharge source(s)	Recharge of aquifers in the coastal plain region generally occurs within interstream areas. Annual recharge to the unconfined aquifers has been estimated in the range of 5 to 21 inches of rainfall (Heath, 1989). The surficial aquifer is recharged by precipitation. The Castle Hayne aquifer is recharged by the surficial aquifer. The movement of groundwater between the surficial and the Castle Hayne aquifers is controlled by the magnitude of the vertical gradients between the aquifers and the hydraulic conductivity of the Castle Hayne confining unit. Cardinell, Berg, and Lloyd (1993) estimated the vertical hydraulic conductivity of the Castle Hayne confining unit, where present, to range from 0.0014 to 0.41 ft/d and indicated that the confining unit only partially restricts the vertical flow of groundwater between the surficial and the Castle Hayne aquifers. As a result of groundwater use, which has significantly lowered groundwater levels in the Castle Hayne aquifer, the vertical hydraulic gradient across the confining unit in some areas is large. Recharge from precipitation to the Castle Hayne aquifer also occurs along its outcrop area, located to the west and northwest of MCB Camp Lejeune where the aquifer is unconfined.
Porous or fracture flow	Groundwater flow at MCB Camp Lejeune is characterized as porous media flow. In the surficial aquifer, groundwater flows primarily

CSM Information Profiles – Groundwater Profile – MCB Camp Lejeune	
Information Needs	**Information**
	through fine sand with silt and some medium-grained sand. In the deeper Castle Hayne aquifer, groundwater flows through fine sand, shell rock, and limestone.
Depth to groundwater	The depth to water table at MCB Camp Lejeune ranges from less than 1 ft bgs along shallow groundwater discharge zones, such as surface water features, to approximately 19 ft bgs in interstream divides (Harden et al., 2004; USGS, 2010; CH2M Hill et al., 2001; Baker Environmental, 1997; O'Brien and Gere, 1988). Depth to the water table in many of the identified MC loading areas ranges from approximately 3 to 13 ft bgs.
Gradient and flow velocity	Groundwater in the shallow aquifer at MCB Camp Lejeune generally flows from areas of high hydraulic head in interstream divides toward areas of low hydraulic head at surface water discharge zones. In the absence of pumping by production wells, groundwater in the deeper confined Castle Hayne aquifer generally flows eastward toward the Atlantic Ocean. However, significant withdrawals by the installation and adjacent county water supply wells have induced strong localized hydraulic gradient toward the water supply wells, as shown in **Figure 4-3**. As a consequence, a significant amount of groundwater from the Castle Hayne aquifer within the installation boundary is captured by these wells. The USGS has examined long-term water level data at selected MCB Camp Lejeune well sites to examine vertical hydraulic gradients between the surficial and the Castle Hayne aquifers. From this investigation, a downward vertical gradient was determined for two well-cluster sites at MCB Camp Lejeune, which indicated flow of water from the surficial aquifer into the underlying Castle Hayne aquifer (Harden et al., 2004). The vertical gradient between two wells (one screened in the surficial aquifer and the other in the Castle Hayne aquifer) was measured to be 0.16 ft/ft. The USGS also determined that the difference in head levels between the surficial and Castle Hayne aquifers can be greater than 30 ft due to groundwater withdrawals and that the Castle Hayne confining unit is relatively thin (measured to be 5 ft at the K-2 and G-10 Impact Areas) to absent with a hydraulic conductivity as high as 0.4 ft/d (Harden et al., 2004). Horizontal hydraulic gradient values were estimated in the shallow

CSM Information Profiles – Groundwater Profile – MCB Camp Lejeune	
Information Needs	**Information**
	aquifer at the G-10 Impact Area, K-2 Impact Area, and the F-6 MC loading areas from measured groundwater elevations at various monitoring wells in or near these loading areas (Harden et al., 2004; O'Brien and Gere, 1988). These estimated values were 0.0042 ft/ft at the G-10 Impact Area MC loading area, 0.0046 ft/ft at the K-2 Impact Area MC loading area, and 0.0071 ft/ft at F-6 MC loading area. Based on an average estimated hydraulic conductivity of 2.3 ft/d in the surficial aquifer at IRP sites 69, 73, and 82 located in the northeast and near the south-central parts of the installation (Baker Environmental, 1998a; Baker Environmental, 1998b), groundwater velocities at the G-10 Impact Area, K-2 Impact Area, and F-6 MC loading areas are estimated to be 0.0024 ft/d, 0.0027 ft/d, and 0.0041 ft/d, respectively.
Known water quality characteristics	Onslow County and MCB Camp Lejeune lay in an area where the Castle Hayne aquifer generally contains freshwater, making the aquifer a viable potable water source for the region (CH2M Hill et al., 2001). In general, water in the Castle Hayne aquifer of the North Carolina Coastal Plain ranges from hard to very hard because of its limestone content. Iron concentrations tend to be high near recharge areas and decrease as the water moves further through the limestone (Huffman, 1996). As part of the REVA baseline assessment for MCB Camp Lejeune, production wells located near the K-2 and the G-10 Impact Areas were sampled for MC, metals, and major ions in November 2007 and April 2008 (Malcolm Pirnie, 2009). With the exception of perchlorate, which was detected below the laboratory reporting limit (RL) in one of the supply wells, MC concentrations were below detection limits. Total and dissolved lead concentrations were detected in several of the water supply wells sampled, but the concentrations in many of the wells were below laboratory RLs. Total lead concentrations in two of the water supply wells sampled were above the laboratory RL but below the Range Munitions Uuse Subcommittee (RMUS) human drinking water screening value of 15 micrograms per liter (µg/L). Concentrations of major ions were below the North Carolina groundwater standards, and the average pH in the production wells sampled was 7.9 (Malcolm Pirnie, 2009). Surface water and groundwater samples were collected in September and December 2010 and in October 2011 as part of the

CSM Information Profiles – Groundwater Profile – MCB Camp Lejeune	
Information Needs	**Information**
	REVA five-year review. Perchlorate and lead were detected in surface water samples, but all results were below RMUS screening values. Perchlorate, lead, and three explosives were detected in wells around the K-2 and G-10 Impact Areas. Perchlorate did not exceed any screening values, but two detection of lead and one detection of 2,4-dinitrotoluene did exceed a screening value. Two of the wells with exceedances were resampled and lead and 2,4-dinitrotoluene were not detected when resampled. The other exceedance of lead was only slightly above screening and downgradient well results did not indicate migration; no receptors are in the vicinity of this well. Surface water pH averaged approximately 8.0 with an average dissolved oxygen concentration of 7.16 milligrams per liter (mg/L). Groundwater pH in the surficial aquifer averaged 5.95 while pH in the Castle Hayne aquifer averaged 7.96. Dissolved oxygen in the surficial aquifer averaged 3.02 mg/L while dissolved oxygen in the Castle Hayne aquifer averaged 1.02 mg/L.
Discharge location(s)	The natural groundwater discharge locations at MCB Camp Lejeune are the New River and all of its tributaries (including swamps, wetlands, and streams) and the Atlantic Ocean (Baker Environmental, 1998a). The shallow groundwater primarily discharges to these surface water features. Most of these features have elevations equivalent to or very near msl. Man-made groundwater discharge locations include the 64 active water supply wells of the installation and the 10 county supply wells located adjacent to the installation that draw water from the Castle Hayne aquifer. Potential off-installation domestic wells are also potential groundwater discharge locations.

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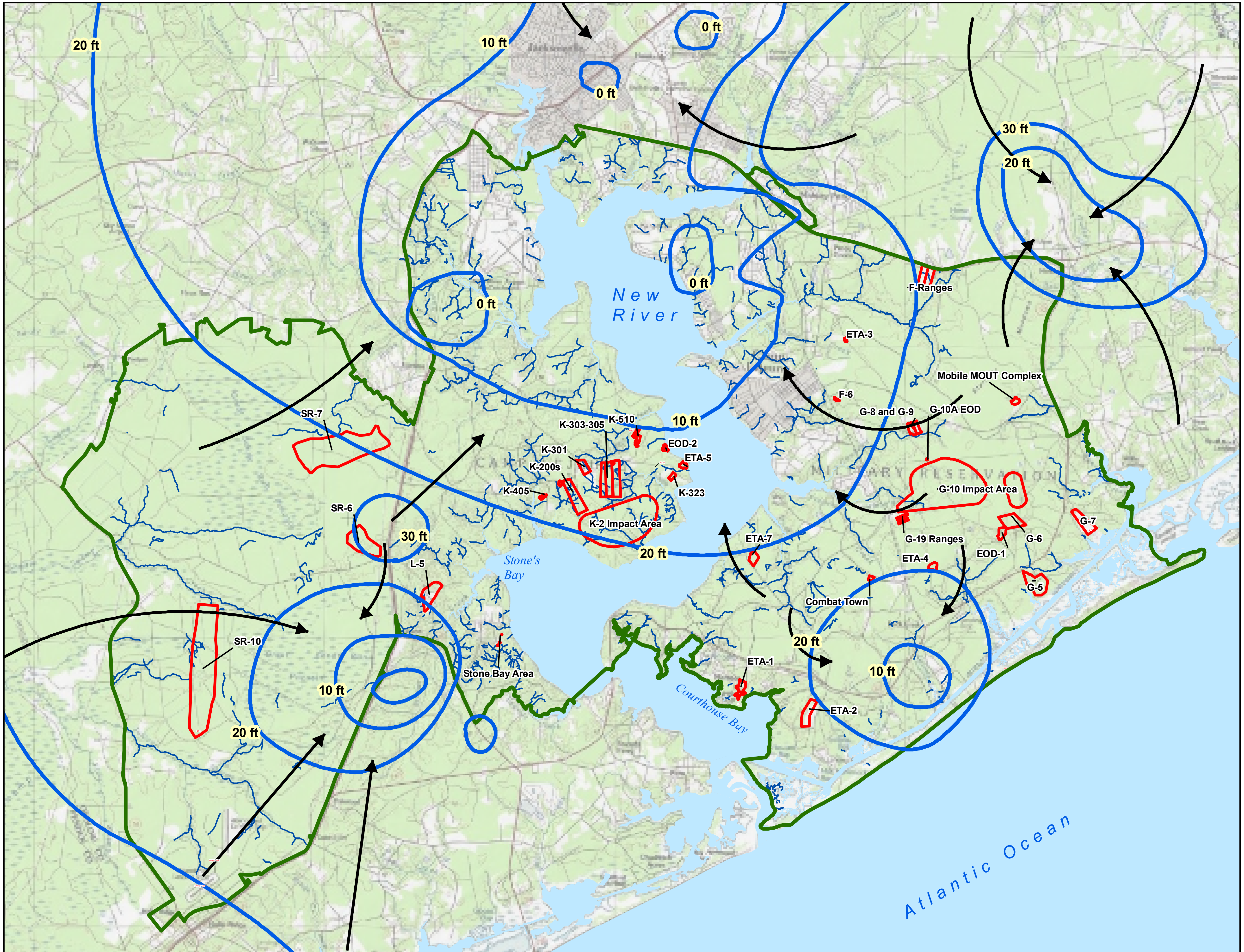

FIGURE 4-3
Potentiometric Map of the Castle Hayne Aquifer

MCB Camp Lejeune
Jacksonville, NC

LEGEND

- INSTALLATION BOUNDARY
- MC LOADING AREA
- STREAM
- SURFACE WATER BODY
- CASTLE HAYNE GROUNDWATER CONTOUR
- CASTLE HAYNE FLOW DIRECTION

Note: Groundwater contour developed based on water level data published by USGS

0 3,450 6,900 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010
Harden et al., 2004 and USGS

ARCADIS MALCOLM PIRNIE

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4.6. Human Land Use and Exposure Profile

CSM Information Profiles – Human Land Use and Exposure Profile – MCB Camp Lejeune	
Information Needs	**Information**
Land use	Land within MCB Camp Lejeune is a mix of undeveloped forested land and developed complexes. Almost two-thirds (65%) of the area is covered by forest, about 22% is palustrine wetland, and about 5% of the area is barren. Developed areas consist of approximately 5% of the total area and include housing and operations buildings. Developed training complexes include Stones Bay Complex, K-2 ranges, G-10 ranges, F ranges, Courthouse Bay Ranges, GSRA, and MCAS New River. From a mission perspective, approximately 88% of the total land area is used for operations and training (primary mission) as of September 2010, including areas such as training, research, development, and testing facilities. Approximately 8% of the total land area is used for mission support and includes areas such as support facilities and administration. The remaining 4% of land use is for personnel support, which includes hospitals, housing, and community facilities (MCB Camp Lejeune, 2009a).
Surface water and ocean use	Surface waters on the installation are used occasionally for training and recreational purposes (such as swimming and fishing). Commercial oyster beds are in portions of the New River adjacent to the K-2 Impact Area. In addition, shellfishing is permitted within most of Courthouse Bay. The Intracoastal Waterway is a toll-free boating channel that extends through the boundaries of the installation and provides a waterway for the New River estuary and Onslow Bay. Although the installation uses the waterway for boat and amphibious training, the waterway is used primarily for transport to various locations. At certain times, portions of the waterway are closed in order to prevent nonmilitary watercraft from entering existing SDZs. Onslow Bay bounds the installation on the southeastern portion, prior to reaching the Atlantic Ocean. Recreational activities are permitted within Onslow Bay and consist of game and sport fishing, diving, sailing, and other recreational boating activities. There is a prohibited area in Onslow Bay that surrounds the BT-3 Impact Area (non-live-

CSM Information Profiles – Human Land Use and Exposure Profile – MCB Camp Lejeune	
Information Needs	**Information**
	fire). Approximately 20 artificial reefs have been established in Onslow Bay to support offshore fishing and recreational diving.
Human receptors	**Surface Water:** Surface waters on the installation are not used as a potable water supply. Use of surface waters for recreational purposes, such as swimming and fishing, is authorized. In addition, commercial oyster beds are located in portions of the New River. **Drinking Water:** The primary exposure to groundwater for humans is groundwater pumped from one of the many drinking water supply wells located on the installation and potentially from the county supply wells located adjacent to the installation. These water supply wells are screened in the Castle Hayne aquifer, and the surficial aquifer is not used as a drinking water source within the installation. There may be some domestic wells outside the installation using the surficial aquifer as a source of water.
Land use restrictions	With the exception of the G-10 and K-2 Impact Areas, no land use restrictions are known to be in place. At these impact areas, the use of live fire results in little human access and is anticipated to continue for the foreseeable future.

4.7. Natural Resources Profile

CSM Information Profiles – Natural Resources Profile – MCB Camp Lejeune	
Information Needs	**Information**
Ecosystems	MCB Camp Lejeune is located in Humid Temperate Domain and the Atlantic Coastal Flatlands Section of the Outer Coastal Plains Mixed Forest Province. Major ecosystem categories in this region include coastal estuarine and forested palustrine wetlands as well as mixed pine and oak forests and floodplain forests (MCB Camp Lejeune, 2006).
Vegetation	Over half of the 143,000 acres at MCB Camp Lejeune are managed commercial forestland. Impact areas G-10, K-2, and BT-3 are not managed. Most forestland is divided into pure pine, pure hardwood,

CSM Information Profiles – Natural Resources Profile – MCB Camp Lejeune	
Information Needs	**Information**
	and mixed pine/hardwood. Loblolly pine is dominant in approximately 60% of the pine stands, and black gum is dominant in bottomland hardwood stands (MCB Camp Lejeune, 2009a). Much of MCB Camp Lejeune is pine savanna cut by drainage pathways. There are many densely forested areas with several large clearings. Loblolly pine (*Pinus taeda*) is very common on the installation, and other common tree species include hickory (*Carya* spp.), white oak (*Quercus alba*), red oak (*Q. rubra*), sweetgum (*Liquidambar styraciflua*), pond pine (*Pinus serotina*), and longleaf pine (*Pinus palustris*). Other species commonly found along creeks include black gum (*Nyssa sylvatica*), southern red oak (*Quercus falcate*), red maple (*Acer rubrum*), beech (*Fagus grandifolia*), American holly (*Ilex opaca*), tulip poplar (*Lirodendron tulipifera*), and water oak (*Quercus nigra)* (MCB Camp Lejeune, 2009b). The shrub layer consists primarily of wax myrtle (*Myrica cerifera*), blue huckleberry (*Gaylussacia frondosa*), and sparkleberry (*Vaccinium arboreum*). Groundcover includes wiregrass (*Aristida stricta*), bracken fern (*Pteridium aquininum*), bluestems (*Schizachyrium* spp.), green briar (*Smilax* spp.), and broomsedge (*Andropogon virginicus*) (MCB Camp Lejeune, 2009b).
Fauna	Mammals common at MCB Camp Lejeune include the white-tailed deer (*Odocoileus virginianus*), eastern gray squirrel (*Sciurius carolinensis*), eastern cottontail rabbit (*Sylvilagus floridanus*), opossum (*Didelphis virginiana*), southern flying squirrel (*Glaucomys volans*), gray fox (*Urocyon cinereoargenteus*), and raccoon (*Procyon lotor*). Occasionally seen are the American black bear (*Ursus americanus*), bobcat (*Lynx rufus*), and coyote (*Canis latrans*) (MCB Camp Lejeune, 2009b). Birds found at MCB Camp Lejeune include the mourning dove (*Zenaida macroura*), northern bobwhite quail (*Colinus virginianus*), wild turkey (*Melagris gallopavo*), mockingbird (*Mimus polyglottos*), American robin (*Turdus migratorius*), catbird (*Dumetella carolinensis*), sparrows (*Fringillidae*) and warblers (*Parulidae*) (MCB Camp Lejeune, 2005; MCB Camp Lejeune, 2009a; MCB Camp Lejeune, 2009b). A number of waterfowl inhabit the New River estuary and barrier island marshes.

CSM Information Profiles – Natural Resources Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Amphibians at the installation include 15 frog species and 6 salamander species. The American bullfrog (*Rana catesbeiana*) and the southern leopard frog (*Rana sphenocephala*) are most common (MCB Camp Lejeune, 2009a). Reptiles include various lizards and snakes, including the mimic glass lizard (*Ophisaurus mimicus*), southern hognose snake (*Heterodon simus*), and the eastern diamondback rattlesnake (*Crotalus adamanteus*) (MCB Camp Lejeune, 2009a).
Special status species	MCB Camp Lejeune has identified six protected species on the installation as of September 2010. These include the bald eagle (*Haliaeetus leucocephalus*), the red-cockaded woodpecker (*Picoides borealis*), the Atlantic loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*), the American alligator (*Alligator mississippiensis*), and the piping plover (*Charadrius melodus*) (MCB Camp Lejeune, 2010a). Although the bald eagle is no longer on the federal T/E list, it is protected by federal law (Bald Eagle and Golden Eagle Protection Act and the Migratory Bird Treaty Act). As of September 2010, there are three known active bald eagle nests located in JE training area, IF training area, and MC training area. No tree cutting or chemical applications are allowed within a 750 ft buffer of the nests, and human entry is prohibited from December to June. Within 1,000 ft of the nests, airspace is restricted from December to June, and all permanent habitat alterations are prohibited within 1,500 ft of the nests (MCB Camp Lejeune, 2010a). The red-cockaded woodpecker is endangered and protected by federal law. These birds live in cavities in live pine trees in forests with little hardwood and open canopy. As of January 2012, MC Camp Lejeune personnel stated that there are 100 active red-cockaded woodpecker clusters on the installation. Each known nesting habitat has a 200 ft buffer and is marked with signs indicating the sensitive habitat. Trees within this buffer are marked with a single white band. Cavity trees are indicated by a blue-white-blue painted band and have a metal tag secured to the tree. Cutting or damaging pine trees and destroying or removing signs is strictly prohibited. Some training activities are not authorized within the marked trees; however, most low impact training is only restricted

CSM Information Profiles – Natural Resources Profile – MCB Camp Lejeune	
Information Needs	**Information**
	within 50 ft of a red-cockaded woodpecker cluster (MCB Camp Lejeune, 2010a). Sea turtles nest on beaches of MCB Camp Lejeune and are very vulnerable during May to October when they are nesting. The endangered leatherback turtle (*Dermochelys coriacea*) may also be present, as it is known to nest on neighboring beaches (MCB Camp Lejeune, 2009a). Known turtle nests are protected with wire cages, and units are to avoid these locations. Tampering with cages is prohibited. The Environmental Conservation Branch relocates any nests identified within the EB training area (Onslow Beach training area). Although the beaches are still used for recreation and training, the installation has rules and policies in place to restrict some activities during the nesting season (MCB Camp Lejeune, 2010a). The American alligator lives within the boundaries of MCB Camp Lejeune, and signs are posted to caution those in alligator habitat. Special caution should be taken in the areas during May and June when alligators lay eggs in mounded vegetation (MCB Camp Lejeune, 2010a). They have been seen in the New River watershed and Atlantic Intracoastal Waterway (MCB Camp Lejeune, 2009a). A piping plover nest was first documented at MCB Camp Lejeune in 2009. They nest in open sandy areas, including wash areas and inlets. Nests are marked and covered with cages. Access to these areas and damaging nests is prohibited (MCB Camp Lejeune, 2010a). Endangered plants identified on the installation include the rough-leaved loosestrife (*Lysimachia asperulifolia*) and the seabeach amaranth (*Amaranthus pumilus*). The rough-leaved loosestrife is found in or adjacent to forested wetlands. Restriction signs are posted in loosestrife habitats, and the lower portion of tree trunks are marked with a single white band. Digging is prohibited, but vehicles are allowed on existing trails. The seabeach amaranth is found on sand dunes on Onslow Beach. Known locations of the plant are clearly marked, and human and vehicle traffic is restricted from these areas, except on existing trails (MCB Camp Lejeune, 2010a).

CSM Information Profiles – Natural Resources Profile – MCB Camp Lejeune	
Information Needs	**Information**
	Other species of conservation significance include shorebirds and colonial waterbirds, the coastal goldenrod (*Solidago villosicarpa*), and the Venus flytrap (*Dionaea muscipula*). The southern part of Onslow Beach is an important nesting habitat for federally protected migratory birds. Portions of Onslow Beach are closed to vehicle traffic from April to August in order to avoid disturbance to nesting habitat. Coastal goldenrod only recently has been identified, and known locations of the plant are marked as conservation areas. The Venus flytrap is a North Carolina protected species (MCB Camp Lejeune, 2010a).
Management areas	MCB Camp Lejeune manages forested areas in order to continue providing an adequate training environment, and restoration of longleaf pine is ongoing at certain locations. A wetland mitigation bank totaling 1,250 acres was established in the GSRA in November 2000 in order to restore, enhance, and preserve pocosin, pine flat, and bottomland wetland systems. The bank was created to mitigate impacts from authorized range and infrastructure development in the GSRA. In coastal areas, beach stabilization is performed by planting dune grasses and installing sand fences to encourage new dune formation at designated areas (Malcolm Pirnie, 2007). Archaeological sites are located throughout the installation and are clearly marked with signs. Training exercises in these areas require coordination with the base archaeologist, and tracked vehicles are to stay on existing trails (MCB Camp Lejeune, 2010a).
Relationship of MC sources to habitat and potential receptors	Details regarding potential receptors from MC loading areas within each subwatershed are found in **Section 6**. The most common T/E species found throughout the installation are the red-cockaded woodpecker and the rough-leaved loosestrife. Other T/E species found on the installation include the American alligator, loggerhead sea turtle, green sea turtle, leatherback sea turtle, seabeach amaranth, and the piping plover.

4.8. Potential Pathways and Receptors

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

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

Exposure pathways considered in the REVA process include consumption of surface water and groundwater for off-range human receptors, as described in the *REVA Reference Manual* (HQMC, 2009). Surface water is a receptor location because the New River is used for recreational purposes and commercial fishing. The Castle Hayne aquifer is used for drinking water; public supply wells are located within the installation and just beyond the installation boundary. 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. Jurisdictional wetlands are considered as receptor location for MC in surface water and sediment runoff, as well for as groundwater discharging into the wetlands. 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. The potential points of exposure for receptors of MC at MCB Camp Lejeune include the following:

- Surface water bodies, including the New River and its tributaries, the Intracoastal Waterway, the Atlantic Ocean, and the numerous swamps and wetland areas. that are used for recreational purposes and commercial fishing and that potentially support special status species, such as the red cockaded woodpecker and the bald eagle
- Public supply wells located within the boundaries of MCB Camp Lejeune
- Potential off-site groundwater wells

4.8.1. Surface Water and Sediment Pathway

As a result of the relatively high precipitation at MCB Camp Lejeune (average of approximately 54 in/yr), surface water runoff is an important potential transport pathway of MC to surface water bodies located within and around MCB Camp Lejeune. Surface water runoff also can cause erosion and transport of MC sorbed to sediment. MC transported in groundwater could discharge into surface water because the shallow groundwater is a known source of base flow to streams. MC released from loading areas at MCB Camp Lejeune could drain to intermittent and perennial streams and discharge into larger surface water features downstream. The soil and site characteristics at MCB Camp Lejeune generally indicate relatively low potential for soil erosion throughout the installation; however, erosion potential is higher at many of the identified MC loading areas (ranging from very low to high) due to the lower vegetative cover and soil/sediment disturbance from range activities and maintenance.

MC transported through surface water runoff or base flow could reach human and ecological receptor locations. Areas of potential human receptors include the New River embayment and its tributaries, the Intracoastal Waterway and its tributaries, and the Atlantic Ocean, which are used for recreational purposes. Ecological receptor locations include streams, tidal creeks, swamps, wetlands, and nearshore marine environments (such as the New River and Onslow Bay) that support ecological receptors, potentially including T/E species, as identified in **Section 4.4**.

The waters offshore of MCB Camp Lejeune, including the New River, the Intracoastal Waterway, and the Atlantic Ocean, ultimately receive drainage from MC loading areas at MCB Camp Lejeune. Limited exposure to humans and ecological receptors is anticipated in these waters because they are tidally influenced and, thus, are subject to mixing with daily fluxes of large volumes of tidal water. This tidal mixing phenomenon is expected to provide a great deal of dilution of water potentially containing MC.

4.8.2. Groundwater Pathway

Approximately 7% to 29% of the precipitation that occurs at MCB Camp Lejeune is recharged to groundwater (Heath, 1989). Due to the shallow water table depth in most areas of the installation and the presence of sandy soils, MC have the potential to migrate toward the water table after dissolution into infiltrating rainwater. However, the concentration of any single MC would be dependent on many factors, such as its mass loading at the surface, aqueous solubility, and retardation of the MC due to soil characteristics.

The potential shallow groundwater pathway at MCB Camp Lejeune is from the upland interstream divides toward the major surface water features (the New River and its tributaries and the Atlantic Ocean). Locally, portions of the shallow groundwater may discharge into smaller streams or other surface water features.

There are no known current shallow groundwater users at MCB Camp Lejeune because all public water supply at the installation and the city of Jacksonville is derived from the deeper Castle Hayne aquifer. To date, it is not anticipated that there are off-site receptors of shallow groundwater; however, an investigation of whether there are any known beneficial uses of the surficial aquifer (e.g., individual domestic wells or irrigation wells) has not been conducted. Potential receptors in the surface water where shallow groundwater discharges include humans that potentially use the water for recreation and ecological receptors, including T/E species, as described in **Section 4.4**.

As of January 2012, there are 50 active wells at MCB Camp Lejeune that supply potable water from the Castle Hayne aquifer. The wells are located on the northern, northeastern, eastern, and southeastern parts of MCB Camp Lejeune. In addition, there are County water supply wells located in proximity to MCB Camp Lejeune on the east and southwest. The Castle Hayne aquifer lies below the Castle Hayne confining layer, which provides some protection from direct recharge from the overlying surficial aquifer, limiting the potential groundwater pathway between the surficial and the Castle Hayne aquifer. However, the Castle Hayne aquifer in the MCB Camp Lejeune area is semiconfined and, in some locations, the confining unit is very limited to absent. As a result, the principal source of recharge to the Castle Hayne aquifer is from the overlying surficial aquifer. Additionally, the Castle Hayne confining unit is relatively thin (generally 5 to 9 ft thick), and in areas where there is a strong induced downward gradient from groundwater use, time of transport through the confining unit can be reduced significantly. If such areas occur near locations of active water supply wells, there is a potential pathway for human receptors from MC entering the surficial aquifer.

A long-term water level study conducted by the USGS at two locations east and west of the New River at MCB Camp Lejeune indicated little to no confinement of the Castle Hayne aquifer at a location east of the New River and some confinement of the Castle Hayne aquifer at a location west of the New River (Harden et al., 2004).

5. Modeling Assumptions and Parameters

As part of the REVA five-year review effort, fate and transport screening-level modeling analyses were conducted for 14 MC loading areas at MCB Camp Lejeune. These areas included G-10 Impact Area, F-6, G-8 and G-9, K-211 and K-212, K-405, K-510, L-5, ETA-1, ETA-3, ETA-4, ETA-7, Stones Bay Area, EOD-2, and F-2 and F-5 MC loading areas. Historical loading (i.e. loading prior to the five-year review period) was conducted only for those MC loading areas that were not assessed in the baseline. For those areas evaluated in the baseline assessment in which no additional loading has occurred, no further assessment of these historical areas was completed. Historical loading affects only groundwater and sediment due to the binding action of sediments, and the attenuation capacity and slow speeds of groundwater.

The primary processes in the fate and transport of MC in marine environments are dissolution kinetics, adsorption to marine sediment, and transformation of the original compound. Perchlorate is very soluble and does not readily adsorb to soil, but can be broken down by perchlorate reducing bacteria. TNT quick disassociates in marine water and next to perchlorate, has the highest solubility of all MC. TNT also sorbs to marine sediment and its distribution in an estuary often mirrors sediment flow. It can be broken down in sediments by microbial degradation. RDX and HMX are most likely to be found in the particulate phase. They have limited solubility and do not adsorb to sediment as readily as TNT. They are also somewhat resistant to biotic transformation. Lead is not very mobile and strongly sorbs to soil. It is likely to be introduced into surface water or groundwater by way of sediment migration. Its distribution in an estuary is very similar to the sediment flow (Headquarters Marine Corps, 2010).

The purpose of the fate and transport screening-level analyses was to determine the potential for release of MC in surface water, groundwater, and sediment from the identified MC loading areas. If the results of the screening-level analyses indicated a potential release of MC, additional assessments (such as sampling) was conducted. Otherwise, no further assessment was conducted at this time, but the identified MC loading areas will be reassessed in the next five-year review to ensure that continued loading at the sites is not impacting surface water, groundwater, or sediment. The screening-level modeling analyses methods and assumptions are presented in this section.

5.1. Surface Water and Sediment Modeling Assumptions

The analyses of potential surface water and sediment impacts for MCB Camp Lejeune were conducted following the REVA process described in the *REVA Reference Manual* and the *REVA Five-Year Review Manual* (HQMC, 2009; HQMC, 2010). The initial step is a qualitative analysis of the surface water and sediment conditions based on the CSM, described in detail in **Section 4,** including the identification of potential exposure pathways, migration routes, and potential receptors (human and ecological). When these qualitative analyses indicate a potential for MC migration from MC loading areas to surface water receptors, screening-level MC transport analyses are performed to quantitatively estimate potential concentrations of indicator MC (RDX, HMX, TNT, and perchlorate) that can migrate in surface water and sediment.

Under REVA, screening-level transport analyses are used first to estimate the MC concentrations in surface water runoff and sediment at the edge of the identified MC loading areas. If these analyses predict potential impacts at the edge of the loading area, then additional calculations are performed to estimate the potential MC concentrations at a downstream receptor location. Average annual surface water and sediment concentrations of the indicator MC are estimated based on the average annual MC loading of each indicator MC to each MC loading area.

The estimation of MC concentrations in surface water assumes that a portion of the MC could enter the surface water by several mechanisms: (1) erosion of particulate or adsorbed MC in soil; (2) direct dissolution of MC in surface water runoff; and/or (3) connectivity of groundwater and surface water.

The mass loading of the indicator MC on the operational ranges was estimated as described in **Section 3**. In accordance with the REVA Part I surface water screening-level methodology, the entire annual MC load was converted to an average daily loading rate. This average daily loading rate was assumed to be loaded to the ground surface soil. The MC loading rates at the MC loading areas modeled varied over four different loading periods:

Time Period C (1938–1976)
Time Period D (1977–1988)
Time Period E (1989–2004)
Time Period F (2005–2010)

Table 5-1 presents the ranges of time periods for which the surface water and sediment screening-level analyses were conducted at the MC loading areas modeled. If a range was evaluated in the baseline assessment, it was assessed only for the current period.

Table 5-1: Time Periods of the Surface Water and Sediment Screening-Level Analyses

MC Loading Area	Years of Analyses	Time Period
G-10 Impact Area	2005–2010	F
F-6	2005–2010	F
G-8 and G-9	2005–2010	F

K-211 and K-212	2005–2010	F
K-405	2005–2008	F
K-510	2008–2010	F
L-5	2005–2010	F
F-2 and F-5	2005–2010	F
ETA-1	1994–2010	E and F
ETA-3	1994–2010	E and F
ETA-4	1994–2010	E and F
ETA-7	2007–2010	F
Stones Bay Area	1942–2010	C, D, E, and F
EOD-2	1970–2010	C, D, E, and F

A conservative, screening-level modeling approach was taken to estimate the annual average concentrations of MC in surface water runoff and sediment from the identified MC loading areas.

Results of the surface water and sediment screening-level analyses were compared to the REVA trigger values (**Table 5-2** and **Appendix B**) to evaluate the potential for MC releases to off-range receptors. The surface water REVA trigger values are applicable to all water sources (i.e., results of the surface water and groundwater screening-level analyses were compared to these REVA trigger values). The screening-level analysis methods are described briefly in the following sections. Additional details on the methods are provided in the *REVA Reference Manual* and the *REVA Five-Year Review Manual* (HQMC, 2009; HQMC, 2010).

Table 5-2: REVA Trigger Values for MC

MC	Trigger Value (µg/L)	Trigger Value for Sediment (µg/kg)
RDX	0.11	32.5
TNT	0.113	25
HMX	0.114	51
Perchlorate	0.021	0.18

Note:
µg/kg – micrograms per kilogram

5.1.1. Surface Water Screening-Level Approch at MC Loading Areas

This subsection discusses the methods used in estimating MC entering surface water through (1) erosion of particulate or adsorbed MC in soil; (2) direct dissolution of MC in surface water runoff; and (3) MC discharge from shallow groundwater.

The MC at loading areas were assumed to be loaded to the ground surface soil. For the MC loading areas where MC loading occurred for more than one loading period (ETA-1, ETA-3, ETA-4, Stones Bay Area, and EOD-2), the MC load of each loading period was modeled separately. The MC residual mass in the soil at the end of the first loading period was added to the MC load of the next loading period.

5.1.1.1. Estimation of the Annual Average MC Concentrations Leaving MC Loading Areas

The following three calculations were carried out in order to estimate average annual MC concentrations in surface water runoff leaving MC loading areas.

Soil Erosion: Estimates of soil erosion were required for subsequent calculation of the mass of MC transported from MC loading areas. Estimation of the soil erosion to calculate transported MC mass is especially important for MC that strongly adsorb to soil (e.g., TNT). Annual soil erosion rates were estimated using the Revised Universal Soil Loss Equation (RUSLE), which incorporates the major factors affecting erosion to predict the rate of soil loss in mass per area per year. The RUSLE is expressed as follows:

$$A = RKLSCP$$

Where: A = Predicted soil loss
R = Rainfall and runoff factor
K = Soil erodibility factor
LS = Topographic factor (factor influenced by length and steepness of slope)
C = Cover and management factor
P = Erosion control practice factor

These factors were estimated for the MC loading areas at MCB Camp Lejeune using available information, such as soil types, land use / land cover, and digital elevation data (MCB Camp Lejeune, 2010a). **Table 5-3** lists parameter values used in estimating soil erosion for the MC loading areas.

Table 5-3: Parameters Used to Estimate Soil Erosion

MC Loading Area	Area (m^2)	R[a]	K[b]	LS[c]	C[d]	P[e]	A (kg/m^2/day)
G-10 Impact Area	4.5E+06	275	0.1	0.97	0.19	0.8[e]	2.8E-03
F-6	9.5E+03	275	0.1	1.44	1	0.8[e]	2.2E-02
G-8 and G-9	1.4E+05	275	0.1	1.10	1	1	2.0E-02
K-211 and K-212	4.1E+05	275	0.17	1.70	0.11	0.8[e]	4.6E-03
K-405	1.7E+04	275	0.1	2.02	0.50	0.8[e]	1.5E-02
K-510	6.7E+04	275	0.1	2.02	0.87	0.8[e]	2.6E-02
L-5	3.4E+05	275	0.1	1.33	0.70	1	1.8E-02
F-2 and F-5	5.2E+05	275	0.17	0.64	0.087	1	1.8E-03
ETA-1	1.2E+05	275	0.1	1.90	0.18	1	6.5E-03
ETA-3	7.7E+03	275	0.1	0.48	1	1	9.1E-03
ETA-4	5.9E+04	275	0.1	0.80	0.87	1	1.3E-02
ETA-7	1.0E+05	275	0.2	0.80	0.47	1	1.4E-02
Stones Bay Area	1.5E+04	275	0.1	1.9	0.87	0.8[e]	2.5E-02
EOD-2	2.7E+04	275	0.1	0.35	0.055	1	3.6E-04

Note:
m^2 = square meters
kg/m^2/day = kilograms per square meter per day
[a] Brady, 1984
[b] USDA SCS, 1992
[c] Slope length and gradient were used to select LS (USDA ARS, 1997).
[d] Estimated based on vegetation cover (USDA ARS, 1997)
[e] Factor selected based on storm water best management practices located on range (MCB Camp Lejeune, 2010a)

Surface Water Runoff: The annual surface water runoff rate from each loading area was estimated simply as the product of the average annual precipitation, the loading area, and a runoff coefficient. The average annual precipitation of 54 in/yr was evaluated from annual precipitation data obtained from two different weather stations in Jacksonville, NC (for the period 1996–2005) and New Bern, NC (for the period 1970–2005). Runoff coefficients were selected from published tabular data (McCuen, 1998) based on soil hydrologic group, slope, and land cover of the MC loading areas being analyzed (**Table 5-4**).

Table 5-4: Soil Types and Hydrologic Properties of MC Loading Areas

MC Loading Area	Land Cover[a]	Hydrologic Soil Group[a,b]	Soil Organic Content (%)[b]	Soil Bulk Density (kg/m^3)[b]	Runoff Coefficient[c]
G-10 Impact Area	Vegetated with shrub/scrub with a large vacant area	A, B, and D	0.8	1600	0.29
F-6	Vacant	A	0.29	1700	0.71
G-8 and G-9	Vacant	A	0.29	1700	0.71
K-211 and K-212	Vegetated with shrub/scrub with some vacant areas	A and B	0.58	1650	0.24
K-405	Mostly vacant and some areas vegetated with pine forest	A	0.44	1600	0.63
K-510	Sparsely vegetated with pine, mixed pine, and hardwood forest	A	0.29	1450	0.66
L-5	Almost all vacant with a very small area of pine forest	A	0.37	1650	0.65
F-2 and F-5	Vegetated mostly with pine and scrub/shrub, includes some vacant areas	A, B, and C	0.87	1600	0.22
ETA-1	Portion of the area is vegetated with pine forest and the rest vacant	A	0.29	1450	0.2
ETA-3	Vacant	A	1.2	1680	0.69
ETA-4	Sparsely vegetated with pine and hardwood forest	A	0.29	1700	0.65
ETA-7	A large vacant area and the remaining is vegetated with shrub/scrub, some pine and hardwood forest	C	1.6	1500	0.67
Stones Bay Area	Sparsely vegetated with mixed pine, hardwood and bottomland hardwood forest	A	0.44	1600	0.68
EOD-2	Vegetated with mixed pine and hardwood and includes vacant spots	A	0.29	1450	0.1

Note:
kg/m^3 = kilogram per cubic meter

% = percent
[a] MCB Camp Lejeune, 2010a
[b] USDA SCS, 1992
[c] McCuen, 1998

MC Mass and Concentration in Runoff: A multimedia partitioning model, CalTOX, was used to estimate the mass of MC transported from surface soil to surface water runoff. This model has the capability of simulating the major transport mechanisms that are likely to affect MC from their point of origin in surface soils to their release into surface water runoff. CalTOX was used to simulate the partitioning of MC loaded into various media (soil, air, and water) over time. The rate at which MC will partition among these media is dependent on both the chemical properties of the MC and the physical/hydrological properties of the site. CalTOX requires the input of landscape properties of the MC loading areas (**Table 5-3** and **Table 5-4**) and chemical properties of the MC (**Table 5-5** and **Table 5-6**). Values of landscape and chemical properties were selected based on local reports, soil surveys, mapping information, and the scientific literature. The following landscape properties were used as input parameters and were estimated to have common values at all MC loading areas analyzed: 1) the annual recharge rate of 13 in/yr, 2) the water content of the surface soil equal to 24%, 3) the air content of the surface soil equal to 19%, 4) the annual average ambient temperature of 56°F, and 5) the annual average wind speed of 8.1 miles per hour.

Table 5-5: Chemical Properties of MC

MC	Molecular Weight (g/mol)	K_{ow}[a]	Melting Point (K)[b]	Vapor Pressure (Pa)[b]	Solubility (mol/m^3)[b]	Henry's Law Constant (atm m^3/mol)[a]	Half-life in Surface Soil (days)[a]	Diffusion Coefficient in Air (m^2/day)[a]	Diffusion Coefficient in Water (m^2/day)[a]	K_{OC} (mL/g)[a]
TNT	227.1	72.4	354	1.47E-04	5.72E-01	1.1E-08	23.1	0.55	5.80E-05	525
RDX	222.1	6.45	477	5.47E-07	1.90E-01	1.2E-05	14.2	0.64	6.18E-05	7.76
HMX	296.2	1.15	551	4.40E-12	1.69E-02	2.63E-15	51.3	0.54	5.2E-05	3.47
Perchlorate	99.45	1.4E-06	571	3.75E-09	2.01E+03	Calc. by model[c]	1.0E+07[d]	7.0E-10[d]	1.9E-12[d]	Calc. by model[c]

Note:
atm m^3/mol = atmospheric cubic meters per mole
g/mol = grams per mole
K = Kelvin
K_{oc} = organic carbon partition coefficient
K_{ow} = octanol-water partition coefficient
m^2/day = square meters per day
mL/g = milliliters per gram
mol/m^3 = moles per cubic meter
Pa = Pascals

[a] HQMC, 2009
[b] Walsh et al., 1995
[c] CalTOX includes an option for estimating the Henry's law constant from the chemical vapor pressure and solubility values and the K_{oc} from the chemical K_{ow} (California Office of Scientific Affairs, 1994).
[d] Conservative assumption

Table 5-6: Organic Carbon Fraction (f_{oc}) and Soil Partition Coefficient (K_D) at MC Loading Areas

MC Loading Area	f_{oc} (%)	K_D (mL/g)			
		TNT	HMX	RDX	Perchlorate
G-10 Impact Area	0.80	4.2	0.028	0.062	5.5E-09
F-6	0.29	1.5	0.010	0.022	2.0E-09
G-8 and G-9	0.29	1.5	0.010	0.022	2.0E-09
K-211 and K-212	0.58	3.0	0.020	0.045	4.0E-09
K-405	0.44	2.3	0.015	0.034	3.0E-09
K-510	0.29	1.5	0.010	0.022	2.0E-09
L-5	0.37	1.9	0.013	0.029	2.56E-09
F-2 and F-5	0.87	4.6	0.031	0.068	6.01E-09
ETA-1	0.29	1.5	0.010	0.022	2.0E-09
ETA-3	1.2	6.3	0.042	0.093	8.3E-09
ETA-4	0.29	1.5	0.010	0.022	2.0E-09
ETA-7	1.6	8.4	0.055	0.124	1.1E-08
Stones Bay Area	0.44	2.3	0.015	0.034	3.04E-09
EOD-2	0.29	1.5	0.010	0.022	2.0E-09

Note:
f_{oc} is a value estimated from the soil organic content.
K_D was calculated from f_{oc} and K_{oc} as given in **Table 5-5**.

The chemical parameter values used in the model were selected as the most recent available at the time the modeling was conducted. Some of the parameter values vary in the literature, such as MC decay rate and MC organic carbon partition coefficient (K_{oc}). In general, variability of many of the chemical parameters in the literature is not wide enough to cause significant variations in model results. Conservative values are selected for parameters to which model results are expected to be sensitive.

The CalTOX output of interest for the surface water analysis was the MC mass transferred from surface soil to surface water, which CalTOX expresses as an average daily load in grams per day. This daily mass transfer rate was divided by the daily runoff volume to estimate the MC concentration in surface water runoff at the edge of the MC loading area, prior to down gradient mixing/dilution in streams.

The CalTOX output of time-averaged ground surface soil concentration was used to estimate the residual MC mass at the end of a loading period. This residual mass was added to the MC load of the following loading period.

Temporal and spatial resolution of the analysis is limited by the basic input parameter, the loading rate, which is input as an annual value. Therefore, the screening analysis inherently results in annual average concentrations.

5.1.1.2. Estimation of Munitions Constituents Concentrations Entering the New River and Intracoastal Waterway

MC loading areas within MCB Camp Lejeune drain to streams that ultimately flow into the New River and the Intracoastal Waterway. For MC loading areas where MC concentrations in surface water runoff at the edge of the MC loading area were estimated to be above the REVA trigger value, a simple approach was taken to estimate the order-of-magnitude reduction in the concentrations at the edge of the MC loading area boundaries that would be expected to be caused by down gradient mixing with runoff from non-MC loading areas. The total drainage area to the potential receptor locations in the New River and the Intracoastal Waterway downstream of the MC loading areas was estimated (**Figure 5-1**). The estimated concentrations at the edge of the MC loading areas then were multiplied by the ratio of the loading area to the total drainage area of the receptor locations in the New River and the Intracoastal Waterway. The down gradient, mixed MC concentrations entering the receptor locations in the New River and the Intracoastal Waterway were estimated as area-weighted sums of the concentrations from the individual loading areas draining to the water bodies:

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

Where: C_{mixed} = Post-mixed concentrations entering receptor locations in the New River and the Intracoastal Waterway (µg/L)

C_{runoff} = Concentration in runoff from loading areas (µg/L)

A_{LA} = Area receiving MC loading (m^2)

A_{DA} = Total drainage area of receptor locations in the New River and the Intracoastal Waterway (m^2)

Table 5-7 shows proportions of MC loading areas draining to receptor locations in the New River and the Intracoastal Waterway. An inherent assumption of this method is that all areas other than MC loading areas contribute runoff that has negligible MC concentrations. This provides a simple estimate of the potential for estimated concentrations to be reduced by mixing with other runoff prior to entry into major tidal water bodies, such as the New River embayment and the Intracoastal Waterway. This approach conservatively assumes no reduction of MC through MC decay in surface water and tidal mixing in the tidal waters.

Table 5-7: Proportions of MC Loading Areas Draining to Receptor Locations

Receptor Location	MC Loading Area Draining to Receptor Location	Approximate Percent of Loading Area Draining to Receptor Location
New River between Town Creek and Stones Bay	G-10 Impact	70
	F-6	100
	G-8 and G-9	100
	ETA-4	50
	ETA-7	100
	K-211 and K-212	15
Bear Creek at the confluence with Intracoastal Waterway	G-10 Impact	30
New River at Stones Bay	K-211 and K-212	85
	K-405	100
	Stones Bay Area	100
New River between Stick and Whitehurst Creek	K-510	100
	EOD-2	100
Stones Creek at the confluence of New River at Stones Bay	L-5	100
New River between Stones Bay and Intracoastal Waterway	ETA-1	100
Wallace Creek at the confluence with New River	ETA-3	100
	F-2 and F-5	100
Freeman Creek at the confluence with Intracoastal Waterway	ETA-4	50

In addition to direct surface water runoff sources, shallow groundwater is a known source of baseflow to streams and tidal water bodies. MC concentrations in groundwater potentially discharging into the nearest surface water receptor location from all MC loading areas were estimated in the groundwater screening-level analysis that is discussed in **Section 5.2**. From the groundwater screening analysis, MC concentrations that were predicted to discharge into surface water receptor locations above REVA trigger values were considered for a mixing calculation with runoff sources. The following steps were followed in the mixing calculation:

i) The MC load in groundwater from the loading area was estimated by multiplying the predicted concentration (result of the groundwater screening analysis from **Section 5.2.2.4**) with a base flow rate of 11.96 in/yr (mid-range value from Baker Environmental, 1998a) and the loading area.

ii) The mixed runoff and baseflow concentration leaving the MC loading area was estimated by dividing the total MC load leaving the MC loading area (the sum of the MC load from groundwater calculated in step i and MC load from runoff estimated from CalTOX) by the total volume of runoff and baseflow.

iii) The mixed runoff and baseflow concentration from step ii was used as the input concentration (instead of the C_{runoff}) in the downstream mixing calculation described above to estimate downstream mixed concentrations entering identified receptor locations in the New River and Intracoastal Waterway. In order to take a conservative approach, if the mixed runoff and baseflow concentration from step ii was lower than the C_{runoff}, then C_{runoff} was used as the input concentration in the downstream mixing calculation.

5.1.2. Sediment Screening-Level Approach at MC Loading Areas

The CalTOX partitioning model was used to estimate MC concentrations in sediment leaving MC loading areas. All the input variables used are similar to the input variables used for the surface water analysis as described in **Section 5.1.1.1**. CalTOX was used to estimate the MC mass transferred to surface water through partitioning into the soil/sediment eroding from the site. The MC concentrations in eroded soil/sediment leaving the MC loading areas then were estimated by dividing the MC mass flow rate eroded (obtained from CalTOX) by the estimated soil erosion rate.

For MC loading areas where MC concentrations in sediment at the edge of the MC loading area were estimated to be above the REVA trigger value, additional screening analysis was carried out to estimate MC concentration in sediment at a downstream receptor location in the New River and the Intracoastal Waterway. This involved using RUSLE to estimate the total annual mass of sediment transported to the downstream receptor location from areas upstream of the receptor location (mass of sediment eroded within the drainage area of the receptor location). The sediment MC concentration at the downstream receptor location in the New River and the Intracoastal Waterway was estimated to be equivalent to the MC mass leaving the MC loading area divided by the total sediment mass transported to the downstream receptor location. The cumulative sediment MC concentration from different MC loading areas draining to the same receptor location was estimated by taking the sum of the MC mass in sediment leaving the individual MC loading areas and dividing it into the sediment mass eroding into the receptor location as follows:

$$C_{sed,mixed} = \sum M_{MC,LA} / M_{sed,DA}$$

Where: $C_{sed,mixed}$ = Post-mixed MC concentration in sediment entering receptor locations in the New River and the Intracoastal Waterway (micrograms per kilogram [µg/kg])

$M_{MC,LA}$ = MC mass in sediment leaving the individual MC loading areas (micrograms per day [µg/d])

$M_{sed,DA}$ = Sediment mass eroded within the drainage area to the receptor location in the New River and the Intracoastal Waterway (kilograms per day [kg/d])

5.2. Groundwater Modeling Assumptions

The purpose of the groundwater analysis in the REVA program is to make best use of the available information to infer whether indicator MC (RDX, HMX, TNT, and perchlorate) can be transported in groundwater from loading areas to receptors. Both conceptual and quantitative methods are used. The initial step is a qualitative analysis of the groundwater conditions based on the CSM, described in detail in **Section 4**, including the identification of potential exposure pathways, migration routes, and potential receptors (human and ecological). When this qualitative analysis indicates there is potential for MC migration from loading areas to groundwater receptors, a screening-level MC transport analysis is performed to quantitatively estimate potential concentrations of indicator MC in groundwater migrating to a receptor or beyond the installation boundaries. This quantitative screening-level analysis method uses multiple conservative assumptions, is more likely to overestimate than underestimate MC concentrations, and is used to determine whether particular MC loading areas merit additional investigation. The groundwater screening-level analysis methods employed for MCB Camp Lejeune follow the approach described in the *Assessment of Models for Evaluating Fate and Transport of Munitions on Operational Ranges* and the *REVA Reference Manual* and are discussed in this section (Malcolm Pirnie, 2005; HQMC, 2009).

5.2.1. Qualitative Analysis

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

- Military munitions expenditure data
- GIS shapefiles (MCB Camp Lejeune GIS office)
- IRP site data

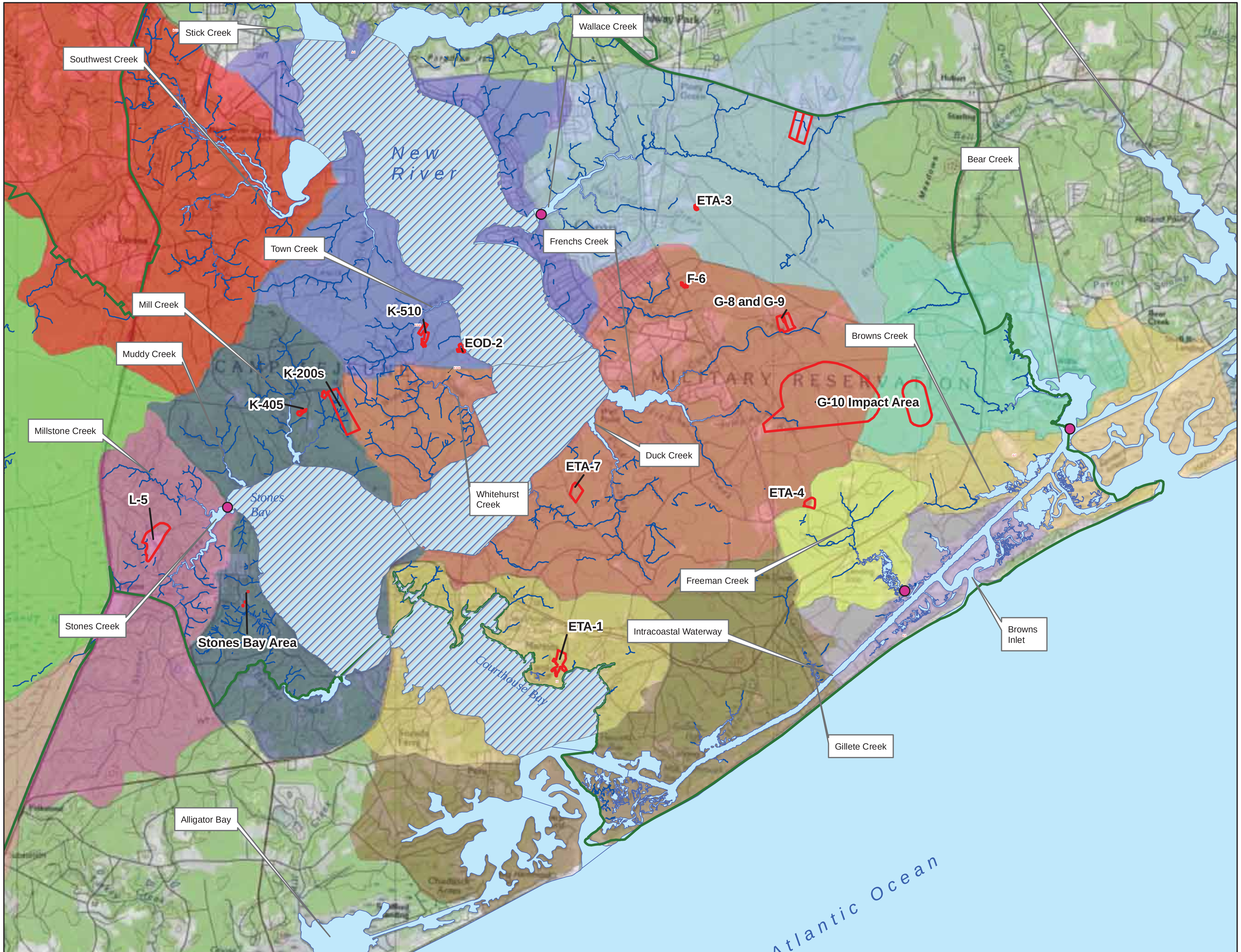

FIGURE 5-1
Surface Water Features and Subwatershed Areas of Receptor Locations

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- Stream
- Surface Water Body
- Surface Water Receptor Location Point
- Surface Water Receptor Location

Subwatershed Area

- Southwest Creek
- Wallace Creek
- New River between Stick Creek and Whitehurst Creek
- Shelter Swamp Creek
- Bear Creek
- New River between Town Creek and Stones Bay
- Intracoastal Waterway between Browns Inlet and Queen Creek
- New River at Stones Bay
- Stones Creek
- Freeman Creek
- Intracoastal Waterway between Gillete Creek and Browns Creek
- Intracoastal Waterway between Alligator Bay and Freeman Creek
- New River between Stones Bay and Intracoastal Waterway
- Juniper Swamp

0 2,500 5,000 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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Underground storage tank program documents

- USGS reports
- Soil survey report of Onslow County

The groundwater conditions, the potential for MC migration in vadose zone and saturated zones, and the presence of potential groundwater receptors at off-range locations are described in more detail in **Section 4.3**, **Section 4.5**, and **Section 4.8.2**.

5.2.2. REVA Groundwater Analysis Procedure

A screening-level fate and transport analysis of potential MC migration via groundwater was conducted as part of the vulnerability assessment for MCB Camp Lejeune. The analysis was conducted for 14 MC loading areas that were identified to be high priority areas for groundwater modeling. These MC loading areas were prioritized high for groundwater modeling based on their current use of munitions containing HE and their proximity to receptor locations (drinking water supply wells and surface water receptor locations). The screening-level analysis was accomplished in four main steps:

1. *Initial groundwater screening analysis*: MC concentrations were estimated in the portion of the precipitation water that infiltrates to the groundwater and assumed to arrive at the groundwater at that concentration.
2. *Vadose zone modeling*: A screening-level vadose zone model was used to evaluate the potential for MC to migrate through the vadose zone to the groundwater at concentrations greater than the REVA trigger value.
3. *Transport to the Castle Hayne aquifer*: The potential vertical migration of MC through the surficial aquifer into the semiconfined Castle Hayne aquifer was estimated by conservatively assuming that the entire MC load that arrives at the water table or the surficial aquifer is transported vertically to the Castle Hayne aquifer.
4. *Saturated zone modeling*: A screening-level groundwater model was used to evaluate if MC from MC loading areas have the potential to reach receptors through saturated groundwater flow at levels above the REVA trigger value. There were two parts to this analysis:
    a) MC transport through the surficial aquifer to a surface water receptor location was evaluated using the results from step 2.
    b) MC transport through the Castle Hayne aquifer to a drinking water supply well was evaluated using the results from step 3.

The above four steps executed for the screening-level analysis are discussed in the following subsections.

5.2.2.1. Initial Groundwater Screening Analysis

The first step in analyzing groundwater transport is an initial analysis of the MC loading rate and the annual groundwater recharge rate to determine a maximum MC concentration in infiltrating water. This approach produces a highly conservative concentration because the majority of the MC (with the exception of perchlorate) are not completely soluble in water and their effective solubilities decrease when in mixtures. Further, most MC have a high rate of decay and some of the MC (TNT and RDX) can have a relatively strong affinity to the soil particles and, thus, can readily sorb to the soil from the aqueous phase. Perchlorate is the only recalcitrant (persistent) indicator MC that does not readily degrade, is miscible (completely soluble) in water, and does not sorb to solid soil particles. This analysis also assumes that there is no removal of MC in the surface water runoff or decay as a result of biotic and abiotic transformations. If this initial, highly conservative analysis indicates the potential for MC to have a concentration in the infiltrating water above the REVA trigger values (**Table 5-2**), a more detailed screening-level modeling analysis is done for that MC using the models outlined in the *Assessment of Models for Evaluating Fate and Transport of Munitions on Operational Ranges* and the *REVA Reference Manual* (Malcolm Pirnie, 2005; HQMC, 2009).

The initial groundwater analysis is performed as a spreadsheet-based mass balance calculation. The basic input data are the estimated average annual MC loading rates at the MC loading areas (presented in **Section 6**) and the estimated infiltration rate (recharge) of 1.06 feet per year (ft/yr) at MCB Camp Lejeune (Heath, 1989). The estimated recharge value of 1.08 ft/yr includes the estimated evapotranspiration rates, which significantly reduces recharge.

The maximum possible concentration of MC in the infiltrating water was calculated by dividing the MC loading rate by the volume of the infiltrating water. MC estimated to have concentrations above the REVA trigger value at MC loading areas were further analyzed for transport through the vadose zone using a screening-level vadose zone model. However, MC estimated to have concentrations below REVA trigger values at MC loading areas were eliminated from additional analysis.

5.2.2.2. Vadose Zone Modeling

When the results from the initial groundwater analysis from **Section 5.2.2.1** indicate a need for further evaluation, the U.S. Environmental Protection Agency (USEPA) VLEACH Model, a vadose zone leaching model, is used to simulate fate and transport of MC through the unsaturated zone to the groundwater table. VLEACH is a one-dimensional finite difference vadose zone leaching model that simulates the movement of organic contaminants within and between three phases: 1) as a solute dissolved in water,

2) as a gas in the vapor phase, and 3) as an adsorbed compound in the solid phase (Ravi and Johnson, 1997). Partitioning between phases occurs according to the contaminant distribution coefficient. Vertical transport in VLEACH is simulated by advection in the liquid phase and by gaseous diffusion in the vapor phase.

At a minimum, RDX was modeled for migration through the vadose zone at all 14 MC loading areas.

At five of the MC loading areas (ETA-1, ETA-3, ETA-4, Stones Bay Area, and EOD-2), MC concentrations from the initial groundwater screening analysis were estimated to exceed REVA trigger values in more than one loading period. For these loading areas, the MC from each loading period were modeled separately, and the steady-state output soil concentration from the initial loading period was used as an input soil concentration of the following loading period. Thus, the input for the later loading periods included initial soil concentration (the residual soil concentration from the previous loading period) and a recharge concentration (from MC loading for the loading period).

Local soils generally consist of fine sand and loamy fine sand. The relevant chemical and physical properties of the vadose zone soils, MC, and climate that were used as input parameters to VLEACH are presented in **Table 5-5** and **Table 5-8**. Parameter values that were common to all MC loading areas include 1) a recharge rate of 1.08 ft/yr, 2) a soil effective porosity of 0.25, and 3) a soil volumetric water content of 0.24.

Table 5-8: Physical Properties of the Vadose Zone Soils

MC Loading Area	Area (acres)	Depth to Groundwater (ft)[a]	Dry Bulk Density (g/cm^3)[b]	Soil Organic Carbon Content[b]
G-10 Impact Area	1,113.6	8.2	1.6	0.008
F-6	2.2	8.8	1.7	0.0029
G-8 and G-9	34.6	8.2	1.7	0.0029
K-211 and K-212	101.0	5	1.65	0.0058
K-405	4.2	5	1.6	0.0044
K-510	16.5	3.5	1.45	0.0029
L-5	85.2	1.82	1.65	0.0037
F-2 and F-5	87	8.8	1.6	0.0087
ETA-1	30.6	7.25	1.45	0.0029
ETA-3	2.0	8.8	1.68	0.012
ETA-4	14.6	8.2	1.7	0.0029
ETA-7	24.7	3.5	1.5	0.016

Stones Bay Area	3.7	1.82	1.6	0.0044
EOD-2	6.6	1.25	1.45	0.0029

Note:
g/cm^3 = grams per cubic centimeters
[a] O'Brien and Gere, 1988; CH2M HILL et al., 2001; CH2M HILL, 2006; CH2M HILL, 2009; and CH2M HILL, 2010; Harden et al., 2004; Baker Environmental, 1996
[b] MCB Camp Lejeune, 2010a; USDA SCS, 1992

5.2.2.3. Transport to Castle Hayne Aquifer

Potential transport to the Castle Hayne Aquifer was assessed for MC loading areas where the MC concentration reaching the water table exceeded the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area. These MC loading areas include G-10 Impact Area, F-6, G-8 and G-9, L-5, F-2 and F-5, ETA-1, ETA-3, ETA-4, ETA-7 and Stones Bay Area.

For MC loading areas located relatively close to drinking water supply wells, it was conservatively assumed that the Castle Hayne confining unit was absent. The potential vertical MC migration through the surficial aquifer to the Castle Hayne aquifer, where the supply wells draw water from, was estimated. In doing so, a simple block mixing approach was used to estimate concentration in the Castle Hayne aquifer at the MC loading area resulting from mixing of vertical and lateral flows in the surficial and Castle Hayne aquifers. The following steps were used:

1. Mixing in the surficial aquifer
   $F_{mixing,surficial} = Q_{recharge} / \sum (Q_{recharge} + Q_{L,surficial})$
2. Mixing in the Castle Hayne aquifer
   $F_{mixing,Castle\ Hayne} = Q_{v,surficial} / \sum (Q_{v,surficial} + Q_{L,Castle\ Hayne})$
3. Mixed concentration potentially reaching the Castle Hayne aquifer
   $C_{mixed,Castle\ Hayne} = F_{mixing,surficial} \times F_{mixing,Castle\ Hayne} \times C_{wt}$

Where: $F_{mixing,surficial}$ = Mixing factor in the surficial aquifer
$F_{mixing,Castle\ Hayne}$ = Mixing factor in the Castle Hayne aquifer
$Q_{recharge}$ = Recharge over the loading area
$Q_{L,surficial}$ = Lateral flow through the cross section for the loading area in surfical aquifer
$Q_{V,surficial}$ = Vertical flow over the loading area in surficial aquifer
$Q_{L,Castle\ Hayne}$ = Lateral flow through the cross section for the loading area in Castle Hayne aquifer
$C_{mixed,Castle\ Hayne}$ = Mixed concentration in the Castle Hayne aquifer at the MC loading area

C_{wt} = Concentration at the water table (VLEACH output described in **Section 5.2.2.2**)

This approach conservatively assumes no loss of MC by dispersion, sorption, volatilization, or degradation. The recharge rate (vertical flow to the surficial aquifer) was equivalent to the value used in the initial groundwater screening analysis.

The lateral flow in the surficial aquifer was estimated as:

$$Q_{L,surficial} = K_{H,surficial} \times I_{H,surficial} \times A_{LAc\text{-}s,surficial}$$

Where: $K_{H,surficial}$ = the horizontal hydraulic conductivity of the surficial aquifer (estimated average value of 5 ft/d was used; Baker Environmental, 1993; Baker Environmental, 1996; Baker Environmental, 1998a and 1998b)

$I_{H,surficial}$ = the estimated hydraulic gradient between the loading area and the surface water discharge point

$A_{LAc\text{-}s,surficial}$ = cross section area of the MC loading area in the surficial aquifer (equivalent to loading area width multiplied by aquifer thickness)

The vertical flow in the surficial aquifer was estimated as:

$$Q_{V,surfiial} = K_{V,surficial} \times I_{V,surficial} \times A_{LA}$$

Where: $K_{V,surficial}$ = the vertical hydraulic conductivity of the surficial aquifer [(estimated to be one tenth of the horizontal hydraulic conductivity [0.5 ft/d])

$I_{V,surficial}$ = the vertical hydraulic gradient at each MC loading area (estimated by dividing the difference of the water level heads in the surficial and the Castle Hayne aquifers by the estimated thickness of the surficial aquifer)

A_{LA} = the MC loading area

The lateral flow in the Castle Hayne aquifer was estimated as:

$$Q_{L,Castle\ Hayne} = K_{H,Castle\ Hayne} \times I_{H,Castle\ Hayne} \times A_{LAc\text{-}s,\ castle\ Hayne}$$

Where: $K_{H,Castle\ Hayne}$ = the horizontal hydraulic conductivity of the Castle Hayne aquifer (estimated average value of 75 ft/d was used; Baker Environmental, 1998a and 1998b; Cardinell et al., 1993)

$I_{H,Castle\ Hayne}$ = the estimated hydraulic gradient in the Castle Hayne between the loading area and the nearest drinking water well

$A_{LAc\text{-}s,\ castle\ Hayne}$ = cross section area of the MC loading area in the Castle Hayne aquifer

Thickness of the surficial aquifer near the MC loading areas analyzed was estimated to range from 30 to 75 ft. The minimum known thickness of 175 ft for the Castle Hayne aquifer in the MCB Camp Lejeune area was used in the calculations.

5.2.2.4. Saturated Zone Modeling

The fate and transport of MC at the various MC loading areas that were estimated to reach 1) the surficial aquifer (from the vadose zone modeling) and 2) the Castle Hayne aquifer (from the analysis on transport to Castle Hayne aquifer) were simulated using BIOCHLOR2.2, a one-dimensional analytical solute transport and fate model (Aziz and Newell, 2002). The model was used to predict the possible movement of MC through the saturated zone to potential receptor locations. It was run on a simple box grid and assumed a homogeneous aquifer with constant velocity.

Transport to Surface Water Receptor Location: Groundwater flow in the surficial aquifer at MCB Camp Lejeune is toward the major surface water features (the New River and its tributaries, the Intracoastal Waterway and its tributaries, and the Atlantic Ocean). Potential receptors in the surface waters where the shallow groundwater discharges include humans (for recreational use) and ecological receptors (including T/E species). The distance from each MC loading area modeled to the nearest potential surface water receptor location was estimated. Using the maximum water table concentration estimated from the result of the vadose zone modeling as an input to the BIOCHLOR model, MC concentrations potentially reaching the nearest surface water receptor location were estimated. The relevant aquifer and chemical properties used as input parameters in the BIOCHLOR model are presented in **Table 5-9**. These values were based on the literature or conservative assumptions. The site-specific model parameters are presented in **Table 5-10**. Saturated zone modeling with BIOCHLOR was not conducted for the EOD-2 Range MC loading area because this loading area is located right next to the New River; therefore, it was assumed that MC reaching the water table at this loading area (as evaluated from the vadose zone modeling) would discharge directly into the New River.

Table 5-9: Aquifer and Chemical Parameters Used in BIOCHLOR

Parameters	Surficial Aquifer	Castle Hayne Aquifer
Hydraulic conductivity (ft/d)[a]	5	75
Effective porosity[b]	0.2	0.14
Longitudinal dispersion (ft)	3	3
Ratio of transverse to longitudinal dispersion	0.1	0.1
Ratio of vertical to longitudinal dispersion	1E-99	1E-99

Parameters	Surficial Aquifer	Castle Hayne Aquifer
Soil bulk density (kg/L)[c]	1.99	1.99
Organic carbon fraction[d]	0.0029	0.0029
Decay constant for HMX (yr^{-1})[e]	4.93	4.93
Decay constant for RDX (yr^{-1})[e]	17.82	17.82
Decay constant for TNT (yr^{-1})[e]	10.95	10.95
Decay constant for perchlorate (yr^{-1})[f]	2.53E-05	2.53E-05

Note:
The chemical K_{oc} values used in BIOCHLOR are listed in **Table 5-5.**
kg/L = kilogram per liter
yr^{-1} = per year
[a] Baker Environmental, 1998a and 1998b
[b] McWhorter and Sunada, 1977
[c] Fetter, 1994
[d] USDA SCS, 1992
[e] HQMC, 2009
[f] Conservative assumption

Table 5-10: Site-Specific Parameters in BIOCHLOR

MC Loading Area	Modeled Area Width (ft)	Surficial Aquifer		Castle Hayne Aquifer	
		Distance to Nearest SW RL (ft)	Hydraulic Gradient[a]	Distance to the Nearest Drinking Water Well (ft)	Hydraulic Gradient[b]
G-10 Impact Area	5,051	6,232[c]; 4,198[d]	0.005[c]; 0.006[d]	1,400	0.0004
F-6	525	1,000	0.021	750	0.0003
G-8 and G-9	1,443	7,872	0.004	4,600	0.001
K-211 and K-212	4,067	2,263[e]; 6,888[c]	0.010[e]; 0.003[c]	N/A	N/A
K-405	787	650	0.039	N/A	N/A
K-510	918	390	0.029	N/A	N/A
L-5	1,410	1,640	0.025	9,400	0.002
F-2 and F-5	1443	689	0.016	N/A	N/A
ETA-1	689	1,000	0.011	1,500	0.001
ETA-3	233	1,600	0.011	4,231	0.0002
ETA-4	984	2,300	0.017	2,560	8.0E-05
ETA-7	984	1,000	0.022	10,700	0.0009
Stones Bay Area	118	460	0.055	12,000	0.002

Note:
SW = surface water
[a] Estimated from the estimated groundwater elevations at the loading areas and known surface water elevations at groundwater discharge points
[b] Estimated from the potentiometric surface map for the Castle Hayne aquifer in **Figure 4-3**
[c] Surface water discharge point within the New River watershed between Town Creek and Stones Bay
[d] Surface water discharge point within the Bear Creek watershed
[e] Surface water discharge point within the Stones Bay watershed

Transport to Groundwater Receptors: From the transport to Castle Hayne aquifer analysis (**Section 5.2.2.3**), MC concentrations at several of the MC loading areas were estimated to reach the Castle Hayne aquifer above REVA trigger values. These MC concentrations were used as input to the BIOCHLOR model, which was used to estimate the MC concentration potentially reaching the nearest drinking water supply well from the MC loading areas. **Figure 4-3** shows locations of the drinking water supply wells and the potentiometric surface for the Castle Hayne aquifer. The relevant model parameters are presented in **Table 5-9** and **Table 5-10**.

6. Screening-Level Assessment Results

MC loading areas, listed in **Table 6-1**, were assessed qualitatively through the development of site-specific CSMs and, if necessary, quantitatively through screening-level transport assessments. The assessments for the MC loading areas are presented in the following subsections, which are organized by subwatershed.

- The subwatershed of the New River between Town Creek and Stones Bay (**Section 6.1**)
- The subwatershed of the New River at Stones Bay (**Section 6.2**)
- The subwatershed of the New River between Stick Creek and Whitehurst Creek (**Section 6.3**)
- The subwatershed of Wallace Creek (**Section 6.4**)
- The subwatershed of the New River between Stones Bay and the Intracoastal Waterway (**Section 6.5**)
- The subwatershed of Stones Creek (**Section 6.6**)
- The subwatershed of Bear Creek (**Section 6.7**)
- The subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek (**Section 6.8**)
- The subwatershed of Shelter Swamp Creek (**Section 6.9**)

There are five additional subwatersheds at MCB Camp Lejeune that also contain MC loading areas. These subwatersheds are not discussed in the following subsections because the MC loading areas within these subwatersheds overlap in other subwatersheds discussed, and insignificant quantities of MC drained through the overlapped subwatershed. These subwatersheds and their respective MC loading areas are as follows:

- The subwatershed of Southwest Creek (contains part of the SR-7 MC loading area, which is discussed in **Section 6.9**)
- The subwatershed of Juniper Creek (contains part of the SR-10 MC loading area, which is discussed in **Section 6.9**)
- The subwatershed of Intracoastal Waterway between Alligator Bay and Freeman Creek (contains part of ETA-2, which is discussed in **Section 6.5**)

- The subwatershed of Intracoastal Waterway between Browns Inlet and Queen Creek (contains parts of the G-6, G-7, and EOD-1 MC loading areas, which are discussed in **Section 6.7**)
- The subwatershed of Freeman Creek (contains part of the ETA-4 MC loading area, which is discussed in **Section 6.1**)

Table 6-1: MC Loading Areas and Subwatersheds

MC Loading Area	Dates of Use	Size of MC Loading Area		% Contained with the Subwatershed
		Acres	1,000 m^2	
Subwatershed of the New River between Town Creek and Stones Bay				
G-10 Impact Area	1953–present	1,114	4,506.5	70
K-2 Impact Area	1950–present	798	3,227.9	90
F-6	1972–present	2.2	8.9	100
G-8 and G-9	Unknown–2008	34.6	140.5	100
G-19A and G-19B	2010–present	12.6	51	100
K-211 and K-212	1970–present	101	3,227.9	15
K-301	1970–2006	30.3	122.8	10
K-303 to K-305	K-303 and K-305: 1970 –2008 K-304: 1970–2010	192	777.4	97
K-323	Unknown–present	7.8	31.5	100
Combat Town	1976–present	6.5	26.3	100
ETA-4	1994–present	14.5	59	50
ETA-5	1994–present	10	41.1	95
ETA-7	2009–present	25	100.3	100
G-10A EOD	Unknown–2010	0.4	1.7	100
Subwatershed of the New River at Stones Bay				
K-405	Unknown–2008	4.2	16.9	100
Stones Bay Area	Unknown–present	3.7	15.1	100
K-211 and K-212	1970–present	101	3,227.9	85
K-2 Impact Area	1950–present	798	3,227.9	10
Subwatershed of the New River at Stones Bay				
K-510	2008–present	16.5	66.9	100
EOD-2	1970–present	6.6	26.8	100
K-301	1970–2006	30.3	122.8	90
K-303 to K-305	1970–2008	192	777.4	3
ETA-5	1994–present	10	41.1	5

MC Loading Area	Dates of Use	Size of MC Loading Area		% Contained with the Subwatershed
		Acres	1,000 m^2	
Subwatershed of Wallace Creek				
ETA-3	1994–present	2.0	7.7	100
F-2 and F-5	F-2: 1950–present F-5: 1972–present	87	353	100
Subwatershed of the New River between Stones Bay and the Intracoastal Waterway				
ETA-1	1994–present	30.6	124.1	100
ETA-2	1994–present	61	247.2	50
Subwatershed of Stones Creek				
L-5	1957–present	85.2	344.6	100
Subwatershed of Bear Creek				
G-10 Impact Area	1953–present	1,114	4,506.5	30
Mobile MOUT	Unknown–present	11.1	44.8	100
EOD-1	1994–present	20.8	84.3	3
G-6	1951–present	72.1	291.9	90
G-7	1947–present	68.3	276.5	3
Subwatershed of the Intracoastal Waterway between Gilette Creek and Browns Creek				
G-5	Unknown–present	101.7	411.4	97
Subwatershed of Shelter Swamp Creek				
SR-6	1995–present	167.9	679.5	100
SR-7	1997–present	637.7	2,726.5	60
SR-10	1997–present	830.7	3,361.7	40

Fourteen of the 31 identified MC loading areas were prioritized based on use and potential for groundwater or surface water receptor exposure. These prioritized areas underwent screening-level modeling during the five-year review.

The subsection for each subwatershed discusses the operational range areas, the site-specific CSM, MC deposition estimates, screening-level modeling results (if applicable), and additional range information. The site-specific CSMs developed for the MC loading areas include the following:

- MC loading estimates
- Geography and topography
- Surface water features
- Soil characteristics and land cover

- Erosion potential
- Groundwater characteristics
- Potential surface water and groundwater pathways
- Potential receptors

Surface Water and Sediment Analyses Summary

The screening-level analyses of MC fate and transport in surface water and sediment were conducted for 14 MC loading areas located within seven subwatershed areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and the presence of surface drainages that lead to potential receptor 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 and baseflow, and sediment entering identified downstream receptor locations (e.g., tidal creeks, New River, Intracoastal Waterway).

MC concentrations in surface water runoff at the edge of all MC loading areas were estimated to be above REVA trigger values, and MC concentrations in sediment at the edge of a majority of the MC loading areas were estimated to be above REVA trigger values. Annual average MC concentrations in surface water runoff and baseflow entering five identified surface water receptor locations were predicted to be above REVA trigger values, while annual average MC concentrations in sediment entering all surface water receptor locations were predicted to be below REVA trigger values.

Groundwater Analysis Summary

Groundwater fate and transport modeling through screening-level analysis was conducted for 14 MC loading areas. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and their proximity to receptor locations (drinking water supply wells and surface water receptor locations). The initial groundwater screening-level analysis (estimation of MC concentration in infiltration water) predicted MC concentrations at all MC loading areas leaching into the vadose zone above REVA trigger values. Therefore, vadose zone modeling was conducted at all MC loading areas. MC concentrations at all MC loading areas were predicted to reach the water table above REVA trigger values and, therefore, were further analyzed for movement through the surficial and the Castle Hayne aquifers. Groundwater concentrations in the surficial aquifer from nine MC loading areas were predicted to potentially discharge to identified down gradient surface water receptor locations above REVA trigger values. Also, groundwater concentrations in the Castle Hayne aquifer from six MC loading areas were predicted to potentially reach groundwater receptor locations (drinking water wells) above REVA trigger values.

6.1. The Subwatershed of the New River between Town Creek and Stones Bay

The subwatershed of the New River between Town Creek and Stones Bay is located in the south-central part of MCB Camp Lejeune, and it is approximately 21,123 acres in size, entirely within the MCB Camp Lejeune boundary (**Figure 6-1**). The subwatershed area encompasses a section of the New River embayment and some of its tributaries, including Frenchs Creek, Duck Creek, and Whitehurst Creek. Part or all of 12 RTAs, 14 identified MC loading areas, and most of the K-2 and G-10 Impact Areas are located within the subwatershed. Screening-level modeling was completed only for prioritized MC loading areas, but all RTAs and MC loading areas within this subwatershed were considered for lead loading.

The following RTAs are partially or fully located in the subwatershed of the New River between Town Creek and Stones Bay:

- FD (1065 acres)
- GA (767 acres)
- GB (535 acres)
- HA (899 acres)
- HB (1542 acres)
- HC (891 acres)
- HD (947 acres)
- HF (1067 acres)
- HG (589 acres)
- HH (744 acres)
- JA (357 acres)
- KD (425 acres)

The date that RTA JA became operational is unknown, but the remaining RTAs in the subwatershed were operational starting in 1941. Historical use RTAs DC and DD were located within this subwatershed but were closed for cantonment in 2004. The RTAs are used for tactical maneuver training and, although munitions use is not heavy, expenditures recorded primarily include donor charges (C-4) and associated blasting charges (fuzes, cap, cord, etc). RTAs DC, DD, FD, GB, and KD had no munitions use recorded in Range Facility Management Support System (RFMSS) for the years 2004–2010.

A brief summary of MC loading areas partially or fully located within the subwatershed of the New River between Town Creek and Stones Bay is provided in **Table 6-1**. The majority of the areas for these ranges lie within this subwatershed (except for Range K-211 and K-212, for which only the southeastern most corner of the range falls within the subwatershed).

Military Munitions

Various high explosive, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of the New River between Town Creek and Stones Bay to support the various primary uses of the ranges in this area. Ranges within this subwatershed receive a great deal of use, and a wide range of munitions types is authorized. Training no longer occurs at ranges G-8, G-9, K-301, K-303, K-304, K-305, and G-10A EOD (dates of use shown in **Table 6-1**). Ranges that are new since the baseline assessment include G-19A and G-19B (opened 2010) and ETA-7 (opened 2009).

6.1.1. Conceptual Site Model

6.1.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the subwatershed of the New River between Town Creek and Stones Bay are shown in **Figure 6-1**. Delineation of the loading areas was based primarily upon target locations, or in the cases where fixed target locations were not used or available, GIS range boundary data layers were used for delineation.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within the MC loading areas over time (**Table 6-2**); the assumptions used to guide the estimates are detailed in **Section 5**. Additional range-specific assumptions had to be developed with regard to UXO disposal for Range G-10A EOD. Commitment sheets including data from a 5-month period were used to account for EOD-related expenditures that may not be captured in the primary records. Munitions counts were summed by DoDIC and demolition location over this time period; assumptions regarding MC content were made as needed, similar to those for the expenditure records. The 5-month sums then were adjusted proportionally to represent a full year (12-month span). It was assumed that the totals and distributions portrayed by these estimates are representative of typical annual patterns associated with uncatalogued EOD activities. Since historical loading was accounted for in the baseline, historical loading was estimated in the five-year review only for those MC loading areas not evaluated in the baseline assessment. Historical loading affects only groundwater and sediment due to the binding action of sediments and the attenuation capacities and slow speeds of groundwater.

FIGURE 6-1
MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay
MCB Camp Lejeune
Jacksonville, NC

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Table 6-2 provides the estimated annual MC loading by time period. MC loading was estimated during the baseline for all but two of the MC loading areas in the subwatershed of the New River between Town Creek and Stones Bay. Loading calculations for ranges evaluated in the baseline assessment include estimates of all historical loading; therefore, loading at these MC loading areas was conducted only for Period F in this five-year review. MC loading was not estimated for MC loading areas ETA 4 and ETA 5 in the baseline; thus, all historical loading calculations were completed and are provided in **Table 6-2**.

MC loading areas were defined differently during the baseline assessment; therefore, a direct comparison is not possible for most of the ranges in this subwatershed. K-ranges and G-ranges were combined into one MC loading area during the baseline assessment, whereas they were assessed separately during the five-year review in order to more accurately reflect where loading occurs. F-6 was assessed in the baseline, and MC loading rates for this review suggest loading has increased since the baseline (RDX and TNT increased by approximately one order of magnitude, while perchlorate loading decreased by approximately one order of magnitude). The loading estimate at Combat Town was similar to that determined in the baseline assessment, except that perchlorate loading increased by approximately two orders of magnitude.

Table 6-2: Estimated Annual MC Loading for the Subwatershed of New River between Town Creek and Stones Bay

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
G-10 Impact Area	F (2005–2010)	2005	2010	2.40E-05	3.51E-05	3.22E-07	1.74E-08
K-2 Impact Area	F (2005–2010)	2005	2010	8.20E-07	1.27E-06	0.00	3.37E-12
F-6	F (2005–2010)	2005	2010	2.80E-04	1.80E-04	0.00	4.55E-07
G-8 and G-9	F (2005–2010)	2005	2008	9.03E-06	4.12E-08	2.06E-07	1.04E-10
G-19 Ranges	F (2005–2010)	2010	2010	4.63E-06	1.78E-07	1.62E-06	5.21E-08
K-211 and K-212	F (2005–2010)	2005	2010	4.47E-05	1.27E-05	5.13E-08	3.61E-08
K-301	F (2005–2010)	2005	2006	1.89E-06	2.83E-07	7.21E-10	3.37E-10
K-303 to K-305	F (2005–2010)	2005	2008, 2010, 2008	1.96E-05	6.97E-06	4.14E-09	3.80E-08
K-323	F (2005–2010)	2005	2010	1.66E-08	4.68E-09	0.00	0.00
Combat Town	F (2005–2010)	2005	2010	4.04E-08	5.08E-09	3.31E-10	1.29E-06
ETA-4	E (1984–2004)	1994	2004	2.14E-05	1.71E-05	5.04E-09	2.12E-09
	F (2005–2010)	2005	2010	1.43E-05	1.14E-05	3.36E-09	1.42E-09

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
ETA-5	E (1984–2004)	1994	2004	1.65E-04	5.01E-05	9.85E-09	9.92E-09
	F (2005–2010)	2005	2010	1.10E-04	3.34E-05	6.57E-09	6.62E-09
ETA-7	F (2005–2010)	2009	2010	3.20E-05	6.05E-05	5.90E-10	6.23E-10
G-10A EOD	F (2005–2010)	2005	2010	1.49E-05	4.59E-08	0.00	0.00

Note:
kg/m^2 = kilograms per square meter

Annual lead deposition for the MC loading areas was estimated during this five-year review. The lead deposition rate is not comparable to an MC loading rate, rather it is an estimate of the total amount of lead deposited in a given MC loading area. Lead deposition estimates for the subwatershed of the New River between Town Creek and Stones Bay are provided in **Table 6-3**. The K-303 to K-305 MC loading area contained the greatest lead deposition with an annual deposition of 46,800 pounds of lead.

Table 6-3: Estimated Annual Lead Deposition for the Subwatershed of the New River between Town Creek and Stones Bay

MC Loading Area	Size (m^2)	Lead (lb/yr)
G-10 Impact Area	4.51E+06	9,764
K-2 Impact Area	3.23E+06	0.1
F-6	9.48E+03	0.4
G-8 and G-9	1.40E+05	37
G-19 Ranges	5.10E+04	105
K-211 and K-212	4.09E+05	19,194
K-301	1.23E+05	182
K-303 to K-305	7.77E+05	46,847
K-323	3.15E+04	27
Combat Town	2.63E+04	0.3
ETA-4	5.90E+04	0.6
ETA-5	4.11E+04	5
ETA-7	1.00E+05	0.9
G-10A EOD	1.69E+03	~0

6.1.1.2. Geography and Topography

The subwatershed of the New River between Town Creek and Stones Bay consists of level flat lands and gently rolling terrain. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level in the New River to approximately 70 ft amsl in an upland area east of the New River. Based on available GIS shapefiles, the slope within the subwatershed area ranges from approximately 0.5% to 19%, with the majority of the subwatershed area having an average slope of 3% (MCB Camp Lejeune, 2010a).

6.1.1.3. Surface Water Features

The subwatershed of the New River between Town Creek and Stones Bay contains intermittent and perennial streams, tidal creeks, and a portion of the New River embayment. Streams east of the New River embayment flow in a southwest and northwest direction and discharge into the New River embayment; and streams west of the New River embayment flow in a southeast direction and discharge into the New River embayment. The major tributaries of the New River within this subwatershed include Frenchs Creek, Duck Creek, and Whitehurst Creek. These tributaries receive drainage from perennial streams and widen into tidal creeks in their downstream segments.

Table 6-4 describes the drainage characteristics of the 14 MC loading areas within the subwatershed of the New River between Town Creek and Stones Bay.

Table 6-4: Drainage Description for the MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay

MC Loading Area	Drainage Description
G-10 Impact Area	Approximately 70% of the MC loading area drains to Jumping Run, which partially drains within the MC loading area. Jumping Run is a tributary stream of Frenchs Creek that drains northwest into the New River.
K-2 Impact Area	A large portion of the MC loading area (approximately 90%) drains to the unnamed tributary streams of the New River that drain south within the MC loading area into the New River.
F-6	Drains southwestward into Cogdels Creek, which is a tributary to the New River. Cogdels Creek drains southwest into the New River.
G-8 and G-9	Drains southward into Cowhead Creek, which is located less than100 ft south of the MC loading area. Cowhead Creek flows southwest into Frenchs Creek, which drains to the New River.
G-19 Ranges	Drains north into Jumping Run, which is a tributary to Frenchs Creek.
K-211 and K-212	Approximately 15%) of the MC loading area drains eastward into Whitehurst Creek, which is a tributary of the New River. Whitehurst Creek drains southeast into the New River.

MC Loading Area	Drainage Description
K-301	Approximately 10% of the MC loading area drains to Whitehurst Creek, which drains south within the MC loading area and ultimately discharges into the New River.
K-303 to K-305	Approximately 97% of this MC loading area drains to Whitehurst Creek, which partially drains within the MC loading area.
K-323	Drains north into an unnamed tributary stream of the New River. The MC loading area is approximately 1,000 ft from the New River.
Combat Town	Drains north to unnamed small streams and to Frenchs Creek, which is approximately 2,600 ft north of the MC loading area.
ETA-4	Approximately 50% of the MC loading area drains northwest into Frenchs Creek..
ETA-5	Approximately 95% of the MC loading area drains directly into the New River, which is approximately 240 ft east of the MC loading area.
ETA-7	Drains into unnamed small streams and Goose Creek, which is a tributary to the New River.
G-10A EOD	Part of the range drains north and part drains south into the tributary streams of Frenchs Creek (Cowhead Creek and Jumping Run).

6.1.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of the New River between Town Creek and Stones Bay include Leon fine sand (Ln), Baymeade-Urban land complex (BmB), Onslow loamy fine sand (On), and Kureb fine sand (KuB). These soils are poorly to excessively well drained, and the acidity of the soils range from neutral to extremely or very strongly acid. The organic contents of the soil map units range from 0.5% to 4% (USDA SCS, 1992). The Ln soil map unit has the highest organic content, and the BmB soil map unit has the lowest organic content. The soil map units have low inherent soil erodibility, with soil erodibility factors ranging from 0.1 to 0.24 tons per acre (tons/acre). The On soil map unit has the higher soil erodibility factor of 0.17 to 0.24 tons/acre, while BmB and KuB soil map units have a soil erodibility of 0.1 tons/acre and Ln soil map unit has a soil erodibility of 0.1 to 0.15 tons/acre (USDA SCS, 1992). Military training areas within the subwatershed are largely unvegetated, but other areas within the subwatershed are covered predominantly with pine forest, shrub or scrub, and mixed pine and hardwood forest.

6.1.1.5. Erosion Potential

The estimated soil erosion potential of the 14 identified MC loading areas within the subwatershed of the New River between Town Creek and Stones Bay ranges from low to high. Eight of the MC loading areas within the subwatershed were estimated to have high erosion potential, one of the MC loading areas was estimated to have a moderate erosion potential, and five of the MC loading areas were estimated to have a low erosion potential. The moderate and high soil erosion potential is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. Many of these areas are either unvegetated or sparsely vegetated. The MC loading areas with low estimated soil erosion potentials generally have high vegetation covers and/or lower topographic slopes.

6.1.1.6. Groundwater Characteristics

The major aquifers and confining units underlying MCB Camp Lejeune are discussed in **Section 4**. The surficial aquifer is recharged from rainfall and is the source of recharge to underlying semiconfined and confined aquifers as well as the source of baseflow to streams. Lithologic data at the G-10 and the K-2 Impact Areas, which are MC loading areas located within the subwatershed of the New River between Town Creek and Stones Bay, indicate the presence of silty fine sand, clay, and sandy clay to a depth of 20 ft (Harden et al., 2004). The thickness of the surficial aquifer at the G-10 and the K-2 Impact Area MC loading areas was estimated to range from 10 to 70 ft and 0 to 40 ft, respectively (Cardinell et al., 1993). The Castle Hayne aquifer underlies the surficial aquifer. This aquifer is semiconfined at MCB Camp Lejeune and is the principal drinking water source for the installation, Onslow County, and the city of Jacksonville. The Castle Hayne confining unit is absent in the area of the New River and some of its large tributaries, such as Frenchs Creek and Duck Creek located within the subwatershed of the New River between Town Creek and Stones Bay (Geophex, 1994; Baker Environmental, 1998a). The confining unit was estimated to be approximately 5 ft thick at the G-10 and K-2 Impact Areas (Harden et al., 2004); however, information is insufficient to determine if the confining unit is laterally continuous throughout these impact areas. Thickness of the Castle Hayne aquifer within the subwatershed is generally greater than 175 ft, and Cardinell et al. (1993) estimated the thickness to be greater than 400 ft at the G-10 Impact Area. The horizontal hydraulic conductivity of the Castle Hayne aquifer is generally greater in areas west of the New River than areas east of the New River.

Based on measurements obtained from environmental site data near the loading areas within the subwatershed of the New River between Town Creek and Stones Bay, the depth to groundwater at the various MC loading areas within the subwatershed is estimated to range from approximately less than 1 to 13 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be 6 ft bgs (O'Brien and Gere, 1988; CH2M Hill et al., 2001; Harden et al., 2004).

6.1.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the subwatershed of the New River between Town Creek and Stones Bay. Runoff coefficients at MC loading areas were assumed to range from 0.24 at mostly vegetated areas to 0.71 at unvegetated areas. As indicated in **Section 6.1.1.5**, many of the MC loading areas within the subwatershed have high soil erosion potential. This makes soil erosion an important mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain northwest, southwest, and southeast into the New River embayment, which is a receptor location.

Groundwater Pathways

MC at the MC loading areas within the subwatershed of the New River between Town Creek and Stones Bay potentially may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the upland interstream divides toward the major surface water feature,s such as the New River, Frenchs Creek, Duck Creek, and Whitehurst Creek. Deeper groundwater, in the Castle Hayne aquifer, generally flows toward the drinking water wells located within and outside of MCB Camp Lejeune (**Figure 4-3**). Within the subwatershed of the New River between Town Creek and Stones Bay, the groundwater in the Castle Hayne aquifer at MC loading areas located east of the New River flows predominantly in a northwest direction; at MC loading areas west of the New River, the groundwater in the Castle Hayne aquifer flows in a northeast direction (**Figure 4-3**).

MC pathways between the surficial and the Castle Hayne aquifers can be limited by the presence of the Castle Hayne confining unit. However, as discussed in **Section 6.1.1.6**, in some locations, the confining unit is very limited to absent. As a result, the principal source of recharge to the Castle Hayne aquifer is from the overlying surficial aquifer. Therefore, a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and being transported to the Castle Hayne aquifer near locations of active water supply wells.

6.1.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of the New River between Town Creek and Stones Bay supports a variety of T/E species (including the red-cockaded woodpecker, the rough-leaved loosestrife, and the bald eagle). In addition, sensitive wetland habitats are present adjacent to streams and tidal creeks. Although surface water is not a drinking water source, the New River is used for recreational purposes. Commercial oyster beds are located along the portion of the New River adjacent to the K-2 Impact Area within the subwatershed.

Groundwater Receptors

The groundwater in the Castle Hayne aquifer is used as the drinking water supply at MCB Camp Lejeune and the surrounding area (including Onslow County and the city of Jacksonville). Active installation water supply wells are located on the eastern portion of the subwatershed of the New River between Town Creek and Stones Bay (**Figure 4-3**). In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to the New River. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.1.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of potential MC concentrations in surface water and sediment from six MC loading areas that drain to the New River between Town Creek and Stones Bay. The MC loading areas were G-10, F-6, G-8 and G-9, K-211 and K-212, ETA-4, and ETA-7. These MC loading areas were selected for quantitative transport analysis based on their current use of munitions containing HE and the presence of surface drainages that lead to potential receptor locations in the New River (human recreational and T/E ecological species). The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (2005–2010 [period F] for G-10 Impact Area, F-6, G-8 and G-9, and K-211 and K-2112 MC loading areas; 2007–2010 [period F] for ETA-7 MC loading area; and 1994–2010 [periods E and F] for ETA-4 MC loading area]. The portions of the MC loading areas draining to the New River between Town Creek and Stones Bay are presented in **Table 5-7**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the subwatershed of the New River between Town Creek and Stones Bay. It is important to note that part of the ETA-4 MC loading area (approximately 50%) is within the subwatershed of Freeman Creek upstream its confluence with Intracoastal Waterway. Although a discussion of this subwatershed is not presented in this report, the ETA-4 MC loading area (the only MC loading area draining within the subwatershed) was estimated to contribute negligible MC concentrations in surface water and sediment into Freeman Creek at its confluence with the Intracoastal Waterway.

Table 6-5 presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to the New River between Town Creek and Stones Bay. The G-10 Impact Area MC loading area was predicted to contribute the highest proportion of all four MC mass (over 80%) to the New River between Town Creek and Stones Bay. The F-6 MC loading area was predicted to contribute a higher percentage of perchlorate mass than the G-8 and G-9, ETA-4, and ETA-7 MC loading areas, while the ETA-7 MC loading area was predicted to contribute higher percentages of RDX and TNT mass than the F-6, G-8 and G-9, and ETA-4 MC loading areas.

Table 6-5: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the New River between Town Creek and Stones Bay.

MC Loading Area	MC Contributed (% Total Mass)			
	RDX	TNT	HMX	Perchlorate
G-10 Impact Area	86	90	96	81
F-6	4	3	0	14
G-8 and G-9	2	< 1	3	< 1
ETA-4	1	1	< 1	< 1
ETA-7	5	5	< 1	< 1
K-211 and K-212	3	1	< 1	4

Table 6-6 and **Table 6-7** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the subwatershed of the New River between Town Creek and Stones Bay. Based on the screening-level calculations, the average annual concentrations of RDX in runoff at the edge of all MC loading areas were predicted to be above REVA trigger values. The average annual concentration of TNT in runoff was predicted to be below the REVA trigger value at the edge of the G-8 and G-9 MC loading area; however, TNT concentrations in runoff at the edge of all other MC loading areas were predicted to be above the REVA trigger value. The average annual concentrations of HMX and perchlorate in runoff at the edge of two (G-10 Impact and G-8 and G-9) and three (G-10 Impact, F-6, and K-211 and K-212) MC loading areas were predicted to be above REVA trigger values, respectively (**Table 6-6**).

Table 6-6: Surface Water Runoff Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations within the Subwatershed of the New River between Town Creek and Stones Bay

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact	**18.83**	**14.64**	**0.36**	**0.02**
F-6	**119.7**	**67.78**	N/A	**0.26**
G-8 and G-9	**3.89**	0.02	**0.11**	~0
K-211 and K-212	**37.7**	**6.59**	0.06	**0.05**
ETA-4	**6.75**	**4.87**	~0	~0
ETA-7	**13.90**	**11.39**	~0	~0

Note:
N/A = not modeled, as the MC loading rate was estimated to be negligible.
Bold indicates concentration exceeds the REVA trigger value.

Table 6-7: Sediment Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations within the Subwatershed of the New River between Town Creek and Stones Bay

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Sediment (µg/L)	32.5	25	51	0.18
MC Concentration (µg/kg)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact Area	1.17	**60.98**	0.01	~0
F-6	3.82	**144.6**	N/A	~0
G-8 and G-9	0.12	0.03	~0	~0
K-211 and K-212	1.70	19.8	0.00	~0
ETA-4	0.20	9.57	~0	~0
ETA-7	2.31	**122.4**	~0	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual TNT concentrations in sediment at the edge of the G-10 Impact, F-6, and ETA-7 MC loading areas were predicted to be above REVA trigger values. The average annual RDX, HMX, and perchlorate concentrations in sediment at the edge of all MC loading areas were predicted to be below REVA trigger values (**Table 6-7**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and, in sediment entering the New River between Town Creek and Stones Bay, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Town Creek and Stones Bay were predicted to be above REVA trigger values. However, the average annual concentrations of HMX and perchlorate in surface water runoff and baseflow entering the New River between Town Creek and Stones Bay were predicted to be below REVA trigger values (**Table 6-8**). All MC concentrations in sediment entering the New River between Town Creek and Stones Bay were predicted to be below REVA trigger values.

Table 6-8: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering the New River between Town Creek and Stones Bay

MC	REVA Trigger Value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.761**
TNT	0.113	**0.568**
HMX	0.114	0.014
Perchlorate	0.021	0.001

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Although potential concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Town Creek and Stones Bay were predicted to exceed REVA trigger values, actual concentrations of these MC are expected to be lower (potentially below detection levels) in this tidally influenced water. A conservative approach was used in the surface water screening-level analysis, whereby MC decay in surface water and tidal mixing were not taken into account, and these mechanisms are likely to reduce concentrations in the New River.

Surface water sampling was carried out within this subwatershed as part of the five-year review for MCB Camp Lejeune in September 2010 and December 2010 to determine the actual MC concentrations in surface water. Four locations in streams up gradient of the New River were sampled within the subwatershed of the New River between Town Creek and Stones Bay. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.1.3. Groundwater Analysis Results

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at six of the MC loading areas assessed within the subwatershed of the New River between Town Creek and Stones Bay (G-10 Impact Area, F-6, G-8 and G-9, K-211 and K-212, ETA-4, and ETA-7). In doing this, the estimated MC loading rates (**Table 6-2**) were divided by a recharge rate of 1.08 ft/yr estimated for MCB Camp Lejeune (Heath, 1989). **Table 6-9** shows the predicted infiltration MC concentrations at the six MC loading areas. RDX and TNT were estimated to exceed REVA trigger values at all six MC loading areas. For this reason, RDX and TNT were modeled for migration through the vadose zone at all six MC loading areas. Furthermore, HMX and perchlorate exceeded REVA trigger values at three MC loading areas (HMX at G-10 Impact Area, G-8 and G-9, and K-211 and K-212; perchlorate at G-10 Impact Area, F-6, and K-211 and K-212); therefore, these MC also were modeled for migration through the vadose zone at the MC loading areas where concentrations were exceeded.

Table 6-9: Estimated Maximum MC Concentrations in Infiltrating Water at MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			**0.110**	**0.113**	**0.114**	**0.021**
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	**Time Period**		**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact	2005–2010	F	**72.9**	**106.6**	**0.977**	**0.050**
F-6	2005–2010	F	**850.2**	**545.9**	N/A	**1.38**
G-8 and G-9	2005–2010	F	**27.4**	**0.130**	**0.626**	~0
K-211 and K-212	2005–2010	F	**135.8**	**38.7**	**0.156**	**0.110**
ETA-4	1994–2004	E	**64.9**	**52.0**	0.020	0.010
	2005–2010	F	**43.3**	**34.7**	0.010	0.000
ETA-7	2007–2010	F	**97.3**	**183.8**	0.002	0.000

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for simulation times ranging from 100 to 200 years.

Figure 6-2 and **Figure 6-3** present sample simulation results for RDX and TNT at the G-10 Impact Area MC loading area. As shown in **Figure 6-2**, near-steady-state conditions were reached for RDX within a time period of 6 years of simulation. However, it took a much longer time period (190 years) for TNT to reach steady-state conditions (**Figure 6-3**) due to its inherent strong affinity to sorb to soil particles (high K_{oc}). Steady-state conditions for TNT were reached for time periods ranging from 88 to 198 years at the

MC loading areas modeled within the subwatershed of the New River between Town Creek and Stones Bay. **Table 6-9** shows the maximum MC concentrations reaching the water table at the MC loading areas modeled within the subwatershed of the New River between Town Creek and Stones Bay. Due to the MC chemical properties (i.e., low volatility and moderate-to-high solubility) and the VLEACH assumption of no degradation, the steady-state MC concentrations at the water table for all MC loading areas were equal to or a little lower than their influent concentrations, which exceed REVA trigger values. For this reason, all MC listed in **Table 6-10** that were modeled for movement through the vadose zone were analyzed further for movement through the surficial aquifer.

Figure 6-2: VLEACH vadose zone model RDX results for the G-10 Impact Area MC loading area

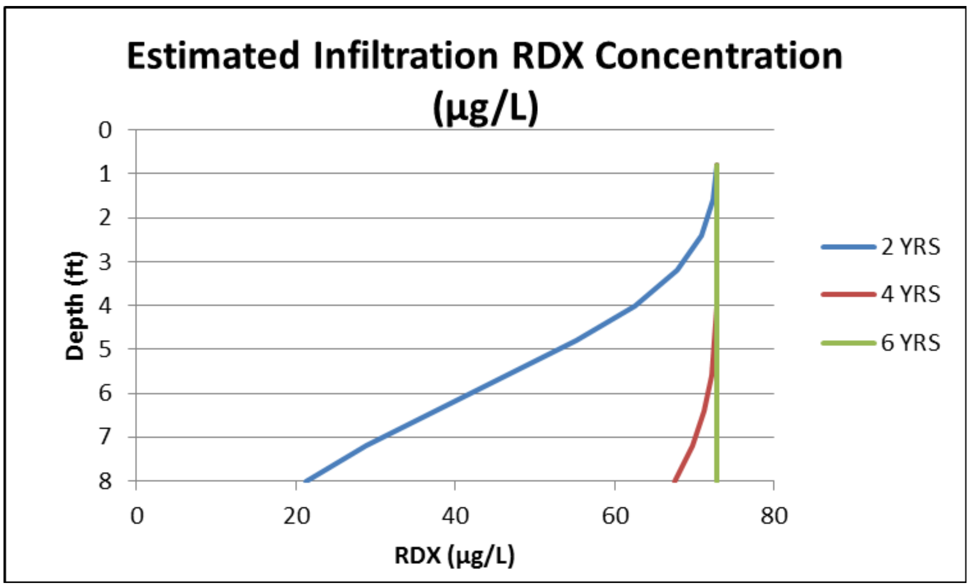

Figure 6-3: VLEACH vadose zone model TNT results for the G-10 Impact Area MC loading area

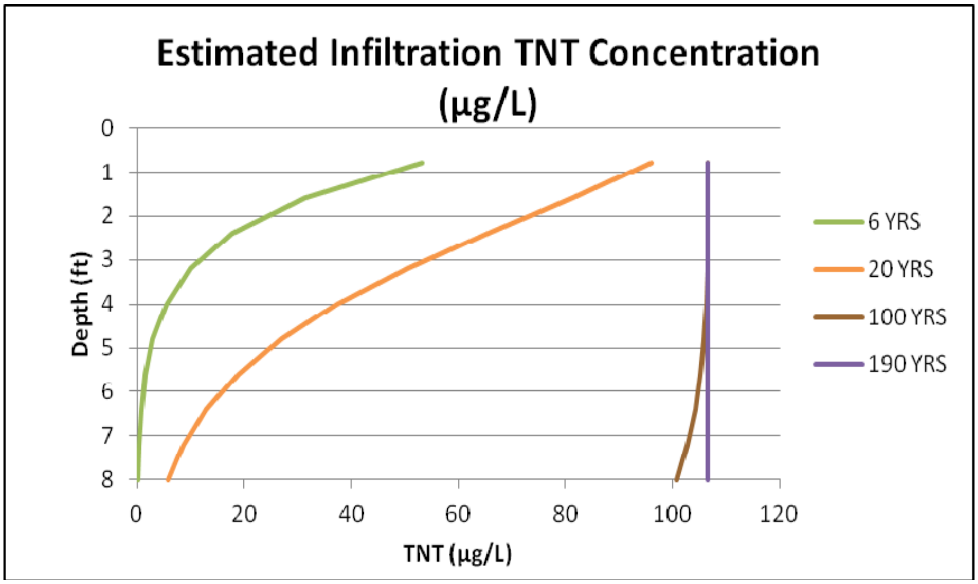

Table 6-10: VLEACH Maximum MC Concentrations Reaching the Water Table at MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact Area	**72.7**	**106.3**	**0.98**	**0.05**
F-6	**847.7**	**544.4**	N/A	**1.38**
G-8 and G-9	**27.3**	**0.13**	**0.63**	N/A
K-211 and K-212	**135.4**	**38.6**	**0.16**	**0.11**
ETA-4	**43.15**	**47.18**	N/A	N/A
ETA-7	**97.04**	**183.4**	N/A	N/A

Note:
N/A = Not modeled, as MC loading rate was negligible or MC was eliminated for further analysis from the initial groundwater screening analysis

Bold indicates concentration exceeds the REVA trigger value.

Potential transport to the Castle Hayne aquifer was assessed for MC loading areas where the MC concentration reaching the water table was predicted to exceed the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area (**Figure 4-3**). Within the subwatershed of the New River between Town Creek and Stones Bay, these MC loading areas are G-10 Impact Area, F-6, G-8 and G-9, ETA-4, and ETA-7. The K-211 and K-212 MC loading area was not considered in this analysis because groundwater from this MC loading does not flow to a drinking water supply well (**Figure 4-3**).

The MC concentrations estimated to potentially reach the Castle Hayne aquifer are presented in **Table 6-11**.

Table 6-11: Estimated MC Concentrations Reaching the Castle Hayne Aquifer at MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay

REVA Trigger value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration Potentially Reaching the Castle Hayne Aquifer (µg/L)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
G-10 Impact Area	**66.4**	**97.0**	**0.895**	**0.046**
F-6	**58.0**	**37.2**	N/A	**0.094**
G-8 and G-9	**14.0**	0.067	**0.323**	N/A
ETA-4	**9.95**	**10.88**	N/A	N/A
ETA-7	**24.1**	**45.5**	N/A	N/A

Note: **Bold** indicates concentration exceeds the REVA trigger value.

HMX and perchlorate were estimated to potentially reach the Castle Hayne aquifer at concentrations above REVA trigger values at two of the MC loading areas analyzed (HMX at the G-10 Impact Area and G-8 and G-9 MC loading areas, and perchlorate at the G-10 Impact Area and F-6 MC loading areas). Furthermore, TNT was estimated to potentially reach the Castle Hayne aquifer at concentrations above the REVA trigger value at four of the five MC loading areas analyzed, whereas RDX was estimated to potentially reach the Castle Hayne aquifer at concentrations above the REVA trigger value at all five MC loading areas analyzed. As a result, MC that were estimated to reach the Castle Hayne aquifer above REVA trigger values at the various MC loading areas were modeled for movement through the Castle Hayne aquifer to potential drinking water wells.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through 1) the surficial aquifer to potential surface water receptor locations in the major surface water features (the New River, Frenchs Creek, Duck Creek and Whitehurst Creek) and 2) the Castle Hayne aquifer to potential groundwater receptors (installation drinking water supply wells). The BIOCHLOR simulation results produced the estimated

MC concentration profile along the centerline of flow between the source zone at the MC loading areas and the nearest receptor location (surface water or drinking water well).

Due to the high decay rates of RDX, TNT, and HMX and the long distances between the loading areas and the surface water receptor locations, these MC were predicted to be below REVA trigger values at the nearest surface water receptor location from all six MC loading areas modeled (**Table 6-12**). However, because perchlorate is very persistent in the environment (has a very low decay rate), results showed the potential for perchlorate to reach the nearest surface water receptor locations above the REVA trigger value from the F-6 and K-211 and K-212 MC loading areas. These results were used to estimate baseflow contributions of MC to the surface water receptor location in the surface water screening-level analysis (**Table 6-8**).

Table 6-12. Model-Estimated MC Concentrations Reaching Surface Water Receptor Locations within the Subwatershed of the New River between Town Creek and Stones Bay

REVA Trigger value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW RL (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact Area	~0	~0	~0	0.016
F-6	~0	~0	N/A	**0.96**
G-8 and G-9	~0	~0	~0	N/A
K-211 and K-212	~0	~0	~0	**0.03**
ETA-4	~0	~0	N/A	N/A
ETA-7	~0	~0	N/A	N/A

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The high decay rates of RDX, TNT, and HMX were predicted to prevent these MC from reaching the nearest drinking water wells above REVA trigger values for all five MC loading areas modeled. For the MC loading areas modeled here, BIOCHLOR predicted concentrations of RDX, TNT, and HMX to be below REVA trigger values at maximum distances of 90, 150 and 70 ft from the source, respectively. The closest distance of a modeled MC loading area to a drinking water well is 750 ft (from the F-6 MC loading area). Perchlorate was predicted to potentially reach the nearest drinking water wells above the REVA trigger value from the G-10 Impact Area and F-6 MC loading areas (**Table 6-13**).

Table 6-13: Model-Estimated MC Concentrations Reaching Groundwater Receptors from MC Loading Areas within the Subwatershed of the New River between Town Creek and Stones Bay

REVA Trigger value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest Drinking Water Well (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
G-10 Impact Area	~0	~0	~0	**0.046**
F-6	~0	~0	N/A	**0.094**
G-8 and G-9	~0	N/A	~0	N/A
ETA-4	~0	~0	N/A	N/A
ETA-7	~0	~0	N/A	N/A

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Groundwater sampling for MC has been conducted regularly by MCB Camp Lejeune in water supply wells, including wells closest to the G-10 Impact Area and F-6 MC loading areas where perchlorate was predicted to reach the closest water supply wells at concentrations above the REVA trigger value. Groundwater was sampled as part of the five-year review in September and December 2010; these results are discussed in **Section 8**.

6.2. The Subwatershed of the New River at Stones Bay

The subwatershed of the New River at Stones Bay is located in the south-central part of MCB Camp Lejeune. It is approximately 12,294 acres in size, with a large portion of the subwatershed area located within MCB Camp Lejeune (**Figure 6-4**). The subwatershed area encompasses a section of the New River embayment (Stones Bay) and some of its tributaries, including Mill Creek, Muddy Creek, and Everett Creek. Part or all of eight RTAs, three identified MC loading areas, and the western one-third of the K-2 Impact Area are located within the subwatershed.

The following RTAs are partially or fully located in the subwatershed of the New River at Stones Bay:

- JA (357 acres)
- JD (108 acres)
- LC (1262 acres)
- LE (818 acres)
- LF (1576 acres)

- LG (214 acres)
- MD (1333 acres)
- MF (1412 acres)

The dates for which RTAs JA and JD became operational are unknown, but the other RTAs became operational in 1941. All RTAs within this subwatershed currently are operational, but use is not heavy. RTAs JD, LE, LF, and LG had no munitions use recorded in RFMSS for the years 2004–2010.

A brief summary of MC loading areas partially or fully located within the subwatershed of the New River at Stones Bay is provided in **Table 6-1**.

Military Munitions

Various high explosive, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of the New River at Stones Bay to support the various primary uses of the ranges in this area. Although Range K-405 is no longer active, the other ranges in this subwatershed are used frequently.

6.2.1. Conceptual Site Model

6.2.1.1. Estimated Munitions Constituents Loading

The MC loading areas for the subwatershed of the New River at Stones Bay are shown in **Figure 6-4**. The Stones Bay Area MC loading area was delineated based on discussions with range control personnel.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within this MC loading area over time (**Table 6-14**); the assumptions used to guide the estimates are detailed in **Section 5**. Because MC loading areas are defined differently in the five-year review and the baseline assessment, a direct comparison is not possible. MC loading was not estimated for the Stones Bay Area in the baseline assessment, so historical loading was calculated. Because the initial dates of operation for ranges within this MC loading area are not known, it was conservatively assumed that they have been operational since ranges at the installation became active.

Table 6-14: Estimated Annual MC Loading for the Subwatershed of the New River at Stones Bay

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
K-405	F (2005–2010)	2005	2008	2.04E-03	1.32E-03	0.00	3.30E-06
Stones Bay Area	C (1938–1976)	1942	1976	2.00E-05	1.38E-06	3.38E-07	9.18E-08
	D (1977–1988)	1977	1988	1.60E-05	1.11E-06	2.70E-07	7.34E-08
	E (1989–2004)	1989	2004	2.00E-05	1.38E-06	3.38E-07	9.18E-08
	F (2005–2010)	2005	2010	1.33E-05	9.21E-07	2.25E-07	6.12E-08
K-211 and K-212	F (2005–2010)	2005	2010	4.47E-05	1.27E-05	5.13E-08	3.61E-08
K-2 Impact Area	F (2005–2010)	2005	2010	8.20E-07	1.27E-06	0.00	3.37E-12

Range K-405 has high loading of RDX and TNT, and this is a function of high loading combined with a small MC loading area. Training ended at Range K-405 in 2008.

Annual lead deposition rates for the MC loading areas are provided in **Table 6-15**. The K-211 and K-212 MC loading area exhibited the greatest lead deposition with an estimated annual deposition of 19,200 pounds of lead.

Table 6-15: Estimated Lead Deposition for the Subwatershed of the New River at Stones Bay

MC Loading Area	Size (m^2)	Lead (lb/yr)
K-405	1.69E+04	9.56
Stones Bay Area	1.51E+04	26
K-211 and K-212	4.09E+05	19,194
K-2 Impact Area	3.23E+06	0.1

6.2.1.2. Geography and Topography

The subwatershed of the New River at Stones Bay generally consists of level flat lands. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level in the New River to approximately 76 ft amsl in an upland area north of Stones Bay. Based on available GIS shapefiles, the slope within the subwatershed area ranges from nearly level in upland areas to approximately 21% on the sides of the stream valleys. The larger part of the subwatershed area has an average slope of less than 5% (MCB Camp Lejeune, 2010a).

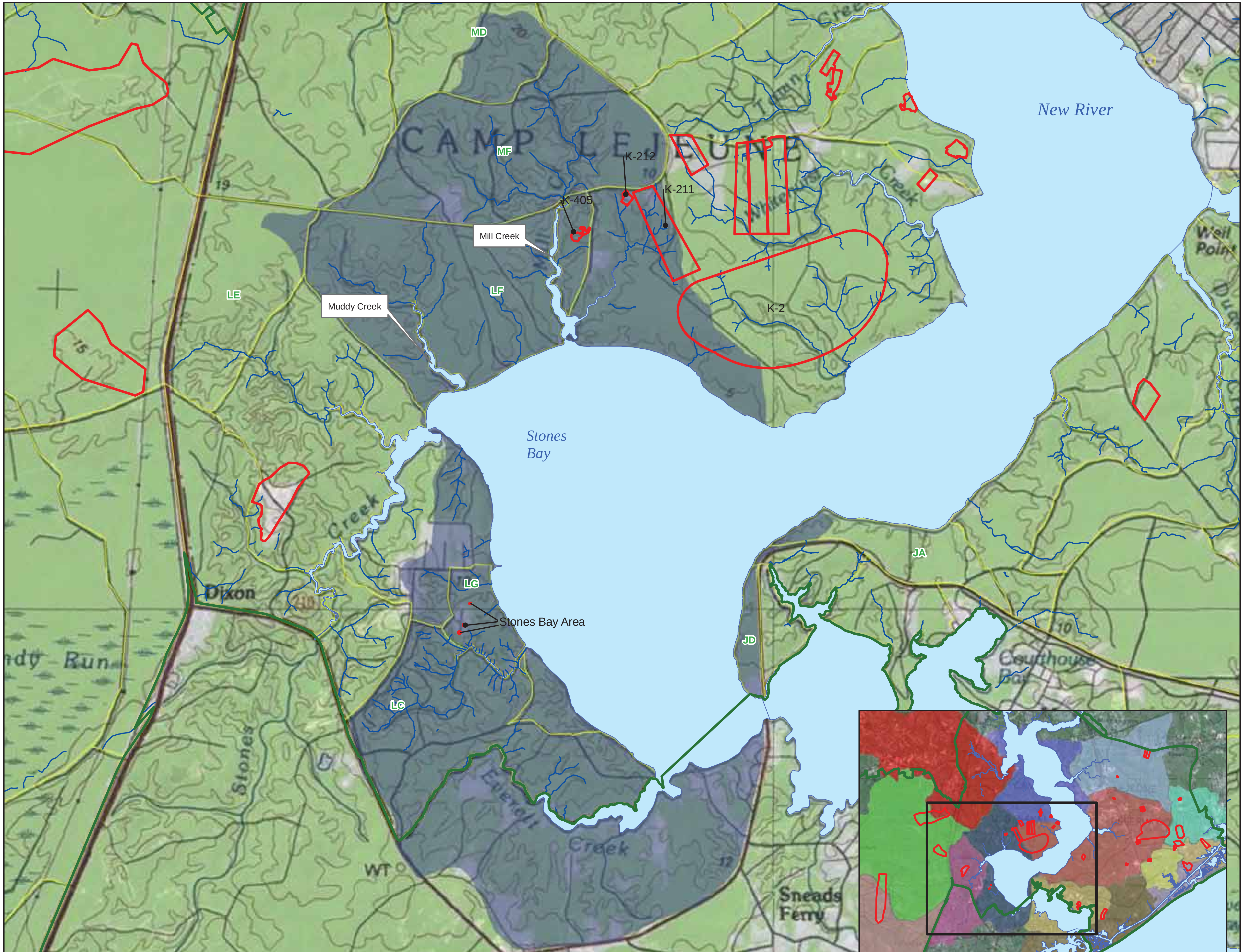

FIGURE 6-4
MC Loading Areas within the Subwatershed of the New River at Stones Bay

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- New River at Stones Bay

0 1,250 2,500 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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6.2.1.3. Surface Water Features

The subwatershed of the New River at Stones Bay contains intermittent and perennial streams, tidal creeks, and a portion of the New River embayment (Stones Bay). Streams north of Stones Bay flow south and discharge into Stones Bay; and streams south of Stones Bay flow in an east and northeast direction and discharge into Stones Bay. The major tributaries of the New River within this subwatershed include Mill Creek, Muddy Creek, and Everett Creek. These tributaries receive drainage from perennial streams and widen into tidal creeks in their downstream segments.

Table 6-16 describes the drainage characteristics of the four MC loading areas within the subwatershed of the New River at Stones Bay.

Table 6-16: Drainage Description for the MC Loading Areas within the Subwatershed of the New River at Stones Bay.

MC Loading Area	Drainage Description
K-405	Drains southwest into Mill Creek, which is located approximately 650 ft west of the MC loading area. Mill Creek drains south into Stones Bay.
Stones Bay Area	Drains south into the unnamed tributary stream of Stones Bay, which is located approximately 460 ft south of the MC loading area. The unnamed stream drains east into Stones Bay.
K-211 and K-212	Approximately 85% of this MC loading area drains into an unnamed tributary stream of Mill Creek. Mill Creek discharges into Stones Bay.
K-2 Impact Area	Approximately 10% of this MC loading area drains into a short unnamed tributary stream of Stones Bay. This stream directly discharges into Stones Bay.

6.2.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of the New River at Stones Bay include BmB and Marvyn loamy fine sand (MaC). These soils are well drained, and the acidity of the soils range from medium acid to very strongly acid. BmB and MaC have equivalent organic contents. The BmB soil map unit has a low inherent soil erodibility factor of 0.1 tons/acre, while the MaC soil map unit has a soil erodibility factor that ranges from low to moderate (factor ranging from 0.17 to 0.32 tons/acre) (USDA SCS, 1992). Military training areas within the subwatershed are largely unvegetated, but other areas within the subwatershed are covered predominantly with pine forest and upland and bottomland hardwood forest.

6.2.1.5. Erosion Potential

The estimated soil erosion potential of the four identified MC loading areas within the subwatershed of the New River at Stones Bay ranges from low to high. The K-2 Impact Area MC loading area was estimated to have a low soil erosion potential, the K-211 and K-212 MC loading area was estimated to have moderate soil erosion potential, and the remaining two MC loading areas within the subwatershed were estimated to have high soil erosion potential. The moderate and high soil erosion potentials are a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. These areas are sparsely vegetated. The K-2 Impact Area MC loading area, which has low estimated soil erosion potential, has a high vegetation cover.

6.2.1.6. Groundwater Characteristics

The major aquifers and confining units underlying MCB Camp Lejeune are discussed in **Section 4**. Based on investigations done near the K-2 Impact Area by Cardinell et al. (1993), thickness of the surficial aquifer within the subwatershed of the New River at Stones Bay can range from 0 to 40 ft. Based on lithologic data at K-2 Impact Area MC loading area, the surficial aquifer within the subwatershed can consist of silty fine sand, clay, and sandy clay to a depth of 20 ft (Harden et al., 2004). The Castle Hayne confining unit is estimated to be approximately 5 ft thick at the K-2 Impact Area, which is partially located within the subwatershed of the New River at Stones Bay. However, detailed information is insufficient to determine if the confining unit is laterally continuous throughout the entire subwatershed area. The confining unit is absent in the area of the New River and some of its larger tributaries and in localized areas containing buried paleochannel deposits (Geophex, 1994; Baker Environmental, 1998a). Thickness of the Castle Hayne aquifer within the subwatershed is generally greater than 175 ft. The horizontal hydraulic conductivity of the Castle Hayne aquifer is generally greater in areas west of the New River than areas east of the New River. Based on measurements obtained from environmental site data near the loading areas within the subwatershed of New River at Stones Bay, the depth to groundwater at the various MC loading areas within the subwatershed is estimated to range from approximately 0.34 to 8.4 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be approximately 4 ft bgs (Baker Environmental, 1996; Harden et al., 2004).

6.2.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important transport pathways of MC to streams within the subwatershed of the New River at Stones Bay. Runoff coefficients at MC loading areas were assumed to range from 0.24 at partially vegetated areas with lower slopes (less than 6%) to 0.68 at a sparsely vegetated area with a higher slope (approximately 6%). As indicated in **Section 6.2.1.5**, many of the MC loading areas within the subwatershed have high or moderate soil erosion potential. This makes soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain south, east, and northeast into the New River embayment at Stones Bay, which is a receptor location.

Groundwater Pathways

MC at the MC loading areas within the subwatershed of the New River at Stones Bay may migrate to the surficial aquifer via infiltration of rain water. The potential shallow groundwater pathway is from the upland interstream divides toward the major surface water features, such as the New River at Stones Bay, Mill Creek, Muddy Creek, and Everett Creek. Deeper groundwater, in the Castle Hayne aquifer, flows in a northeast direction in the northern parts of the subwatershed and in a southwest direction in the southern parts of the subwatershed (**Figure 4-3**). The Stones Bay Area MC loading area located in the southwestern part of the subwatershed potentially can flow toward off-installation wells located near the MCB Camp Lejeune installation boundary (**Figure 4-3**).

Due to the noncontinuous presence of the Castle Hayne confining unit (as described in **Section 6.2.1.6**), a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and being transported to the Castle Hayne aquifer near locations of active water supply wells.

6.2.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of the New River at Stones Bay supports T/E species (red-cockaded woodpecker). In addition, sensitive wetland habitats are present adjacent to streams and tidal creeks mostly in the southwestern parts of the subwatershed area. Although surface water is not a drinking water source, the New River is used for recreational purposes. Commercial oyster beds are located along the portion of the New River adjacent to the K-2 Impact Area within the subwatershed.

Groundwater Receptors

There are no active installation water supply wells located within the subwatershed of the New River at Stones Bay or near MC loading areas within the subwatershed. However, there is an unidentified potential off-installation water supply well on the southern boundary of the subwatershed and three identified off-installation County wells located southwest of the subwatershed (**Figure 4-3**). These wells, which potentially are used for drinking, likely draw water from the Stones Bay Area MC loading area. In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to the New River. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.2.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of potential MC concentrations in surface water and sediment from three MC loading areas that drain to the New River at Stones Bay (K-405, Stones Bay Area, and K-211 and K-212). The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (2005–2008 [period F] for K-405 MC loading area; 2005–2010 [period F)] for K-211 and K-212 MC loading area; and 1942–2010 [periods C, D,E and F] for Stones Bay Area MC loading area). The portion of the MC loading areas draining to the New River at Stones Bay is presented in **Table 5-7**. **Figure 5-1** shows surface water features and MC loading areas analyzed within the subwatershed of the New River at Stones Bay.

Table 6-17 presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to the New River at Stones Bay. The K-405 MC loading area was predicted to contribute significant portions of the total RDX, TNT, and perchlorate mass (over 75%) to the New River at Stones Bay, whereas the K-211 and K-212 MC loading area was predicted to contribute significant portion of the total HMX mass (80%) into the New River at Stones Bay.

Table 6-17: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the New River at Stones Bay

MC Loading Area	MC Contributed (% Total Mass)			
	RDX	TNT	HMX	Perchlorate
K-405	76	91	0	85
K-211 and K-212	23	9	80	13
Stones Bay Area	< 1	< 1	20	1

Table 6-18 and **Table 6-19** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the subwatershed of the New River at Stones Bay. Based on the

screening-level calculations, the average annual concentrations of RDX, TNT, and perchlorate in runoff at the edge of all three MC loading areas were predicted to be above REVA trigger values (**Table 6-18**). The average annual concentration of HMX in runoff at the edge of the Stones Bay MC loading area also was predicted to be above the REVA trigger value (**Table 6-19**).

Table 6-18: Surface Water Runoff Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Subwatershed of the New River at Stones Bay

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-405	**979.2**	**495.9**	N/A	**2.09**
K-211 and K-212	**37.7**	**6.59**	0.06	**0.05**
Stones Bay Area	**5.94**	**0.34**	**0.13**	**0.04**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-19: Sediment Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Subwatershed of the New River at Stones Bay

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Sediment (µg/L)	32.5	25	51	0.18
MC Concentration (µg/kg)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-405	**42.12**	**1423.6**	N/A	~0
K-211 and K-212	1.70	19.8	~0	~0
Stones Bay Area	0.28	1.04	~0	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual RDX and TNT concentrations in sediment at the edge of the K-405 MC loading area were predicted to be above REVA trigger values (**Table 6-19**). However, the average annual HMX and perchlorate concentrations in sediment at the edge of the K-405 MC loading area and the average annual concentrations of all MC at the edge of the K-211 and K-212 and the Stones Bay Area MC loading areas were predicted to be below REVA trigger values (**Table 6-19**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and in sediment entering the New River at Stones Bay (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX and TNT in surface water runoff and baseflow entering the New River at Stones Bay were predicted to be above REVA trigger values (**Table 6-20**). However, the average annual concentrations of HMX and perchlorate in surface water runoff and baseflow entering the New River at Stones Bay were predicted to be below REVA trigger values (**Table 6-20**). All MC concentrations in sediment entering the New River at Stones Bay were predicted to be below REVA trigger values.

Table 6-20: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering the New River at Stones Bay

MC	REVA Trigger value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.598**
TNT	0.113	**0.215**
HMX	0.114	~0
Perchlorate	0.021	0.001

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Although concentrations of RDX and TNT in surface water runoff and baseflow entering the New River at Stones Bay were predicted to exceed REVA trigger values, actual concentrations of these MC are expected to be lower (potentially below detection levels) in this tidally influenced water due to MC decay and tidal mixing in the water.

Surface water sampling was carried out as part of the five-year review for MCB Camp Lejeune in September 2010 and December 2010 to determine the actual MC concentrations in surface water. A location in Mill Creek upstream of Stones Bay and downstream of the K-405 and K-211 and K-212 MC loading areas (the MC loading areas contributing significant portions of MC mass to Stones Bay) was sampled within the subwatershed of the New River at Stones Bay. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.2.3. Groundwater Analysis Results

Three MC loading areas were assessed for groundwater within the subwatershed of the New River at Stones Bay, including K-405, K-211 and K-212, and Stones Bay Area MC loading areas. The groundwater analysis results for K-211 and K-212 are presented in **Section 6.1.3**, as this MC loading area is located partially in the subwatershed of the New River at Stones Bay. Therefore, with the exception of BIOCHLOR results showing groundwater concentrations potentially reaching surface water receptor locations within the subwatershed of the New River at Stones Bay, no other groundwater results for the K-211 and K-212 MC loading area are presented in this section.

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the MC loading areas assessed within the subwatershed of the New River at Stones Bay. **Table 6-21** shows the resulting infiltration MC concentrations at the K-405 and the Stones Bay Area MC loading areas. With the exception of HMX at the K-405 MC loading area, all other MC at the K-405 and all MC at the Stones Bay Area MC loading areas were estimated to exceed REVA trigger values (**Table 6-21**). For this reason, RDX, TNT, and perchlorate at the K-405 MC loading area and all MC at the Stones Bay Area MC loading area were modeled for migration through the vadose zone.

Table 6-21: Estimated Maximum MC Concentrations in Infiltrating Water at MC Loading Areas Located within the Subwatershed of the New River at Stones Bay

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	**Time Period**		**RDX**	**TNT**	**HMX**	**Perchlorate**
K-405	2005–2010	F	**6,193.2**	**4,002.5**	N/A	**10.04**
Stones Bay Area	1942–1976	C	**60.8**	**4.20**	**1.03**	**0.280**
	1977–1988	D	**48.6**	**3.36**	**0.820**	**0.220**
	1989–2004	E	**60.8**	**4.20**	**1.03**	**0.280**
	2005–2010	F	**40.5**	**2.80**	**0.684**	**0.190**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for simulation times ranging from 100 to 200 years.

Steady-state conditions for TNT were reached at much longer time periods (81 to 115 years) than for RDX, HMX, and perchlorate (a maximum of 6 years) at the MC loading areas modeled. This is a result of the high K_{oc} of TNT. **Table 6-22** shows the maximum MC concentrations reaching the water table at the MC loading areas modeled within the subwatershed of the New River at Stones Bay. Due to the MC chemical properties (i.e., low volatility and moderate-to-high solubility) and the VLEACH assumption of no degradation, the steady-state MC concentrations at the water table for all MC loading areas were equal to or a little lower than their influent concentrations, which exceed REVA trigger values. For this reason, all MC listed in **Table 6-22** that were modeled for movement through the vadose zone were analyzed further for movement through the surficial aquifer.

Table 6-22: VLEACH Maximum MC Concentrations Reaching the Water Table at MC Loading Areas within the Subwatershed of the New River at Stones Bay

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-405	**6,174.7**	**3,990.6**	N/A	**10.04**
Stones Bay Area	**40.41**	**3.38**	**0.68**	**0.19**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Potential transport to the Castle Hayne aquifer was assessed for MC loading areas where the MC concentration reaching the water table exceeded the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area (**Figure 4-3**). Within the subwatershed of the New River at Stones Bay, only the Stones Bay Area MC loading area has the potential to reach drinking water supply wells; therefore, this loading area was assessed for transport to the Castle Hayne aquifer. This MC loading area has the potential to reach off-installation wells (County wells and an unidentified potential supply well). The K-405 MC loading area was not included in this analysis because groundwater from this MC loading area does not flow to a drinking water supply well (**Figure 4-3**). The methodology used for this analysis is discussed in **Section 5.2.2.3**.

The resulting MC concentrations estimated to potentially reach the Castle Hayne aquifer are presented in **Table 6-23**.

Table 6-23: Estimated MC Concentrations Reaching the Castle Hayne Aquifer at MC Loading Areas within the Subwatershed of the New River at Stones Bay

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration Potentially Reaching the Castle Hayne Aquifer (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
Stones Bay Area	**4.02**	**0.336**	0.068	0.019

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Concentrations of RDX and TNT were estimated to potentially reach the Castle Hayne aquifer above REVA trigger values at the Stones Bay Area MC loading area (**Table 6-**

23). As a result, RDX and TNT were modeled for movement through the Castle Hayne aquifer to potential drinking water wells from the Stones Bay Area MC loading area.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through 1) the surficial aquifer to potential surface water receptor locations in the major surface water features (the New River at Stones Bay, Mill Creek, and Muddy Creek) and 2) the Castle Hayne aquifer to potential groundwater receptors (off-installation drinking water supply wells). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading areas and the nearest receptor location (surface water or drinking water well).

Due to the high decay rates of RDX, TNT, and HMX and the long distances between the loading areas and the surface water receptor locations, these MC were predicted to be below REVA trigger values at the nearest surface water receptor location from all MC loading areas modeled within the subwatershed of the New River at Stones Bay (**Table 6-24**). However, because perchlorate is very persistent in the environment (has a very low decay rate), results showed the potential for perchlorate to reach the nearest surface water receptor locations above the REVA trigger value from all MC loading areas modeled within the subwatershed of the New River at Stones Bay (**Table 6-24**). These results were used to estimate baseflow contributions of MC to the surface water receptor location in the surface water screening-level analysis (**Table 6-20**).

Table 6-24: Model-Estimated MC Concentrations Reaching Surface Water Receptor Locations within the Subwatershed of the New River at Stones Bay

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW EP (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-211 and K-212	~0	~0	~0	**0.055**
K-405	~0	~0	N/A	**7.98**
Stones Bay Area	~0	0.0002	0.01	**0.16**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

RDX and TNT were the only MC modeled for migration to the nearest drinking water wells from the Stones Bay Area MC loading area, as these were the only MC estimated to reach the Castle Hayne aquifer above REVA trigger values at the MC loading area. Similar to the BIOCHLOR estimates for MC reaching surface water receptor locations, the high decay rates of RDX and TNT prevented these MC from reaching the nearest drinking water wells above REVA trigger values from the Stones Bay Area MC loading area. Therefore, no MC were estimated to reach drinking water wells above REVA trigger values within the subwatershed of the New River at Stones Bay.

6.3. The Subwatershed of the New River between Stick Creek and Whitehurst Creek

The subwatershed of the New River between Stick Creek and Whitehurst Creek is located in the north-central part of MCB Camp Lejeune; it is approximately 14,544 acres in size, with all of the subwatershed area located within MCB Camp Lejeune (**Figure 6-5**). The subwatershed area encompasses the northern section of the New River embayment within MCB Camp Lejeune and some of its tributaries, including Town Creek and Lewis Creek. A total of 7 RTAs and five identified MC loading areas are located within the subwatershed.

The following RTAs are partially or fully located in the subwatershed of the New River between Stick Creek and Whitehurst Creek:

- AC (525 acres)
- KA (617 acres)
- KB (1092 acres)
- KC (1009 acres)
- KD (425 acres)
- MC (1298 acres)
- MD (1333 acres)

It is unknown when RTA AC became operational, but the remaining RTAs within this subwatershed became operational in 1941. Historical use RTAs CB and CC were located within this subwatershed but were closed in 2004 for cantonment. Only KC, MC, and MD contained munitions use recorded in RFMSS.

A brief summary of MC loading areas partially or fully located within the subwatershed of the New River between Stick Creek and Whitehurst Creek is provided in **Table 6-1**. Only parts of ranges K-301, K-303, K-304, and K-305 lie with this subwatershed, whereas K-510, EOD-2, and ETA-5 are located entirely in the subwatershed.

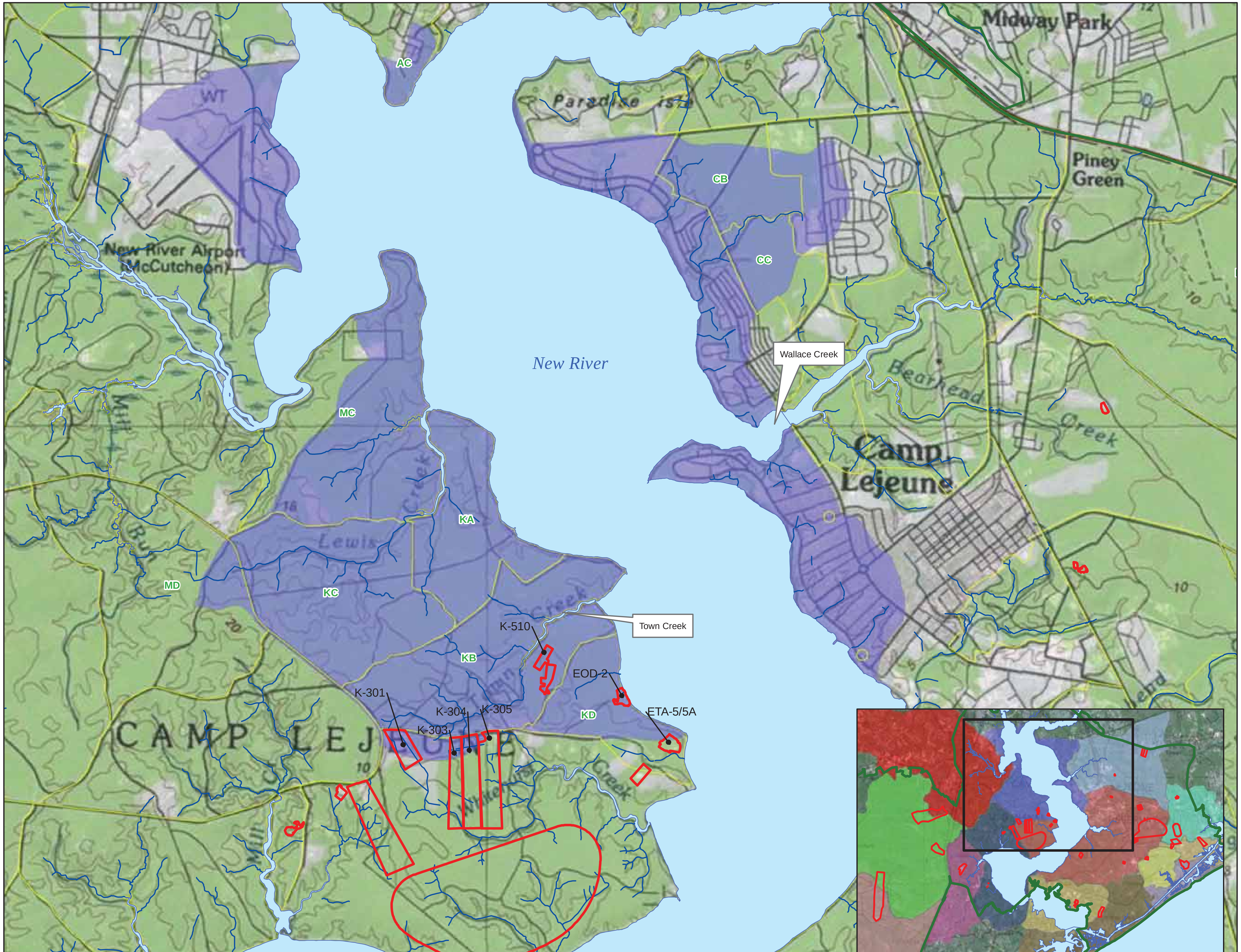

FIGURE 6-5
MC Loading Areas within the Subwathershed of the New River between Stick Creek and Whitehurst Creek

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- New River between Stick Creek and Whitehurst Creek

0 1,250 2,500 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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Military Munitions

Various high explosive, demolition, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of the New River between Stick Creek and Whitehurst Creek to support the various primary uses of the ranges in this area. Although K-301 and K-303 to K-305 are no longer active, they were heavily used when they were operational. Ranges K-510, EOD-2, and ETA-5 are heavily used, but it should be noted that Range K-510 first became operational in 2008.

6.3.1. Conceptual Site Model

6.3.1.1. Estimated Munitions Constituents Loading

The MC loading area for the subwatershed of the New River between Stick Creek and Whitehurst Creek is shown in **Figure 6-5**. The delineation of the area was based primarily upon GIS shapefiles. MC loading was estimated using munitions use data recorded in RFMSS and provided by range control.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within this MC loading area over time (**Table 6-25**); the assumptions used to guide the estimates are detailed in **Section 5**. MC loading areas were defined differently during the baseline assessment, so a direct comparison is not possible; however, MC loading was not completed for EOD-2 and ETA-5 during the baseline assessment. Therefore, all historical loading was completed for these two MC loading areas during the five-year review.

Table 6-25: Estimated Annual MC Loading for the Subwatershed of the New River between Stick Creek and Whitehurst Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
K-510	F (2005–2010)	2008	2010	2.19E-04	1.41E-04	3.61E-10	3.54E-07
EOD-2	C (1938–1976)	1970	1976	1.37E-04	8.95E-05	5.72E-07	3.14E-08
	D (1977–1988)	1977	1988	1.10E-04	7.16E-05	4.58E-07	2.51E-08
	E (1989–2004)	1989	2004	1.37E-04	8.95E-05	5.72E-07	3.14E-08
	F (2005–2010)	2005	2010	9.17E-05	5.97E-05	3.81E-07	2.10E-08
K-303 to K-305	F (2005–2010)	2005	2010	1.96E-05	6.97E-06	4.14E-09	3.80E-08
K-301	F (2005–2010)	2005	2006	1.89E-06	2.83E-07	7.21E-10	3.37E-10
ETA-5	E (1989–2004)	1994	2004	1.65E-04	5.01E-05	9.85E-09	9.92E-09
	F (2005–2010)	2005	2010	1.10E-04	3.34E-05	6.57E-09	6.62E-09

Annual lead deposition estimates for the MC loading areas are provided in **Table 6-26**. The K-303 to K-305 MC loading area exhibited the greatest lead deposition with an annual deposition of 46,847 pounds of lead.

Table 6-26: Estimated Annual Lead Deposition for the Subwatershed of the New River between Stick Creek and Whitehurst Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
K-510	6.69E+04	5.50
EOD-2	2.68E+04	0.2
K-303 to K-305	7.77E+05	46,847
K-301	1.23E+05	182
ETA-5	4.11E+04	5.25

6.3.1.2. Geography and Topography

The subwatershed of the New River between Stick Creek and Whitehurst Creek generally consists of level flat lands. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level in the New River to approximately 70 ft amsl in an upland area in the southwestern part of the subwatershed. Based on available GIS shapefiles, the slope within the subwatershed area ranges from approximately 0.3 % in upland areas to approximately 19% on the sides of the stream valleys. The larger part of the subwatershed area has an average slope of less than 5% (MCB Camp Lejeune, 2010a).

6.3.1.3. Surface Water Features

The subwatershed of the New River between Stick Creek and Whitehurst Creek contains intermittent and perennial streams, tidal creeks, and a portion of the New River embayment. Streams east of the New River flow in a southwest direction into the New River; and streams west of the New River flow in a southeast and northeast direction into the New River. The major tributaries of the New River within this subwatershed include Lewis Creek and Town Creek. These tributaries receive drainage from perennial streams and widen into tidal creeks in their downstream segments.

Table 6-27 describes the drainage characteristics of the five MC loading areas within the subwatershed of the New River between Stick Creek and Whitehurst Creek

Table 6-27: Drainage Description for the MC Loading Areas within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

MC Loading Area	Drainage Description
K-510	Drains northwest into Town Creek, which is located approximately 390 ft north of the MC loading area. Town Creek flows northeast into the New River.
EOD-2	Drains directly to the New River, which is located adjacent to the MC loading area.
K-303 to K-305	Approximately 3% of this MC loading area drains north into Town Creek, which is located approximately 980 ft north of the MC loading area.
K-301	Approximately 90% of this MC loading area drains northeast into Town Creek, which is located approximately 920 ft north of the MC loading area.
ETA-5	Approximately 5% of this MC loading area drains northeast into the New River, which is approximately 420 ft northeast of the MC loading area.

6.3.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of the New River between Stick Creek and Whitehurst Creek include Baymeade fine sand (BaB), BmB, On, Muckalee loam (Mk), and MaC. These soils are poorly to well drained, and the acidity of the soils ranges from moderately alkaline to very strongly acid. The organic content of the soil map units ranges from 0.5% to 2%. The On soil map unit can have an organic content as high as 2%, and the other soil map units have organic content of 0.5% to 1%. The soil map units generally have a low inherent soil erodibility; however, the On and the MaC soil map units can have close to moderate soil erodibility (factors as high as 0.32 tons/acre) (USDA SCS, 1992). Many of the military training areas within the subwatershed are largely unvegetated, but other areas within the subwatershed are covered predominantly with pine forest, mixed pine and hardwood forest, and bottomland hardwood forest.

6.3.1.5. Erosion Potential

The estimated soil erosion potential of the five identified MC loading areas within the subwatershed of the New River between Stick Creek and Whitehurst Creek ranges from low to high. The K-510 and the ETA-5 MC loading areas were estimated to have high soil erosion potential, while the EOD-2, K-303 to K-305, and K-301 MC loading areas wer estimated to have low soil erosion potential. The high soil erosion potential is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. These areas are sparsely vegetated. The EOD-2, K-303 to K-305, and K-301 MC loading areas, which have low estimated soil erosion potential, have higher vegetation covers and lower slopes.

6.3.1.6. Groundwater Characteristics

Based on investigations conducted by Harned et al. (1989) in the northern part of MCB Camp Lejeune, which partially includes the northern part of the subwatershed of the New River between Stick Creek and Whitehurst Creek, the surficial and Castle Hayne aquifers and the Castle Hayne confining unit dip gently to the east. The combined total thickness of the surficial and Castle Hayne aquifers in this area ranges from about 195 to 360 ft. In general, the surficial aquifer occurs in the upper 40 ft. The surficial aquifer is absent in the New River and the Northeast Creek areas and is thickest (40 ft) in areas east of the New River (Harned et al., 1989). Lithologic data obtained from Installation Restoration (IR) sites near the K-510 MC loading area indicate that the surficial aquifer consists of fine sand with varying amounts of silts and clays up to a depth of 15 ft bgs (Rhea Engineers & Consultants, 2010). The presence of a continuous confining unit between the surficial and the Castle Hayne aquifers (the Castle Hayne confining unit) occurs only in the easternmost parts of the subwatershed area. There appears to be no continuous confining unit or clay bed separating the two aquifers in other areas of the northern part of the subwatershed (Harned et al., 1989). The Castle Hayne aquifer can vary in thickness and lithology throughout the subwatershed area. The aquifer thickness can range from 175 ft in the western part to approximately 340 ft in the eastern part of the subwatershed. The lithology of the Castle Hayne aquifer varies with depth, where the upper part of the aquifer tends to be more unconsolidated than the lower half. Limestone makes up a greater portion of the aquifer in the western part of the subwatershed than in the eastern part of the subwatershed (Harned et al., 1989).

Based on measurements obtained from environmental site data near the loading areas within the subwatershed of the New River between Stick Creek and Whitehurst Creek, the depth to groundwater at the various MC loading areas within the subwatershed is estimated to range from approximately less than 1 ft to 11.5 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be approximately 4.8 ft bgs (CH2M Hill, 2006; CH2M Hill, 2009).

6.3.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of the New River between Stick Creek and Whitehurst Creek. Runoff coefficients at MC loading areas were assumed to range from 0.1 at a largely vegetated area with a lower slope (approximately 1.5%) to 0.66 at a sparsely vegetated area with a higher slope (approximately 6%). As indicated in **Section 6.3.1.5**, two of the MC loading areas within the subwatershed have high soil erosion potential. This makes soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain northeast and east into the New River embayment, which is a receptor location.

Groundwater Pathways

MC at the MC loading areas within the subwatershed of the New River between Stick Creek and Whitehurst Creek may migrate to the surficial aquifer via infiltration of rain water. The potential shallow groundwater pathway is from the MC loading areas toward the major surface water features, such as the New River and Town Creek. Deeper groundwater, in the Castle Hayne aquifer, flows in a northeast direction west of the New River and in a northwest direction east of the New River within the subwatershed (**Figure 4-3**).

6.3.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of the New River between Stick Creek and Whitehurst Creek supports T/E species (red-cockaded woodpecker). In addition, sensitive wetland habitats are present adjacent to streams and tidal creeks in the eastern parts of the subwatershed area. Although surface water is not a drinking water source, the New River is used for recreational purposes.

Groundwater Receptors

There are two active installation water supply wells located in the northeastern part of the subwatershed of the New River between Stick Creek and Whitehurst Creek, but these wells are located significant distances from the MC loading areas within the subwatershed. Therefore, MC from the loading areas are unlikely to migrate to the wells (**Figure 4-3**). Shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to the New River. Potential receptors in these surface waters include T/E species and humans (exposure by recreational use of the waters).

6.3.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from two MC loading areas that drain to the New River between Stick Creek and Whitehurst Creek (K-510 and EOD-2). The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (2008–2010 [period F] for K-510

MC loading area; 1970–2010 [periods C, D, E, and F] for EOD-2 MC loading area). As presented in **Table 5-7**, all of the K-510 and the EOD-2 MC loading areas drain to the New River between Stick Creek and Whitehurst Creeek. **Figure 5-1** shows surface water features and MC loading areas assessed within this subwatershed.

Table 6-28 presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to the New River between Stick Creek and Whitehurst Creek. The K-510 MC loading area was predicted to contribute the highest portions of RDX, TNT, and perchlorate mass (over 70%) to the New River between Stick Creek and Whitehurst Creek, whereas the EOD-2 MC loading area was predicted to contribute almost all of the HMX mass to the New River between Stick Creek and Whitehurst Creek.

Table 6-28: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into the New River between Stick Creek and Whitehurst Creek

MC Loading Area	MC Contributed (% Total Mass)			
	RDX	TNT	HMX	Perchlorate
K-510	75	73	< 1	98
EOD-2	25	27	100	2

Table 6-29 and **Table 6-30** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the subwatershed of the New River between Stick Creek and Whitehurst Creek. Based on the screening-level calculations, the average annual concentrations of all MC in runoff at the edge of the EOD-2 MC loading area were predicted to be above REVA trigger values. Furthermore, the average annual concentrations of RDX, TNT, and perchlorate in runoff at the edge of the K-510 MC loading area were predicted to be above REVA trigger values (**Table 6-29**).

Table 6-29: Surface Water Runoff Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrtions in Surface Water Runoff within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-510	**101.8**	**59.90**	~0	**0.21**
EOD-2	**100.03**	**59.94**	**0.71**	**0.04**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-30: Sediment Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrtions in Sediment within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Sediment (µg/L)	32.5	25	51	0.18
MC Concentration (µg/kg)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
K-510	3.02	**118.5**	~0	~0
EOD-2	2.25	**91.16**	0.01	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual TNT concentration in sediment at the edge of the K-510 and EOD-2 MC loading areas was predicted to be above the REVA trigger value. However, the average annual RDX, HMX, and perchlorate concentrations in sediment at the edge of both MC loading areas were predicted to be below REVA trigger values (**Table 6-30**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and in sediment entering the New River between Stick Creek and Whitehurst Creek, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Stick Creek and Whitehurst Creek were predicted to be above REVA trigger values (**Table 6-31**). However, the average annual concentrations of HMX and perchlorate in surface water runoff and baseflow entering the New River between Stick Creek and Whitehurst Creek were predicted to be below REVA trigger values (**Table 6-31**). All MC concentrations in sediment entering the New River between Stick Creek and Whitehurst Creek were predicted to be below REVA trigger values.

Table 6-31: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering the New River between Stick Creek and Whitehurst Creek

MC	REVA Trigger Value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.212**
TNT	0.113	**0.118**
HMX	0.114	~0
Perchlorate	0.021	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Although concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Stick Creek and Whitehurst Creek were predicted to exceed REVA trigger values, actual concentrations of these MC are expected to be lower (potentially below detection levels) in this tidally influenced water due to MC decay and tidal mixing in the water. Sampling was carried out as part of the five-year review MCB Camp Lejeune in September 2010 and December 2010 to determine the actual MC concentrations in surface water. A location in the New River just downstream of Town Creek was sampled within this subwatershed of the New River between Stick Creek and Whitehurst Creek. Additionally, a location downstream of EOD-2 in the New River was sampled in October 2011 as part of the five-year review. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.3.3. Groundwater Analysis Results

Two MC loading areas were assessed for groundwater within the subwatershed of the New River between Stick Creek and Whitehurst Creek (the K-510 and the EOD-2 MC loading areas).

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the MC loading areas assessed within the subwatershed of the New River between Stick Creek and Whitehurst Creek. **Table 6-32** shows the resulting infiltration MC concentrations at the K-510 and EOD-2 MC loading areas. With the exception of HMX at the K-510 MC loading area, all other MC at the K-510 MC loading area and all MC at the EOD-2 MC loading area were estimated to exceed REVA trigger values. For this reason, RDX, TNT, and perchlorate at the K-510 MC loading area and all MC at the EOD-2 MC loading area were modeled for migration through the vadose zone.

Table 6-32: Estimated Maximum MC Concentrations in Infiltrating Water at MC Loading Areas located within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	**Time Period**		**RDX**	**TNT**	**HMX**	**Perchlorate**
K-510	2008–2010	F	**664.6**	**426.9**	0.001	**1.08**
EOD-2	1970–1976	C	**417.6**	**271.8**	**1.74**	**0.095**
	1977–1988	D	**334.1**	**217.5**	**1.39**	**0.076**
	1989–2004	E	**417.6**	**271.8**	**1.74**	**0.095**

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	**Time Period**		**RDX**	**TNT**	**HMX**	**Perchlorate**
	2005–2010	F	**278.4**	**181.2**	**1.16**	**0.064**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for a 100-year simulation time.

Steady-state conditions for TNT were reached at much longer time periods (88 and 89 years) than for RDX, HMX, and perchlorte (a maximum of 6 years) at the MC loading areas modeled. This is a result of the high K_{oc} of TNT. **Table 6-33** shows the maximum MC concentrations reaching the water table at the MC loading areas modeled within the subwatershed of the New River between Stick Creek and Whitehurst Creek. Due to the MC chemical properties (i.e., low volatility and moderate-to-high solubility) and the VLEACH assumption of no degradation, the steady-state MC concentrations at the water table for both MC loading areas were equal to or a little lower than their influent concentrations, which exceed REVA trigger values. For this reason, all MC listed in **Table 6-33** that were modeled for movement through the vadose zone were further analyzed for movement through the surficial aquifer.

Table 6-33: VLEACH Maximum MC Concentrations Reaching the Water Table at MC Loading Areas within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-510	**664.3**	**425.6**	N/A	**1.08**
EOD-2	**278.4**	**187.4**	**1.16**	**0.064**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Within the subwatershed of the New River between Stick Creek and Whitehurst Creek, none of the MC loading areas have the potential to reach drinking water supply wells, as they are located at significant distances from the supply wells (**Figure 4-3**). Therefore, the MC loading areas within the subwatershed were not assessed for potential transport to the Castle Hayne aquifer.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through the surficial aquifer to potential surface water receptor locations in the major surface water features (the New River and Town Creek). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading areas and the nearest surface water receptor location.

Saturated zone modeling with BIOCHLOR was not conducted for the EOD-2 MC loading area because this loading area is located right next to the New River; therefore, it was conservatively assumed that MC reaching the water table at this loading area (as evaluated from the vadose zone modeling) would discharge directly into the New River. Thus, all MC from the EOD-2 MC loading area were predicted to discharge into the New River above REVA trigger values (**Table 6-34**). Concentrations of RDX, TNT, and HMX were predicted to be below REVA trigger values at the nearest surface water receptor location (Town Creek) to the K-510 MC loading area, whereas the concentration of perchlorate was predicted to exceed the REVA trigger value at the nearest surface water receptor location to the K-510 MC loading area (**Table 6-34**). These results were used to estimate baseflow contributions of MC to the surface water receptor location in the surface water screening-level analysis (**Table 6-31**).

Table 6-34: Model-Estimated MC Concentrations Reaching Surface Water Receptor Locations within the Subwatershed of the New River between Stick Creek and Whitehurst Creek

REVA Trigger value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW EP (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
K-510	~0	~0	~0	**0.97**
EOD-2	**278.4**	**187.4**	**1.16**	**0.064**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

6.4. The Subwatershed of Wallace Creek

The subwatershed of Wallace Creek is located on the northeastern part of MCB Camp Lejeune; it is approximately 12,868 acres in size, with a large portion of the area located within MCB Camp Lejeune (**Figure 6-6**). The subwatershed area encompasses Wallace Creek and its tributaries. A total of 13 RTAs and two identified MC loading areas are located within the subwatershed.

The following RTAs are partially or fully located in the subwatershed of Wallace Creek upstream of its confluence with the New River:

- CC (287 acres)
- DA (429 acres)
- DB (392 acres)
- DE (229 acres)
- DF (376 acres)
- FA (1082 acres)
- FB (923 acres)
- FC (1983 acres)
- FE (922 acres)
- FF (1021 acres)
- FG (2173 acres)
- RA (1035 acres)
- RB (780 acres)

These RTAs are minimally used for any munitions. Blasting charges also were used but only sparingly. No munitions use was recorded in RFMSS for RTAs CC, DA, DB, DE, and FA for the years 2004–2010.

A brief summary of MC loading areas located within the subwatershed of Wallace Creek upstream of its confluence with the New River is provided in **Table 6-1**. Both MC loading areas lie entirely within this subwatershed.

Military Munitions

Various high explosive, demolition, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of Wallace Creek to support the various primary uses of the ranges in this area. ETA-3 is used frequently for engineering demolition training, and F-2 and F-5 are very heavily used. The installation currently plans to relocate Ranges F-2 and F-5 south of the G-10 Impact Area by FY2015.

6.4.1. Conceptual Site Model

6.4.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the subwatershed of Wallace Creek are shown in **Figure 6-6**. Delineation of the ETA-3 was based on GIS shapefiles, while the delineation of the F-2 and F-5 MC loading area was based on fixed target locations.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within the MC loading areas over time (**Table 6-35**); the assumptions used to guide the estimates are detailed in **Section 5**. MC loading was not completed for ETA-3 during the baseline assessment, but loading calculations were completed for Range F-5. However, a direct comparison is not possible because MC loading in the five-year review is combined with Range F-2, whereas two historical ranges were included in the F-5 MC loading area in the baseline assessment.

Table 6-35: Estimated Annual MC Loading for the Subwatershed of Wallace Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
ETA-3	D (1989–2004)	1994	2004	3.48E-03	2.23E-03	1.06E-07	5.23E-08
	F (2005–2010)	2005	2010	2.32E-03	1.49E-03	7.04E-08	3.49E-08
F-2 and F-5	F (2005–2010)	2005	2010	2.40E-07	3.78E-10	0.00	1.28E-08

Annual lead deposition estimates for the MC loading areas are provided in **Table 6-36**. The F-2 and F-5 MC loading area exhibited the greatest deposition of lead per year with 6,183 pounds; however, this is considerably less than that deposited on other ranges at the installation, such as Ranges K-303 to K-305 and K-211 and K-212.

Table 6-36: Estimated Annual Lead Deposition for the Subwatershed of Wallace Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
ETA-3	7.75E+03	1.36
F-2 and F-5	3.53E+05	6,183

6.4.1.2. Geography and Topography

The subwatershed of Wallace Creek consists of level flat lands with very minor relief. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level in the downstream segments of Wallace Creek to approximately 70 ft amsl in an upland area south of the upper segment of Wallace Creek. Based on available topographic data, the slope within the subwatershed area ranges from nearly level to approximately 14% on the sides of stream valleys, with the majority of the subwatershed area having an average slope of approximately 3% (MCB Camp Lejeune, 2010a).

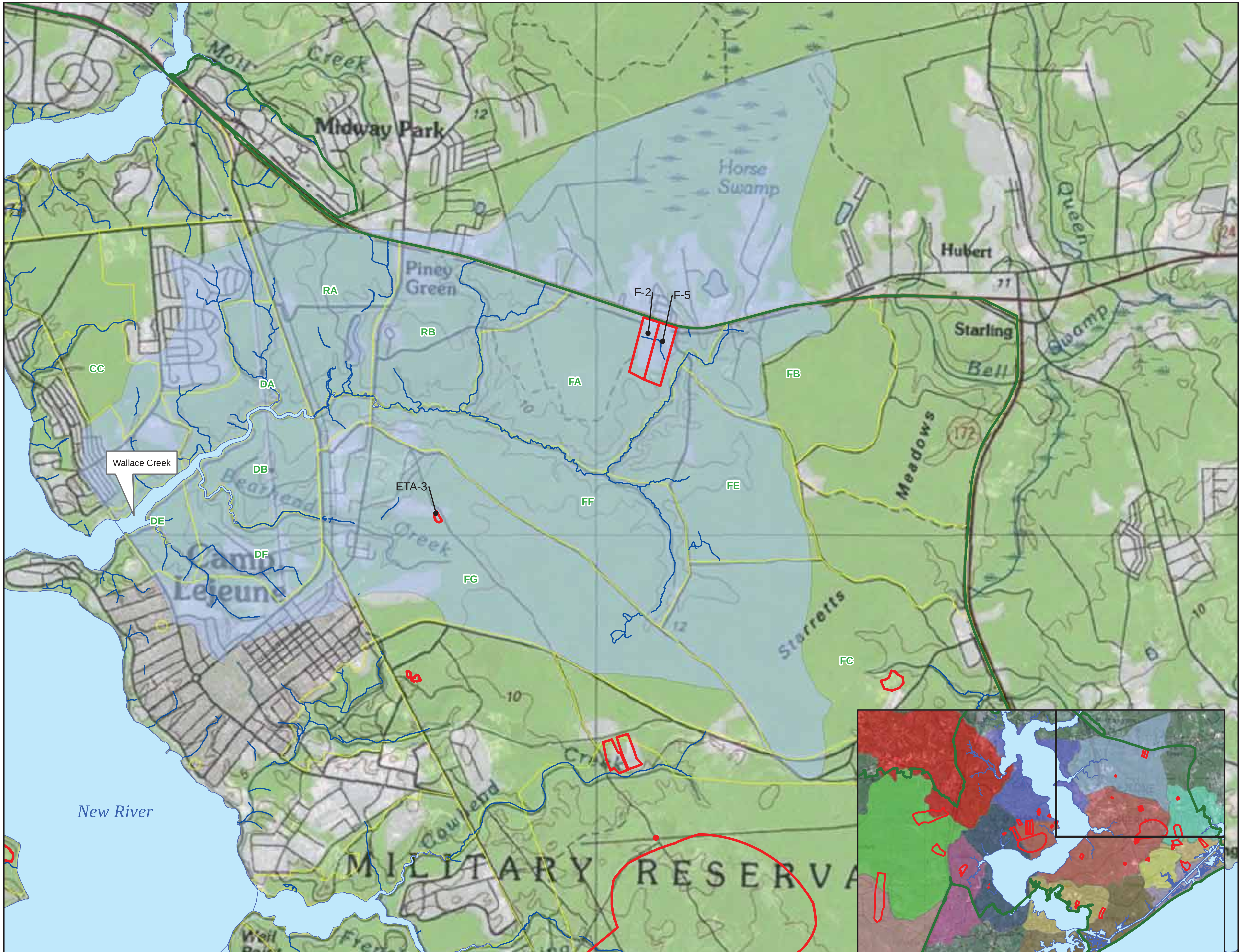

FIGURE 6-6
MC Loading Areas within the Subwatershed of Wallace Creek

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- Wallace Creek

0 1,250 2,500 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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6.4.1.3. Surface Water Features

The subwatershed of Wallace Creek contains intermittent and perennial streams and tidal creeks. Streams flow southwest and west into Wallace Creek. The two major tributaries of Wallace Creek are Bearhead Creek and Beaverdam Creek. These tributaries originate as perennial streams and widen into tidal creeks in their downstream segments. They drain southwest to the downstream segments of Wallace Creek.

Table 6-37 describes the drainage characteristics of the two MC loading areas within the subwatershed of Wallace Creek.

Table 6-37: Drainage Description for the MC Loading Areas within the Subwatershed of Wallace Creek

MC Loading Area	Drainage Description
ETA-3	Drains southwest into Bearhead Creek, which is located approximately 1,600 ft west of the MC loading area, and ultimately discharges into Wallace Creek.
F-2 and F-5	Drains into a short unnamed stream located within the MC loading area. Also drains to Wallace Creek, which is located approximately 450 ft west of the loading area.

6.4.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of Wallace Creek include BmB, On, Mk, and MaC. These soils are poorly to well drained, and the acidity of the soils ranges from moderately alkaline to very strongly acid. The organic contents of the soil map units range from 0.5% to 2% (USDA SCS, 1992). The On soil map unit can have organic content as high as 2%, where as the organic content for the other soil map units (BmB, Mk, and MaC) ranges from 0.5% to 1%. The soil map units generally have a low inherent soil erodibility; however, the On and the MaC soil map units can have close to moderate soil erodibility (factors as high as 0.32 tons/acre) (USDA SCS, 1992). The ETA-3 and some parts of the F-2 and F-5 MC loading areas are unvegetated. Other areas within the subwatershed are covered predominantly with pine forest, and some areas also include mixed pine and hardwood forest.

6.4.1.5. Erosion Potential

The estimated soil erosion potential of the two identified MC loading areas within the subwatershed of Wallace Creek ranges from low to high. The ETA-3 MC loading area was estimated to have high soil erosion potential, while the F-2 and F-5 MC loading area was estimated to have low soil erosion potential. The high soil erosion potential is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the area. The low estimated soil erosion potential is due to higher vegetation cover and low topographic slope.

6.4.1.6. Groundwater Characteristics

The hydrogeologic characteristics of a section covering a distance of approximately 3 miles north of Wallace Creek within the subwatershed of Wallace Creek was investigated by Harned et al (1989). Based on this investigation, the total thickness of the surficial and Castle Hayne aquifers and the Castle Hayne confining unit in the section ranged from 300 to 360 ft. It was determined that the surficial aquifer occurs in the upper 40 ft of the section. The thickness of this aquifer ranges from zero in the channels of streams to 40 ft in the eastern part of the section (Harned et al., 1989). Based on lithologic data obtained from site investigations at IRP site 82 located just south of Wallace Creek and north of the ETA-3 MC loading area, the surficial aquifer consists of beds of silty sand and discontinuous sandy to clayey silt layers (CH2M Hill, 2008). There is a relatively thin (5 ft) Castle Hayne confining unit in the eastern part of the section investigated by Harned et al (1989); in other parts of the section, the Castle Hayne confining unit is either absent or discontinuous. Estimated thickness of the Castle Hayne aquifer measured at a single well within the subwatershed is 300 ft (Harned et al., 1989). Based on aquifer testing conducted near IR sites 6, 9, and 82 located within the subwatershed, the hydraulic conductivity of the surficial and Castle Hayne aquifers has been estimated to be approximately 3.4 ft/d and 35 ft/d, respectively (Baker Environmental, 1993).

Based on measurements obtained from environmental site data near the loading areas within the subwatershed of Wallace Creek, the depth to groundwater at the MC loading areas ranges from approximately 6 to 11.6 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be 8.7 ft bgs (O'Brien and Gere, 1988).

6.4.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of Wallace Creek. Runoff coefficients at MC loading areas were assumed to range from 0.22 at a largely vegetated area to 0.69 at an unvegetated area. As indicated in **Section 6.4.1.5**, the ETA-3 MC loading area has high soil erosion potential. This makes soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a source of baseflow to streams. MC in streams would drain southwest into Wallace Creek, which flows into the New River. Wallace Creek and the New River are receptor locations.

Groundwater Pathways

MC at the MC loading areas within the subwatershed of Wallace Creek may migrate to the surficial aquifer via infiltration of rain water. The potential shallow groundwater pathway is from the MC loading areas toward Wallace Creek and its tributaries. Deeper groundwater, in the Castle Hayne aquifer, generally flows west and northwest toward drinking water wells located just west of the subwatershed area (**Figure 4-3**).

Due to the noncontinuous presence of the Castle Hayne confining unit (as described in **Section 6.4.1.6**), a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and transported to the Castle Hayne aquifer near locations of active water supply wells.

6.4.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of Wallace Creek upstream of its confluence with the New River supports T/E species, including the red-cockaded woodpecker and the American alligator. In addition, sensitive wetland habitats are present adjacent to streams and tidal creeks. Although surface water is not a drinking water source, Wallace Creek and the New River potentially are used for recreational purposes.

Groundwater Receptors

There are various active installation water supply wells located within the subwatershed of Wallace Creek (**Figure 4-3**). MC from MC loading areas within the subwatershed can potentially migrate to water supply wells within and outside of the subwatershed area. In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to Wallace Creek and the New River. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.4.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from two MC loading areas that drain to Wallace Creek upstream of its confluence with the New River (ETA-3 and F-2 and F-5 MC loading areas). The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (1994–2010 [periods E and F] for ETA-3; 2005–2010 [period F] for F-2 and F-5 MC loading areas). As presented in **Table 5-7**, all of the ETA-3 and the F-2 and F-5 MC loading areas drain to Wallace Creek at its confluence with the New River. **Figure 5-1** shows surface water features and MC loading areas analyzed within the subwatershed of Wallace Creek upstream of its confluence with the New River.

Table 6-38 presents the estimated percentage of total MC mass contributed by the individual MC loading areas draining to Wallace Creek at its confluence with the New River. The ETA-3 MC loading area was predicted to contribute almost all of the RDX, TNT, and HMX mass and a significant portion (97%) of the perchlorate mass to Wallace Creek at its confluence with the New River (**Table 6-38**).

Table 6-38: Screening-Level Estimates of Percentage MC Mass Contributed by Individual MC Loading Areas into Wallace Creek at its Confluence with the New River

MC Loading Area	MC Contributed (% Total Mass)			
	RDX	TNT	HMX	Perchlorate
ETA-3	100	100	100	97
F-2 and F-5	< 1	< 1	< 1	3

Table 6-39 and **Table 6-40** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from individual MC loading areas draining within the subwatershed of Wallace Creek. Based on the screening-level calculations, the average annual concentrations of RDX in runoff at the edge of the ETA-3 and the F-2 and F-5 MC loading areas were predicted to be above REVA trigger values. The average annual concentrations of TNT and perchlorate in runoff at the edge of the ETA-3 MC loading area also were predicted to be above REVA trigger values (**Table 6-39**).

Table 6-39: Surface Water Runoff Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Subwatershed of Wallace Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-3	**984.9**	**324.1**	0.04	**0.02**
F-2 and F-5	**0.14**	~0	N/A	0.01

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-40: Sediment Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Subwatershed of Wallace Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Sediment (µg/L)	32.5	25	51	0.18
MC Concentration (µg/Kg)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-3	**126.5**	**2,755.0**	~0	~0
F-2 and F-5	0.01	~0	N/A	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual concentrations of RDX and TNT in sediment at the edge of the ETA-3 MC loading area was predicted to be above REVA trigger values. The average annual concentrations of all MC in sediment at the edge of the F-2 and F-5 MC loading area and the average annual concentrations of HMX and perchlorate in sediment at the edge of the ETA-3 MC loading area were predicted to be below REVA trigger values (**Table 6-40**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and in sediment entering Wallace Creek at its confluence with the New River, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX in surface water runoff and baseflow entering Wallace Creek at its confluence with the New River were predicted to be above the REVA trigger value (**Table 6-41**). However, the average annual concentrations of TNT, HMX, and perchlorate in surface water runoff and baseflow entering Wallace Creek at its confluence with the New River were predicted to be below REVA trigger values. Furthermore, all MC concentrations in sediment entering Wallace Creek at its confluence with the New River were predicted to be below REVA trigger values.

Table 6-41: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering Wallace Creek

MC	REVA Trigger Value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.148**
TNT	0.113	0.048
HMX	0.114	~0
Perchlorate	0.021	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Although the concentration of RDX in surface water runoff and baseflow entering Wallace Creek at its confluence with the New River was predicted to exceed the REVA trigger value, the actual concentration of this MC is expected to be lower (potentially below detection levels) in this tidally influenced water due to MC decay and tidal mixing that occurs in the water. However, surface water sampling was carried out in Wallace Creek in October 2011 as part of the five-year review to determine the actual MC concentrations in surface water. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.4.3. Groundwater Analysis Results

Two MC loading areas were assessed for groundwater within the subwatershed of Wallace Creek, the ETA-3 and the F-2 and F-5 MC loading areas.

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the MC loading areas assessed within the subwatershed of Wallace Creek upstream of its confluence with the New River. In doing this, the estimated MC loading rates (**Table 6-35**) were divided by a recharge rate of 1.08 ft/yr estimated for MCB Camp Lejeune (Heath, 1989). **Table 6-42** shows the resulting infiltration MC concentrations at the ETA-3 and the F-2 and F-5 MC loading areas. All MC concentrations at the ETA-3 MC loading area and concentrations of RDX and perchlorate at the F-2 and F-5 MC loading area were estimated to exceed REVA trigger values (**Table 6-42**). For this reason, all MC at the ETA-3 MC loading area and RDX and perchlorate at the F-2 and F-5 MC loading area were modeled for migration through the vadose zone.

Table 6-42: Estimated Maximum MC Concentrations in Infiltrating Water at MC Loading Areas within the Subwatershed of Wallace Creek

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	Time Period		RDX	TNT	HMX	Perchlorate
ETA-3	1994–2004	E	**10,570.9**	**6,770.9**	**0.320**	**0.160**
	2005–2010	F	**7,047.3**	**4,513.9**	**0.214**	**0.110**
F-2 and F-5	2007–2010	F	**0.492**	0.001	~0	**0.026**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for simulation times ranging from 100 to 200 years.

Steady-state conditions for TNT at the ETA-3 MC loading area was reached at 200 years. Steady-state conditions for other MC modeled (RDX, HMX, and perchlorate) were reached at a maximum time of 6 years. **Table 6-43** shows the maximum MC concentrations reaching the water table at the MC loading areas modeled within the subwatershed of Wallace Creek upstream its confluence with the New River. Due to the MC chemical properties (i.e., low volatility and moderate-to-high solubility) and the VLEACH assumption of no degradation, the steady-state MC concentrations at the water table for the MC loading areas modeled were equal to or a little lower than their influent concentrations, which exceed REVA trigger values. For this reason, all MC listed in **Table 6-43** that were modeled for movement through the vadose zone were analyzed further for movement through the surficial aquifer.

Table 6-43: VLEACH Maximum MC Concentrations Reaching the Water Table at MC Loading Areas within the Subwatershed of Wallace Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-3	**7,026.1**	**6,566.7**	**0.21**	**0.11**
F-2 and F-5	**0.489**	N/A	N/A	**0.026**

Note:
N/A = Not modeled, as MC loading rate was negligible or MC was eliminated for further analysis from the initial groundwater screening analysis
Bold indicates concentration exceeds the REVA trigger value.

Potential transport to the Castle Hayne aquifer was assessed for MC loading areas where the MC concentration reaching the water table exceeded the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area (**Figure 4-3**). Within the subwatershed of Wallace Creek, both the ETA-3 and F-2 and F-5 MC loading areas satisfied these conditions; therefore, the MC that were predicted to reach the water table above REVA trigger value at the MC loading areas were analyzed further for transport to the Castle Hayne aquifer. The methodology used for this analysis is discussed in **Section 5.2.2.3**.

The resulting MC concentrations estimated to potentially reach the Castle Hayne aquifer are presented in **Table 6-44**.

Table 6-44: Estimated MC Concentrations Reaching the Castle Hayne Aquifer at MC Loading Areas within the Subwatershed of Wallace Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration Potentially Reaching the Castle Hayne Aquifer (µg/L)				

MC Loading Area	RDX	TNT	HMX	Perchlorate
ETA-3	**1470.9**	**1374.7**	0.044	**0.023**
F-2 and F-5	**0.308**	~0	N/A	0.016

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Concentration of RDX was estimated to potentially reach the Castle Hayne aquifer above the REVA trigger value at both the ETA-3 and F-2 and F-5 MC loading areas (**Table 6-44**). Furthermore, concentrations of TNT and perchlorate were estimated to potentially reach the Castle Hayne aquifer above REVA trigger values at the ETA-3 MC loading area (**Table 6-44**). As a result, MC that were estimated to reach the Castle Hayne aquifer above REVA trigger values at the two MC loading areas were modeled for movement through the Castle Hayne aquifer to potential drinking water wells.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through 1) the surficial aquifer to potential surface water receptor locations in the major surface water features (Wallace Creek and Bearhead Creek) and 2) the Castle Hayne aquifer to potential groundwater receptors (installation drinking water supply wells). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading areas and the nearest receptor location (surface water or drinking water well).

Due to the high decay rates of RDX, TNT, and HMX and the long distances between the loading areas and the surface water receptor locations, these MC were predicted to be below REVA trigger values at the nearest surface water receptor location from both the ETA-3 and F-2 and F-5 MC loading areas (**Table 6-45**). However, results showed the potential for perchlorate to reach the nearest surface water receptor locations above the REVA trigger value from the ETA-3 MC loading area (**Table 6-45**). These results were used to estimate baseflow contributions of MC to the surface water receptor location in the surface water screening-level analysis (**Table 6-41**).

Table 6-45: Model-Estimated MC Concentrations Reaching Surface Water Receptor Locations within the Subwatershed of Wallace Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW RL (µg/L)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
ETA-3	~0	~0	~0	**0.06**
F-2 and F-5	N/A	~0	N/A	0.02

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Saturated zone modeling with BIOCHLOR was not conducted for the F-2 and F-5 MC loading area because this loading area is approximated to overlie a drinking water well; therefore, it was assumed that MC potentially reaching the Castle Hayne aquifer at this loading area (as evaluated from the transport to Castle Hayne aquifer analysis) would directly enter the underlying drinking water well. Thus, RDX was estimated to potentially reach the nearest drinking water well from the F-2 and F-5 MC loading area above the REVA trigger value (**Table 6-46**). Concentrations of RDX, TNT, and HMX were predicted to be below REVA trigger values at the nearest drinking water well to the ETA-3 MC loading area; however, perchlorate was predicted to potentially reach the nearest drinking water well above the REVA trigger value from the ETA-3 MC loading area (**Table 6-46**).

Table 6-46: Model-Estimated MC Concentrations Reaching Groundwater Receptors from MC Loading Areas within the Subwatershed of Wallace Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest Drinking Water Well (µg/L)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
ETA-3	~0	~0	~0	**0.021**
F-2 and F-5	**0.308**	**~0**	N/A	0.016

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Groundwater sampling for MC has been conducted regularly by MCB Camp Lejeune in water supply wells, including wells closest to the ETA-3 and F-2 and F-5 MC loading areas where perchlorate and RDX were predicted to reach concentrations above REVA trigger values. The most recent sampling event occurred in March 2011; the sampling results are discussed in **Section 8**.

6.5. The Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

The subwatershed of the New River between Stones Bay and the Intracoastal Waterway is located on the southern part of MCB Camp Lejeune; it is approximately 7,810 acres in size, with a large portion of the area located outside the MCB Camp Lejeune installation boundary (**Figure 6-7**). The subwatershed area encompasses Courthouse Bay and Traps Bay and several tributaries of the New River. A total of 6 RTAs and two identified MC loading areas are located within the subwatershed.

The following RTAs are partially or fully located within the subwatershed of the New River between Stones Bay and the Intracoastal Waterway:

- IE (1438 acres)
- IF (1445 acres)
- JA (358 acres)
- JB (195 acres)
- JC (357 acres)
- JE (129 acres)

The RTAs in this subwatershed are not heavily used. No munitions use was recorded for RTAs JB and JE for the years 2004–2010. RTAs JB and JC are considered amphibious support exercise areas. A brief summary of the two MC loading areas located within this subwatershed is provided in **Table 6-1**.

Military Munitions

Various high explosive and blank military munitions are allowed in the RTAs within the subwatershed of the New River between Stones Bay and Intracoastal Waterway to support the various primary uses of the ranges in this area.Data recorded in RFMSS indicate that ETA-1 is used more heavily than ETA-2, with blasting charges accounting for the greatest use.

6.5.1. Conceptual Site Model

6.5.1.1. Estimated Munitions Constituents Loading

The MC loading areas for the subwatershed of the New River between Stones Bay and the Intracoastal Waterway are shown in **Figure 6-7**. The delineation of the areas was based primarily upon GIS shapefiles.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within an MC loading area over time (**Table 6-47**); the assumptions used to guide the estimates are detailed in **Section 5**. MC loading was not estimated for these two MC loading areas during the baseline assessment, so historical loading was completed back to 1994 when the ranges became operational.

Table 6-47: Estimated Annual MC Loading for the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
ETA-1	E (1989–2004)	1994	2004	4.53E-05	5.15E-05	3.28E-09	8.18E-08
	F (2005–2010)	2005	2010	3.02E-05	3.43E-09	2.18E-09	5.45E-08
ETA-2	E (1989–2004)	1994	2004	2.05E-06	1.48E-06	0.00	3.18E-09
	F (2005–2010)	2005	2010	1.37E-06	9.87E-07	0.00	2.12E-09

Annual lead deposition estimates for the ETA-1 and ETA-2 MC loading areas are presented in **Table 6-48**. The amount of lead loading at both MC loading areas in this subwatershed is insignificant at less than a total of 2 lb/yr of lead.

Table 6-48: Estimated Annual Lead Deposition for the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

MC Loading Area	Size (m^2)	Lead (lb/yr)
ETA-1	1.24E+05	1.43
ETA-2	2.47E+05	0.05

6.5.1.2. Geography and Topography

The subwatershed of the New River between Stones Bay and the Intracoastal Waterway consists of level flat lands with relatively low relief. Available elevation contour data indicate the elevation of the subwatershed area ranges from approximately 2 ft bmsl in the New River to approximately 50 ft amsl in an upland area southeast of the New River. Based on available topographic data, the slope within the subwatershed area ranges from nearly level to approximately 15% on the sides of stream valleys, with the majority of the subwatershed area having an average slope of approximately 5% (MCB Camp Lejeune, 2010a).

6.5.1.3. Surface Water Features

The subwatershed of the New River between Stones Bay and the Intracoastal Waterway contains intermittent and perennial streams and tidal creeks. Streams flow in southwest, west, and northeast directions into the New River. The major tributaries of the New River within the subwatershed include Sneads North Creek, Sneads South Creek, Traps Creek, Toms Creek, Fannie Creek, and Wheeler Creek. These tributaries originate as perennial streams and widen into tidal creeks in their downstream segments.

Table 6-49 describes the drainage characteristics of the two MC loading areas within the subwatershed of the New River between Stones Bay and the Intracoastal Waterway.

Table 6-49: Drainage Description for the MC Loading Areas within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

MC Loading Area	Drainage Description
ETA-1	Drains southwest into the New River approximately 1,000 ft south of the MC loading area.
ETA-2	Approximately 50% of the loading area drains northwest into Toms Creek located approximately 1,400 ft west of the loading area into the New River.

6.5.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of the New River between Stones Bay and Intracoastal Waterway located within the boundaries of MCB Camp Lejeune include Wando fine sand (WaB), BmB, MaC, Mk, and Ln. These soils are poorly to excessively well drained, and the acidity of the soils ranges from moderately alkaline to very strongly acidic. The organic contents of the soil map units range from 0.5% to 4% (USDA SCS, 1992). The Ln soil map unit can have organic content as high as 4%, where as the organic content for the other soil map units (WaB, BmB, MaC, and Mk) ranges from 0.5% to 1%. The soil map units generally have a low inherent soil erodibility; however, the MaC soil map unit can have close to moderate soil erodibility (a factor as high as 0.32 tons/acre) (USDA SCS, 1992). Part of the ETA-1 and most of the ETA-2 MC loading areas are unvegetated. Other areas of the subwatershed located within the boundaries of MCB Camp Lejeune are covered predominantly with pine forest and mixed pine and hardwood forest.

6.5.1.5. Erosion Potential

The estimated soil erosion potential of the two identified MC loading areas within the subwatershed of the New River between Stones Bay and Intracoastal Waterway ranges from moderate to high. The ETA-1 MC loading area was estimated to have moderate soil erosion potential, while the ETA-2 MC loading area was estimated to have high soil erosion potential. The moderate and high soil erosion potentials estimated at the MC loading areas are a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas.

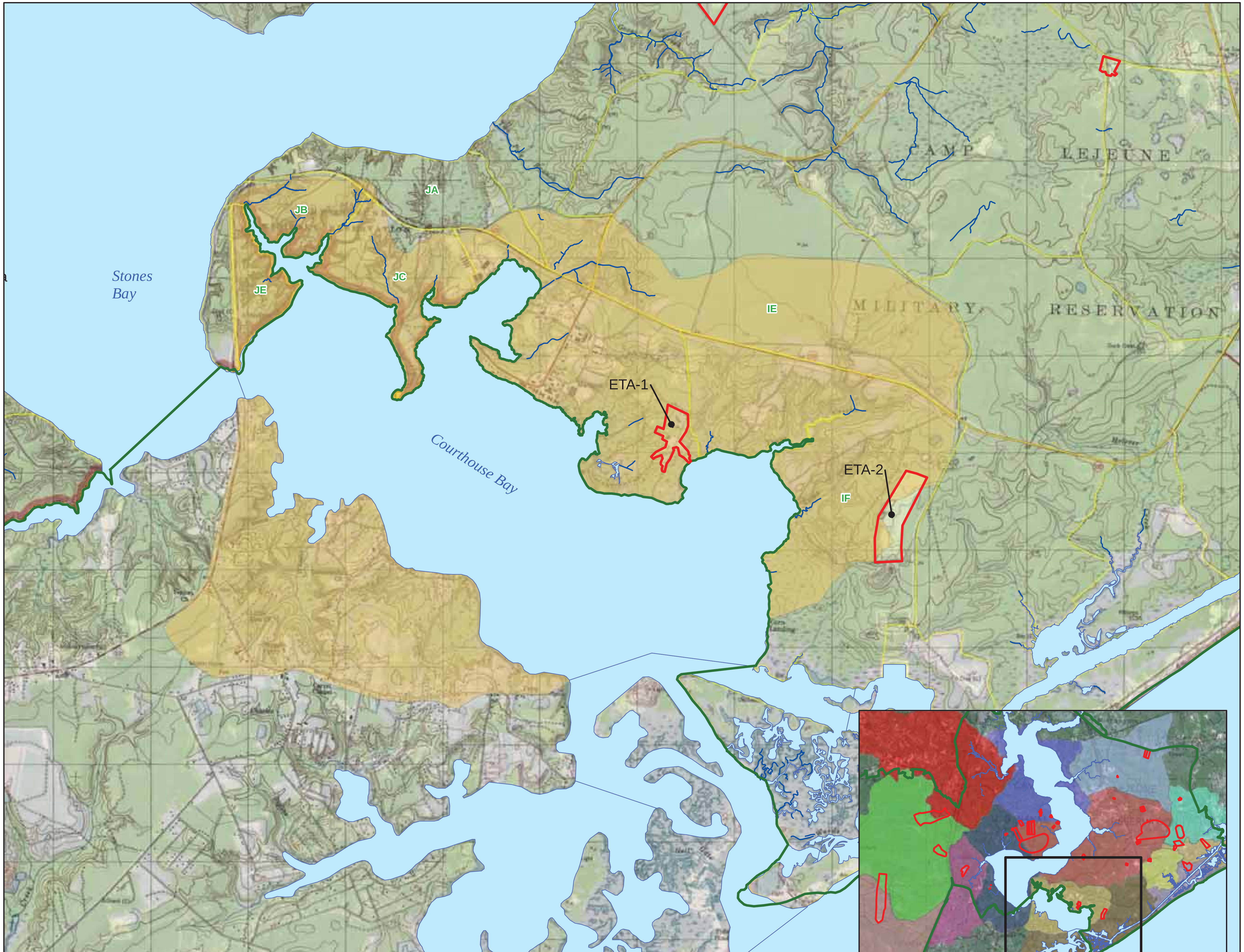

FIGURE 6-7
MC Loading Areas within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- New River between Stones Bay and Intracoastal Waterway

0 1,000 2,000 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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6.5.1.6. Groundwater Characteristics

Based on a USGS geophysical data presented for two wells near the ETA-1 MC loading area, the thickness of the surficial aquifer ranges from 27 to 40 ft (Cardinell et al., 1993). The surficial aquifer near the ETA-1 MC loading area consist of mostly fine- to medium-grained sands with varying amounts of silts and clays (CH2M Hill, 2010). Based on aquifer tests performed at Solid Waste Management Unit 474 located near the ETA-1 MC loading area, the hydraulic conductivity of the surficial aquifer ranged from 0.516 to 1.23 ft/d, with a geometric mean of 1.32 ft/d (CH2M Hill, 2010). The USGS geophysical data indicate the presence of the Castle Hayne confining unit at a thickness of 15 to 22 ft near the ETA-1 MC loading area. However, detailed information is insufficient to determine if the confining unit is laterally continuous throughout the subwatershed area. The confining unit is absent in the area of the New River and some of its larger tributaries and in localized areas containing buried paleochannel deposits (Geophex, 1994; Baker Environmental, 1998a). The confining unit near the ETA-1 MC loading area is known to consist of clay, silt, and sandy clay beds. Near the ETA-1 MC loading area, the Castle Hayne aquifer was estimated to be 293 ft thick and the aquifer is encountered at approximately 44 ft bgs (Cardinell et al., 1993).

Based on measurements obtained from environmental site data near the loading areas within the subwatershed of the New River between Stones Bay and the Intracoastal Waterway, the depth to groundwater at the MC loading areas ranges from approximately 12.3 to 14.5 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be 13.5 ft bgs (CH2M Hill, 2010).

6.5.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of the New River between Stones Bay and Intracoastal Waterway. Runoff coefficients at MC loading areas were assumed to range from 0.2 at a partially vegetated area to 0.65 at a mostly unvegetated area. As indicated in **Section 6.5.1.5**, the MC loading areas within the subwatershed have moderate and high soil erosion potential. This makes soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain northwest into the New River, which is a receptor location.

Groundwater Pathways

MC at the MC loading areas within the subwatershed of the New River between Stones Bay and the Intracoastal Waterway may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the MC loading areas toward the New River and its tributaries. Deeper groundwater, in the Castle Hayne aquifer, flows north toward the drinking water wells located within the subwatershed from the ETA-1 MC loading area and east toward the drinking water wells located east of the subwatershed area from the ETA-2 MC loading area (**Figure 4-3**).

Due to the noncontinuous presence of the Castle Hayne confining unit (as described in **Section 6.5.1.6**), a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and transported to the Castle Hayne aquifer near locations of active water supply wells.

6.5.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of the New River between Stones Bay and Intracoastal Waterway supports T/E species (including the red-cockaded woodpecker, the rough-leaved loosestrife, and the bald eagle). In addition, sensitive wetland habitats are present adjacent to Sneads North and Sneads South Creeks and Traps Bay. Although surface water is not a drinking water source, the New River potentially is used for recreational purposes. Shellfishing is permitted within most of Courthouse Bay.

Groundwater Receptors

There are various active installation water supply wells located within the subwatershed of the New River between Stones Bay and Intracoastal Waterway (**Figure 4-3**). MC from MC loading areas within the subwatershed potentially can migrate to water supply wells within and outside of the subwatershed area. In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to the New River. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.5.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from the ETA-1 MC loading area, which drains to the New River between Stones Bay and Intracoastal Waterway. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading periods (1994–2010 [periods E and F]). As presented in **Table 5-7**, all of the ETA-1 MC loading areas drains to the New River between Stones Bay and Intracoastal Waterway. **Figure 5-1** shows surface water features and MC loading area analyzed within the subwatershed of the New River between Stones Bay and Intracoastal Waterway.

Table 6-50 and **Table 6-51** present the estimated annual average edge-of-loading-area concentrations in surface water runoff and sediment from the ETA-1 MC loading area draining within the subwatershed of the New River between Stones Bay and Intracoastal Waterway. Based on the screening-level calculations, the average annual concentrations of RDX, TNT, and perchlorate in runoff at the edge of the ETA-1 MC loading area were predicted to be above REVA trigger values, while the average annual concentration of HMX in runoff at the edge of the ETA-1 MC loading area was predicted to be below the REVA trigger value (**Table 6-50**).

Table 6-50: Surface Water Runoff Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	**27.8**	**29.22**	~0	**0.08**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-51: Sediment Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Sediment within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Sediment (µg/L)	32.5	25	51	0.18
MC Concentration (µg/kg)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	0.63	**44.06**	~0	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual concentration of TNT in sediment at the edge of the ETA-1 MC loading area was predicted to be above the REVA trigger value, while the average annual concentrations of RDX, HMX, and perchlorate in sediment at the edge of the ETA-1 MC loading area were predicted to be below REVA trigger values (**Table 6-51**).

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and in sediment entering the New River between Stones Bay and Intracoastal Waterway, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Stones Bay and Intracoastal Waterway were predicted to be above REVA trigger values. However, the average annual concentrations of HMX and perchlorate in surface water runoff and baseflow entering the New River between Stones Bay and the Intracoastal Waterway were predicted to be below REVA trigger values (**Table 6-52**). Furthermore, all MC concentrations in sediment entering the New River between Stones Bay and the Intracoastal Waterway were predicted to be below REVA trigger values.

Table 6-52: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering the New River between Stones Bay and the Intracoastal Waterway

MC	REVA Trigger Value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.109**
TNT	0.113	**0.115**
HMX	0.114	~0
Perchlorate	0.021	~0

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Although the concentrations of RDX and TNT in surface water runoff and baseflow entering the New River between Stones Bay and Intracoastal Waterway were predicted to exceed REVA trigger values, actual concentrations of these MC are expected to be lower (potentially below detection levels) in this tidally influenced water due to MC decay and tidal mixing that occurs in the water. Surface water sampling was carried out in the New River west of ETA-1 MC loading area in October 2011 to determine the actual MC concentrations in surface water. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.5.3. Groundwater Analysis Results

The ETA-1 MC loading area was assessed for groundwater within the subwatershed of the New River between Stones Bay and the Intracoastal Waterway.

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the MC loading area assessed within the subwatershed of the New River between Stones Bay and Intracoastal Waterway. In doing this, the estimated MC loading rates (**Table 6-47**) were divided by a recharge rate of 1.08 ft/yr estimated for MCB Camp Lejeune (Heath, 1989). **Table 6-53** shows the resulting infiltration MC concentrations at the ETA-1 MC loading area. Concentrations of RDX, TNT, and perchlorate at the ETA-1 MC loading area were estimated to exceed REVA trigger values. For this reason, these MC at the ETA-1 MC loading area were modeled for migration through the vadose zone.

Table 6-53: Estimated Maximum MC Concentrations in Infiltrating Water at the MC Loading Area within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	Time Period		RDX	TNT	HMX	Perchlorate
ETA-1	1994–2004	E	**137.6**	**156.3**	0.010	**0.250**
	2005–2010	F	**91.7**	**104.2**	0.007	**0.170**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for simulation times ranging from 100 to 200 years.

Steady-state conditions for TNT at the ETA-1 MC loading area was reached at 40 years. Steady-state conditions for other MC modeled (RDX and perchlorate) was reached at a maximum time of 6 years. **Table 6-54** shows the maximum MC concentrations reaching the water table at the ETA-1 MC loading area. Due to the MC chemical properties (i.e., low volatility and moderate-to-high solubility) and the VLEACH assumption of no degradation, the steady-state MC concentrations at the water table for the ETA-1 MC loading area were equal to or a little lower than their influent concentrations, which exceed REVA trigger values. For this reason, all MC listed in **Table 6-54** that were modeled for movement through the vadose zone were analyzed further for movement through the surficial aquifer.

Table 6-54: VLEACH Maximum MC Concentrations Reaching the Water Table at the MC Loading Area within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	**91.73**	**139.1**	N/A	**0.17**

Note:
N/A = Not modeled as MC loading rate was negligible or MC was eliminated for further analysis from the initial groundwater screening analysis
Bold indicates concentration exceeds the REVA trigger value.

Potential transport to the Castle Hayne aquifer was assessed for MC loading areas where the MC concentration reaching the water table exceeded the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area (**Figure 4-3**). Within the subwatershed of the New River between Stones Bay and Intracoastal Waterway, the ETA-1 MC loading area satisfied these conditions; therefore, the MC that were predicted to reach the water table above REVA trigger values at the MC loading area were analyzed further for transport to the Castle Hayne aquifer. The methodology used for this analysis is discussed in **Section 5.2.2.3**. The resulting MC concentrations estimated to potentially reach the Castle Hayne aquifer at the ETA-1 MC loading area are presented in **Table 6-55**.

Table 6-55: Estimated MC Concentrations Reaching the Castle Hayne Aquifer at the MC Loading Area within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration Potentially Reaching the Castle Hayne Aquifer (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	**56.6**	**85.8**	N/A	**0.105**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Concentrations of RDX, TNT, and perchlorate were estimated to potentially reach the Castle Hayne aquifer above the REVA trigger value at the ETA-1 MC loading area (**Table 6-55**). As a result, MC that were estimated to reach the Castle Hayne aquifer above REVA trigger values were modeled for movement through the Castle Hayne aquifer to potential drinking water wells.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through 1) the surficial aquifer to potential surface water receptor locations in the major surface water features (the New River) and 2) the Castle Hayne aquifer to potential groundwater receptors (installation drinking water supply wells). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading area and the nearest receptor location (surface water or drinking water well).

Due to the high decay rates of RDX and TNT and the long distances between the loading area and the nearest receptor locations (surface water or drinking water well), these MC were predicted to be below REVA trigger values at the nearest receptor locations from the ETA-1 MC loading area (**Table 6-56** and **Table 6-57**). However, results showed the potential for perchlorate to reach the nearest receptor locations (both surface water and drinking water well) above the REVA trigger value from the ETA-1 MC loading area. The perchlorate concentration estimated to reach the nearest surface water receptor location was used to estimate baseflow contributions of this MC to the surface water receptor location in the surface water screening-level analysis (**Table 6-52**).

Table 6-56: Model-Estimated MC Concentrations Reaching Surface Water Receptor Locations within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW RL (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	~0	~0	N/A	**0.12**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-57: Model-Estimated MC Concentrations Reaching Groundwater Receptors from the MC Loading Area within the Subwatershed of the New River between Stones Bay and the Intracoastal Waterway

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest Drinking Water Well (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
ETA-1	~0	~0	N/A	**0.105**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Groundwater sampling for MC has been conducted regularly by MCB Camp Lejeune in water supply wells, including the well closest to the ETA-1 MC loading area where perchlorate was predicted to reach the closest water supply well at a concentration above the REVA trigger value. The most recent sampling event occurred in March 2011; the sampling results are discussed in **Section 8**.

6.6. The Subwatershed of Stones Creek

The subwatershed of Stones Creek is located on the southwestern part of MCB Camp Lejeune; it is approximately 7,587 acres in size, with approximately one-half the area located outside the MCB Camp Lejeune installation boundary (**Figure 6-8**). The subwatershed area encompasses Stones Creek, its tributary Millstone Creek, and other unnamed short tributary streams of Stones Creek and Millstone Creek. A total of four RTAs and one identified MC loading area are located within the subwatershed.

The following RTAs are partially or fully located within the subwatershed of Stones Creek:

- LA (1438 acres)
- LB (723 acres)
- LD (349 acres)
- LE (818 acres)

RTA LD was reduced in size in 2006 for Marine Corps Special Operations Command. All RTAs have been operational since 1941 and are used for tactical maneuver training. No munitions use was recorded in RFMSS for any of the RTAs in this subwatershed for the years 2004–2010. A brief summary of the MC loading area located within this subwatershed is provided in **Table 6-1**.

Military Munitions

Various high explosive and small arms military munitions are allowed in the RTAs within the subwatershed of Stones Creek to support the various primary uses of the ranges in this area.

6.6.1. Conceptual Site Model

6.6.1.1. Estimated Munitions Constituents Loading

The MC loading area for the subwatershed of Stones Creek is shown in **Figure 6-8**. The delineation of the MC loading area was based primarily upon GIS shapefiles. Although Range L-5 was assessed in the baseline, it was included in an MC loading area with historical ranges; therefore, a direct comparison is not possible. However, it should be noted that loading in the five-year review reflects rates two to four magnitudes of order higher than that determined in the baseline. This could be due partly to the decreased MC loading area size in the five-year review since historical ranges are not included. It also should be noted that the baseline determined no HMX was loaded into the MC loading area, whereas HMX was loaded during the time period 2005–2010. This may reflect a change in use of the range. MC loading estimated for Range L-5 is presented in **Table 6-58**.

Table 6-58: Estimated Annual MC Loading for the Subwatershed of Stones Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
L-5	F (2005–2010)	2005	2010	1.16E-06	5.43E-07	4.50E-12	3.49E-07

Annual lead deposition for the L-5 MC loading area was estimated for this five-year review and is presented in Table 6-59. Approximately 13,700 lb/yr of lead are deposited annually on the L-5 MC loading area.

Table 6-59: Estimated Annual Lead Deposition for the Subwatershed of Stones Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
L-5	3.45E+05	13,662

6.6.1.2. Geography and Topography

The subwatershed of Stones Creek consists of level flat lands and gently rolling terrain. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level in Stones Creek to approximately 94 ft amsl in an upland area at the northeast boundary of the subwatershed. Based on available topographic data, the slope within the subwatershed area ranges from nearly level to approximately 15% on the sides of stream valleys, with the majority of the subwatershed area having an average slope of approximately 5% (MCB Camp Lejeune, 2010a).

6.6.1.3. Surface Water Features

The subwatershed of Stones Creek contains intermittent and perennial streams and tidal creeks. Streams within the subwatershed flow in southeast and northeast directions into the New River at Stones Bay. The major tributary of Stones Creek is Millstone Creek. The subwatershed area has other short unnamed streams. Stones Creek and Millstone Creek originate as perennial streams and widen into tidal creeks in their downstream segments.

The L-5 MC loading area located within the subwatershed drains south into Stones Creek, which drains approximately 500 ft south of the MC loading area.

6.6.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the part of the subwatershed of Stones Creek located within the boundaries of MCB Camp Lejeune include BmB, MaC, Mk, and Ln. These soils are poorly to excessively well drained, and the acidity of the soils ranges from moderately alkaline to very strongly acidic. The organic contents of the soil map units range from 0.5% to 4% (USDA SCS, 1992). The Ln soil map unit can have organic content as high as 4%, whereas the organic content for the other soil map units (BmB, MaC, and Mk) ranges from 0.5% to 1%. The soil map units generally have a low inherent soil erodibility; however, the MaC soil map unit can have close to moderate soil erodibility (a factor as high as 0.32 tons/acre) (USDA SCS, 1992). Almost all of the L-5 MC loading area is unvegetated. Other areas of the subwatershed located within the boundaries of MCB Camp Lejeune are covered predominantly with pine forest, bottomland hardwood forest, and mixed pine and hardwood forest.

6.6.1.5. Erosion Potential

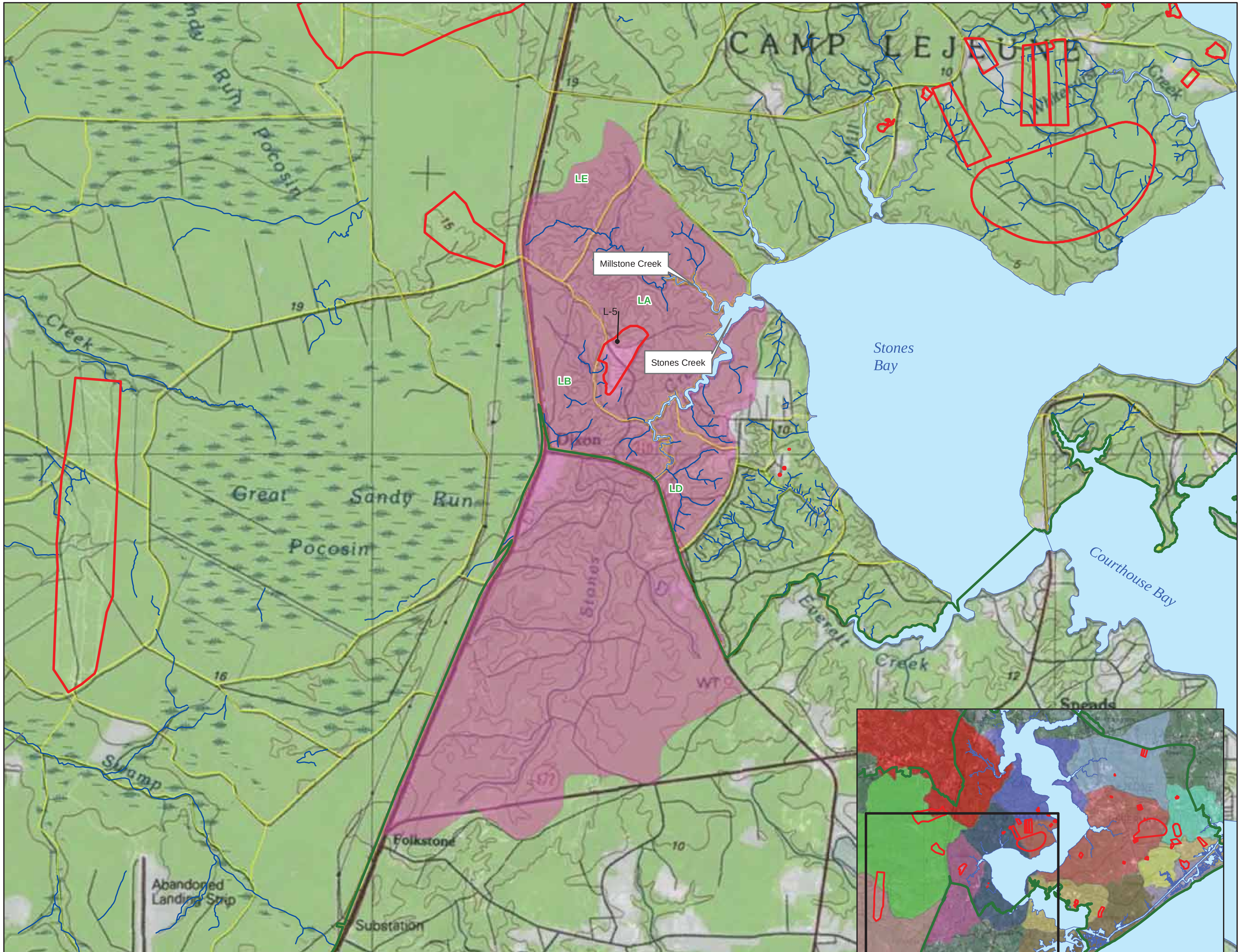
The estimated soil erosion potential of the L-5 MC loading area identified within the subwatershed of Stones Creek is high. The high soil erosion potential is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the area.

6.6.1.6. Groundwater Characteristics

Based on investigations conducted at IR site 69 located near the L-5 MC loading area within the subwatershed of Stones Creek upstream of its confluence with Stones Bay, the surficial aquifer consists of silty sand to a depth of approximately 12 to 15 ft bgs and the horizontal hydraulic conductivity is estimated to be 1.64 ft/d (Baker Environmental, 1996). Thickness of the surficial aquifer within the subwatershed area can range from 0 to 40 ft. The surficial aquifer material near the L-5 MC loading area is underlain by a fairly continuous sandy clay, sand, and clay unit to a depth of approximately 26 to 36 ft bgs (Baker Environmental, 1996). The clay horizons of this unit act as an aquitard. The long-term water level study conducted by USGS at a location close to the L-5 MC loading area has indicated some confinement of the underlying Castle Hayne aquifer (Harden et al., 2004). However, detailed information is insufficient to determine if the confining unit is laterally continuous throughout the subwatershed area. The upper unit of the Castle Hayne aquifer, which is encountered below the clay confining unit, consists

FIGURE 6-8
MC Loading Areas within the Subwatershed of Stones Creek

MCB Camp Lejeune
Jacksonville, NC



Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- Stones Creek

0 1,400 2,800 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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of sitly sand with shell and limestone fragments. The horizontal hydraulic conductivity of the Castle Hayne aquifer is generally higher within the subwatershed area than in areas east of the New River.

Based on measurements obtained from environmental site data near the L-5 MC loading area, the depth to groundwater ranges from approximately 0.34 to 3.3 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be 1.8 ft bgs (Baker Environmental, 1996).

6.6.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of Stones Creek. Runoff coefficient at the L-5 MC loading area was assumed to be 0.65 because the area is largely unvegetated. As indicated in **Section 6.6.1.5**, the MC loading area has high soil erosion potential, making soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain northeast and southeast into Stones Creek and ultimately into the New River, which is a receptor location.

Groundwater Pathways

MC at the L-5 MC loading area within the subwatershed of Stones Creek upstream of its confluence with Stones Bay may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the MC loading area toward Stones Creek and Millstone Creek. Deeper groundwater, in the Castle Hayne aquifer, flows south toward the off-installation drinking water wells (County wells) located just outside the MCB Camp Lejeune boundary but within the subwatershed of Stones Creek (**Figure 4-3**).

As discussed in **Section 6.6.1.6**, there is potentially no continuous presence of the Castle Hayne confining unit within the subwatershed. As a result, a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and transported to the Castle Hayne aquifer near locations of active water supply wells.

6.6.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of Stones Creek upstream of its confluence with Stones Bay supports T/E species (including the red-cockaded woodpecker). In addition, sensitive wetland habitats are present adjacent to Stones Creek and Millstone Creek. Although surface water is not a drinking water source, Stones Bay potentially is used for recreational purposes.

Groundwater Receptors

MC from the L-5 MC loading area located within the subwatershed potentially can migrate to County water supply wells located outside the installation boundary (**Figure 4-3**). In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to the New River at Stones Bay. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.6.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of MC concentrations in surface water and sediment from the L-5 MC loading area, which drains to Stones Creek and ultimately into Stones Bay. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading period (2005–2010 [period F]). As presented in **Table 5-7**, all of the L-5 MC loading area drains to Stones Creek at its confluence with Stones Bay. **Figure 5-1** shows surface water features and the L-5 MC loading area.

Table 6-60 presents the estimated annual average edge-of-loading-area concentrations in surface water runoff from the L-5 MC loading area draining within the subwatershed of Stones Creek upstream of its confluence with Stones Bay. Based on the screening-level calculations, the average annual concentrations of RDX, TNT, and perchlorate in runoff at the edge of the L-5 MC loading area were predicted to be above REVA trigger values, while the average annual concentration of HMX in runoff at the edge of the L-5 MC loading area was predicted to be below the REVA trigger value (**Table 6-60**).

Table 6-60: Surface Water Screening-Level Estimates of Annual Average Edge-of-Loading-Area MC Concentrations in Surface Water Runoff within the subwatershed of Stones Creek

	RDX	TNT	HMX	Perchlorate
REVA Trigger Value for Water (µg/L)	0.110	0.113	0.114	0.021
MC Concentration (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
L-5	**0.55**	**0.21**	~0	**0.21**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

The average annual concentrations of all MC in sediment at the edge of the L-5 MC loading area were predicted to be below REVA trigger values.

Additional analysis was conducted to estimate the annual average MC concentrations in surface water runoff and baseflow entering Stones Creek at its confluence with Stones Bay, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). All MC concentrations in surface water runoff and baseflow entering Stones Creek at its confluence with Stones Bay were predicted to be below REVA trigger values. No additional analysis was conducted for sediment, as all MC concentrations leaving the loading area were estimated to be below REVA trigger values. No surface water or sediment samples were collected from this subwatershed.

6.6.3. Groundwater Analysis Results

The L-5 MC loading area was assessed for groundwater within the subwatershed of Stones Creek.

The initial step of the Part I groundwater screening analysis was used to determine the maximum MC concentrations potentially reaching the groundwater table at the MC loading area assessed within the subwatershed of Stones Creek upstream of its confluence with Stones Bay. In doing this, the estimated MC loading rates (**Table 6-58**) were divided by a recharge rate of 1.08 ft/yr estimated for MCB Camp Lejeune (Heath, 1989). **Table 6-61** shows the resulting infiltration MC concentrations at the L-5 MC loading area. Concentrations of RDX, TNT, and perchlorate at the L-5 MC loading area were estimated to exceed REVA trigger values. For this reason, these MC at the L-5 MC loading area were modeled for migration through the vadose zone.

Table 6-61: Estimated Maximum MC Concentrations in Infiltrating Water at the MC Loading Area within the Subwatershed of Stones Creek

			RDX	TNT	HMX	Perchlorate
REVA Trigger Value (µg/L)			0.110	0.113	0.114	0.021
Estimated Maximum Infiltration Concentration (µg/L)						
MC Loading Area	Time Period		RDX	TNT	HMX	Perchlorate
L-5	2005–2010	F	**3.51**	**1.65**	~0	**1.06**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Vadose zone modeling was performed using VLEACH, a vadose zone leaching model. The screening-level model was conducted using the methodology described in **Section 5.2.2.2**. The flow and transport parameters used in the model also are presented in **Section 5.2.2.2**. The model was run for simulation times ranging from 100 to 200 years.

Steady-state conditions for TNT at the L-5 MC loading area was reached at 41 years. Steady-state conditions for other MC modeled (RDX and perchlorate) was reached at a maximum time of 6 years. **Table 6-62** shows the maximum MC concentrations reaching the water table at the L-5 MC loading area. The steady-state MC concentrations at the water table for the L-5 MC loading area were above REVA trigger values. For this reason, all MC listed in **Table 6-62** that were modeled for movement through the vadose zone were analyzed further for movement through the surficial aquifer.

Table 6-62: VLEACH Maximum MC Concentrations Reaching the Water Table at the MC Loading Area within the Subwatershed of Stones Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
VLEACH Maximum Concentration at Water Table (µg/L)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
L-5	**3.50**	**1.65**	N/A	**1.06**

Note:
N/A = Not modeled as MC loading rate was negligible or MC was eliminated for further analysis from the initial groundwater screening analysis
Bold indicates concentration exceeds the REVA trigger value.

Potential transport to the Castle Hayne aquifer was assessed for MC loading areas where the MC concentration reaching the water table exceeded the REVA trigger value and where a drinking water supply well is located relatively close to the MC loading area (**Figure 4-3**). Within the subwatershed of Stones Creek upstream of its confluence with Stones Bay, the L-5 MC loading area satisfied these conditions; therefore, the MC that were predicted to reach the water table above REVA trigger values at the MC loading area were analyzed further for transport to the Castle Hayne aquifer. The methodology used for this analysis is discussed in **Section 5.2.2.3**. The resulting MC concentrations estimated to potentially reach the Castle Hayne aquifer at the L-5 MC loading area are presented in **Table 6-63**.

Table 6-63: Estimated MC Concentrations Reaching the Castle Hayne Aquifer at the MC Loading Area within the Subwatershed of Stones Creek

REVA Trigger value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration Potentially Reaching the Castle Hayne Aquifer (µg/L)				
MC Loading Area	RDX	TNT	HMX	Perchlorate
L-5	**1.87**	**0.880**	N/A	**0.565**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Concentrations of RDX, TNT, and perchlorate were estimated to potentially reach the Castle Hayne aquifer above the REVA trigger value at the L-5 MC loading area (**Table 6-63**). As a result, MC that were estimated to reach the Castle Hayne aquifer above REVA trigger values were modeled for movement through the Castle Hayne aquifer to potential drinking water wells.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through 1) the surficial aquifer to potential surface water receptor location (Stones Creek) and 2) the Castle Hayne aquifer to potential groundwater receptors (County drinking water supply wells located outside the installation boundary). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading area and the nearest receptor location (surface water or drinking water well).

Due to the high decay rates of RDX and TNT and the long distances between the loading area and the nearest receptor locations (surface water or drinking water well), these MC were predicted to be below REVA trigger values at the nearest receptor locations from the L-5 MC loading area (**Table 6-64** and **Table 6-65**). However, results showed the potential for perchlorate to reach the nearest receptor locations (both surface water and drinking water well) above the REVA trigger value from the L-5 MC loading area (**Table 6-64** and **Table 6-65**). The perchlorate concentration estimated to reach the nearest surface water receptor location was used to estimate baseflow contributions of this MC to the surface water receptor location in the surface water screening-level analysis.

Table 6-64: Model-Estimated MC Concentrations Reaching Surface Water Receptor Location within the Subwatershed of Stones Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest SW RL (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
L-5	~0	~0	N/A	**0.61**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Table 6-65: Model-Estimated MC Concentrations Reaching Groundwater Receptors from the MC Loading Area within the Subwatershed of Stones Creek

REVA Trigger Value (µg/L)	RDX	TNT	HMX	Perchlorate
	0.110	0.113	0.114	0.021
Concentration at Nearest Drinking Water Well (µg/L)				
MC Loading Area	**RDX**	**TNT**	**HMX**	**Perchlorate**
L-5	~0	~0	N/A	**0.431**

Note: **Bold** indicates concentration exceeds the REVA trigger value.

Groundwater sampling was carried out from a monitoring well installed in the Castle Hayne aquifer south of the L-5 MC loading area and approximately 50 ft north of the MCB Camp Lejeune installation boundary (i.e., down gradient of the L-5 MC loading area and up gradient of the County drinking water supply wells). This sampling was carried out in October 2011 as part of the five-year review to determine the actual concentration of MC in the Castle Hayne aquifer down gradient from the L-5 MC loading area. The sampling results are discussed in **Section 8**.

6.7. The Subwatershed of Bear Creek

The subwatershed of Bear Creek is located on the southeastern part of MCB Camp Lejeune. It is approximately 6,886 acres in size, including area outside the MCB Camp Lejeune installation boundary (**Figure 6-9**). The subwatershed area encompasses Bear Creek and its tributary Mill Creek. A total of 5 RTAs and five identified MC loading areas are located within the subwatershed.

The following RTAs are partially or fully located in the subwatershed of Bear Creek:

- FC (1983 acres)
- GB (536 acres)
- GC (623 acres)
- GE (528 acres)
- GI (560 acres)

FC and GI are the only RTAs listed above for which munitions use was recorded in RFMSS. Minimal use included blasting charges and pyrotechnics. More use was recorded for GI than FC, but neither RTA contained significant use. A brief summary of MC loading areas partially or fully within the subwatershed of Bear Creek is provided in **Table 6-1**.

Military Munitions

Various high explosive, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of Bear Creek to support the various primary uses of the ranges in this area. Several ranges fire into the G-10 Impact Area, and the Mobile MOUT, EOD-1, and G-6 are used frequently. Based on data recorded in RFMSS, Range G-7 is not used as frequently as many of the other ranges.

6.7.1. Conceptual Site Model

6.7.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the subwatershed of Bear Creek upstream of its confluence with the Intracoastal Waterway are shown in **Figure 6-9**. Delineations of MC loading areas in this subwatershed were based on GIS shapefiles, fixed targets, and information from installation personnel.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within the MC loading areas over time; the assumptions used to guide the estimates are detailed in **Section 5. Table 6-66** provides the estimated annual MC loading by time period. MC loading was not conducted during the baseline assessment for the Mobile MOUT Complex and EOD-1, so all historical loading was estimated for these ranges in this five-year review. Although loading was estimated for G-6, G-7, and the G-10 Impact Area in the baseline assessment, MC loading areas were delineated differently; therefore, a direct comparison is not possible.

Table 6-66: Estimated Annual MC Loading for the Subwatershed of Bear Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
G-10 Impact	F (2005–2010)	2005	2010	2.40E-05	3.51E-05	3.22E-07	1.74E-08
Mobile MOUT Complex	E (1989–2004)	1994	2004	7.65E-07	2.09E-07	1.04E-09	1.49E-07
	F (2005–2010)	2005	2010	5.10E-07	1.39E-07	6.92E-10	9.94E-08
EOD-1	E (1989–2004)	1994	2004	3.54E-06	9.27E-07	2.07E-08	5.58E-09
	F (2005–2010)	2005	2010	2.36E-06	6.18E-07	1.38E-08	3.72E-09
G-6	F (2005–2010)	2005	2010	1.51E-07	7.26E-08	1.90E-11	3.57E-09
G-7	F (2005–2010)	2005	2010	1.28E-06	1.86E-06	0.00	0.00

Annual lead deposition estimates for the MC loading areas are provided in **Table 6-67**. Of the MC loading areas within this subwatershed, the most lead is deposited in the G-10 Impact Area, with approximately 9,760 lb/yr of lead deposited. The Mobile MOUT Complex, EOD-1, and G-7 receive minimal lead deposition.

Table 6-67: Estimated Annual Lead Deposition for the Subwatershed of Bear Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
G-10 Impact	4.51E+06	9,764
Mobile MOUT Complex	4.49E+04	1.2
EOD-1	8.43E+04	0.09
G-6	2.92E+05	1,942
G-7	2.77E+05	40

6.7.1.2. Geography and Topography

The subwatershed of Bear Creek generally consists of level flat lands. Elevation contour data indicate the elevation of the subwatershed area ranges from 2 ft bmsl in Bear Creek to approximately 54 ft amsl in an upland area at the southwestern bondary of the subwatershed. Based on available topographic data, the slope within the subwatershed area ranges from nearly level to approximately 18% on the sides of stream valleys, with the majority of the subwatershed area having an average slope of approximately 3% (MCB Camp Lejeune, 2010a).

6.7.1.3. Surface Water Features

The subwatershed of Bear Creek contains perennial streams and tidal creeks and small depressions or ponds. Streams within the subwatershed flow in south and southeast directions into the Intracoastal Waterway. The major tributary of Bear Creek is Mill Creek. Bear Creek and Mill Creek originate as perennial streams and widen into tidal creeks in their downstream segments.

Table 6-68 describes the drainage characteristics of the MC loading areas within the subwatershed of Bear Creek.

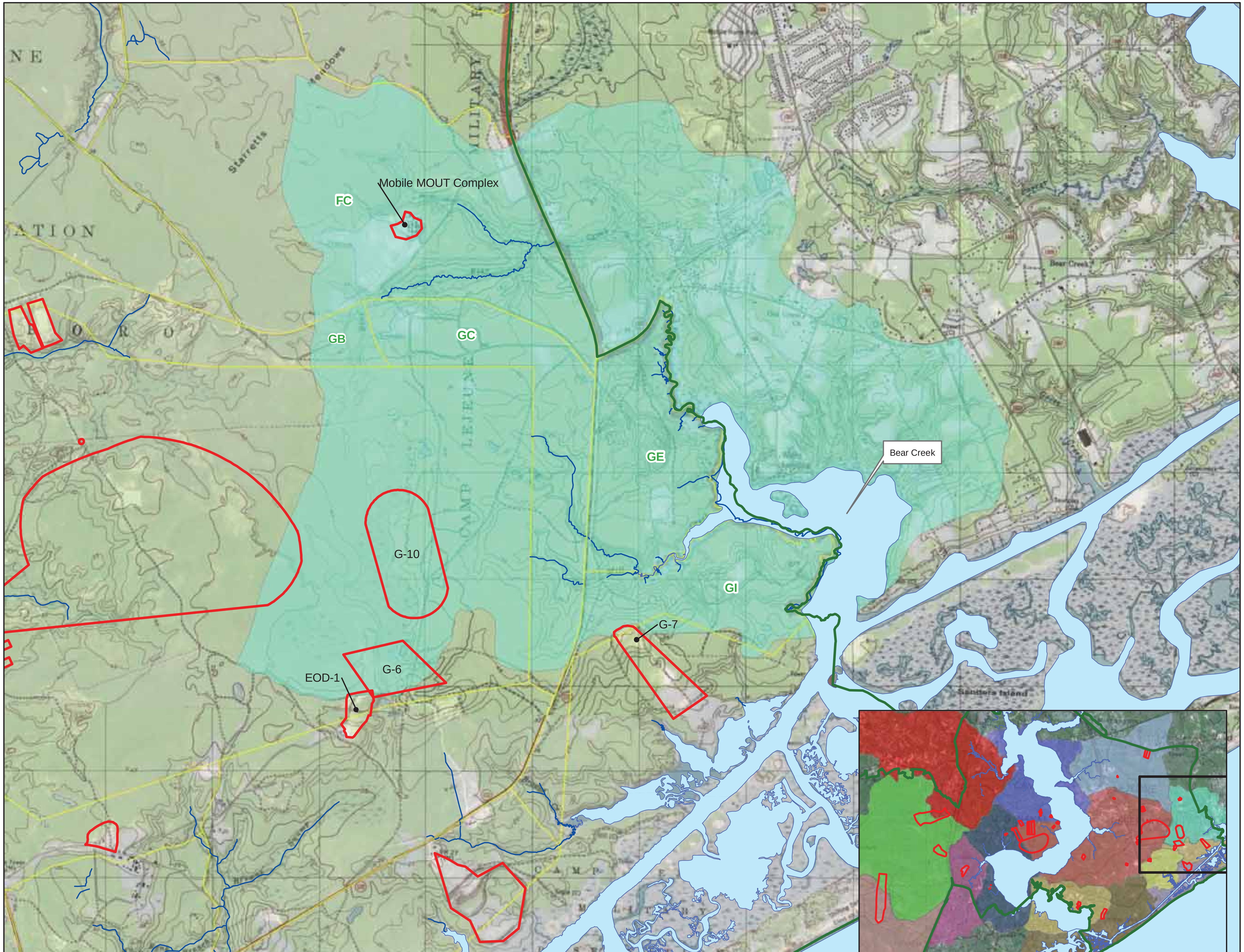

FIGURE 6-9
MC Loading Areas within the Subwatershed of Bear Creek

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- Bear Creek

0 900 1,800 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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Table 6-68: Drainage Description for the MC Loading Areas within the Subwatershed of Bear Creek

MC Loading Area	Drainage Description
G-10 Impact	Approximately 30% of the loading area drains east into Mill Creek, which is located approximately 2,800 ft east of the loading area.
Mobile MOUT Complex	Drains south into Bear Creek, which is located approximately 750 ft south of the loading area.
EOD-1	Approximately 3% of the loading area drains northeast into small depressions or ponds that are located proximal to the loading area. Drainage from this very small area ultimately discharges into Mill Creek, which is located approximately 1.2 miles northeast of the loading area.
G-6	Approximately 90% of the loading area drains to a small depression or pond located within the MC loading area. Drainage from this area ultimately discharges into Mill Creek, which is located approximately 0.9 miles northeast of the loading area.
G-7	Approximately 3% of the loading area drains northeast into Mill Creek, which is located approximately 1,540 ft northeast of the MC loading area.

6.7.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the part of the Bear Creek subwatershed located within the boundaries of MCB Camp Lejeune include Ln, Kureb fine sand (KuB), BmB, On, and WaB. These soils are poorly to excessively well drained, and the acidity of the soils ranges from neutral to very strongly acidic. The organic contents of the soil map units range from 0.5% to 4% (USDA SCS, 1992). The Ln and the On soil map units can have organic content as high as 4% and 2%, respectively. The organic content for the other soil map units (KuB, BmB, and WaB) ranges from 0.5% to 1%. The soil map units generally have a low inherent soil erodibility; however, the On soil map unit can have close to moderate soil erodibility (a factor as high as 0.32 tons/acre) (USDA SCS, 1992). Many of the MC loading areas are sparsely vegetated. Other areas of the subwatershed located within the boundaries of MCB Camp Lejeune are covered predominantly with pine forest and scrub and shrub.

6.7.1.5. Erosion Potential

The estimated soil erosion potential of the MC loading areas identified within the subwatershed of Bear Creek range from low to high. Three of the MC loading areas have high soil erosion potential, while two MC loading areas have low soil erosion potential. The high soil erosion potential estimated at most of the MC loading areas is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. These MC loading areas are sparsely vegetated. The

MC loading areas with low estimated soil erosion potentials generally have high vegetation covers and lower topographic slope.

6.7.1.6. Groundwater Characteristics

Lithologic data obtained by USGS at the G-10 Impact area, which is partially located within the subwatershed of Bear Creek, indicate the presence of silty fine sand, clay, and sandy clay to a depth of 20 ft (Harden et al., 2004). Based on a USGS study at the G-10 Impact area, thickness of the surficial aquifer within the subwatershed can range from 0 to 70 ft (Cardinell et al., 1993). The Castle Hayne confining unit was estimated to be approximately 5 ft thick at the G-10 Impact Area (Harden et al., 2004). However, detailed information is insufficient to determine if the confining unit is laterally continuous throughout the subwatershed area or the impact area. The thickness of the Castle Hayne aquifer at the G-10 Impact Area is estimated to be greater than 400 ft (Cardinell et al., 1993).

Based on measurements obtained from environmental site data near the loading areas within the subwatershed, the depth to groundwater at the MC loading areas within the subwatershed is estimated to range from approximately 1 to 13 ft bgs, and the average depth to groundwater at the MC loading areas is estimated to be 8 ft bgs (Harden et al., 2004).

6.7.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of Bear Creek. Runoff coefficients at MC loading areas were assumed to range from 0.16 at a vegetated area to 0.68 at sparsely vegetated areas. As indicated in **Section 6.7.1.5**, many of the MC loading areas within the subwatershed have high soil erosion potential, making soil erosion an important potential mechanism for MC mobilization into surface water runoff. In addition, MC transported in groundwater also could discharge into surface water because the shallow groundwater is a known source of baseflow to streams. MC in streams would drain southeast into Bear Creek and ultimately into the Intracoastal Waterway, whichis a receptor location.

Groundwater Pathways

MC at the MC loading area within the subwatershed of Bear Creek may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the MC loading area toward Bear Creek, Mill Creek, and the Intracoastal Waterway. Deeper groundwater, in the Castle Hayne aquifer, flows west toward the installation drinking water wells located west of the subwatershed area.

As discussed in **Section 6.7.1.6**, there is potentially no continuous presence of the Castle Hayne confining unit within the subwatershed. As a result, a potential pathway exists for human receptors from MC potentially entering the surficial aquifer and being transported to the Castle Hayne aquifer near locations of active water supply wells.

6.7.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the subwatershed of Bear Creek supports T/E species (including the red-cockaded woodpecker and the rough-leaved loosestrife). In addition, sensitive wetland habitats are present adjacent to Bears Creek. Although surface water is not a drinking water source, Bears Creek and the Intracoastal Waterway potentially are used for recreational purposes.

Groundwater Receptors

MC from MC loading areas within the subwatershed potentially can migrate to installation water supply wells located west of the subwatershed area (**Figure 4-3**). In addition, shallow groundwater from the surficial aquifer discharges into streams and tidal creeks and ultimately to Bear Creek and the Intracoastal Waterway. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.7.2. Surface Water and Sediment Analysis Results

A screening-level analysis was used to obtain conservative estimates of potential MC concentrations in surface water and sediment from the G-10 Impact Area MC loading area, which drains to Mill Creek and ultimately into Bear Creek and the Intracoastal Waterway. The screening-level analyses for surface water and sediment were conducted as described in **Section 5.1.1** and **Section 5.1.2**.

The surface water and sediment screening-level analyses were carried out for time periods matching the estimated MC loading period (2005–2010 [periods F]). As presented in **Table 5-7**, approximately 30% of the G-10 Impact Area MC loading area drains to Bear Creek at its confluence with the Intracoastal Waterway. **Figure 5-1** shows surface water features and the MC loading area analyzed within the subwatershed of Bear Creek upstream of its confluence with the Intracoastal Waterway.

The estimated average annual edge of loading area MC concentrations in surface water runoff and sediment for the G-10 Impact Area MC loading area are presented in **Section 6.1.2** (**Table 6-7** and **Table 6-8**), where the analysis results for the subwatershed of the New River between Town Creek and Stones Bay are presented, as a large portion of the G-10 Impact Area MC loading area drains within that subwatershed.

Additional analyses were conducted to estimate the annual average MC concentrations in surface water runoff and baseflow and in sediment entering Bear Creek at its confluence with the Intracoastal Waterway, the identified downstream receptor location (as described in **Section 5.1.1.2** and **Section 5.1.2**). The average annual concentrations of RDX and TNT in surface water runoff and baseflow entering Bear Creek at its confluence with the Intracoastal Waterway were predicted to be above REVA trigger values (**Table 6-69**). However, the average annual concentrations of HMX and perchlorate in surface water runoff and baseflow entering Bear Creek at its confluence with the Intracoastal Waterway were predicted to be below REVA trigger values (**Table 6-69**). Furthermore, all MC concentrations in sediment entering Bear Creek at its confluence with the Intracoastal Waterway were predicted to be below REVA trigger values.

Table 6-69: Screening-Level Estimates of Annual Average MC Concentrations in Surface Water Runoff and Baseflow Entering Bear Creek at its Confluence with the Intracoastal Waterway

MC	REVA Trigger Value (µg/L)	Down Gradient Concentrations (µg/L)
RDX	0.110	**0.914**
TNT	0.113	**0.711**
HMX	0.114	0.018
Perchlorate	0.021	0.001

__Note:__ **Bold** indicates concentration exceeds the REVA trigger value.

Although the concentration of RDX and TNT in surface water runoff and baseflow entering Bear Creek at its confluence with the Intracoastal Waterway were predicted to exceed REVA trigger values, actual concentrations of these MC are expected to be lower (potentially below detection levels) in this tidally influenced water due to MC decay and tidal mixing that occurs in the water. Surface water sampling was carried out in Mill Creek, the tributary of Bear Creek down gradient of the G-10 Impact Area MC loading area in September and December 2010 as part of the five-year review for MCB Camp Lejeune to determine the actual MC concentrations in surface water. The sampling results are discussed in **Section 8**. No sediment samples were collected from this subwatershed.

6.7.3. Groundwater Analysis Results

The G-10 Impact Area MC loading area was assessed for groundwater within the subwatershed of Bear Creek. The groundwater analysis results for this MC loading area are presented in **Section 6.1.3**, as the MC loading area is partially located in the subwatershed of the New River between Town Creek and Stones Bay. Therefore, with the exception of BIOCHLOR results showing groundwater concentrations potentially reaching surface water receptor locations within the subwatershed of the Bear Creek, no other groundwater results for the G-10 Impact Area MC loading area are presented in this section.

The saturated zone modeling was conducted using BIOCHLOR 2.2 for movement through the surficial aquifer to potential surface water receptor location (Bear Creek). The modeling was conducted as described in **Section 5.2.2.4**. The BIOCHLOR simulation results produced the estimated MC concentration profile along the centerline of flow between the source zone at the MC loading area and the nearest surface water receptor location.

All MC concentrations were predicted to be below REVA trigger values at the nearest surface water receptor location from the G-10 Impact Area MC loading area. Concentrations of RDX, TNT, and HMX were estimated to be nearly zero, and the concentration of perchlorate was estimated to be approximately equal to 0.019 µg/L. The estimated perchlorate concentration was used as the baseflow contribution of this MC to the surface water receptor location in the surface water screening-level analysis.

6.8. The Subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek

The subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek is located on the southeastern part of MCB Camp Lejeune; it is approximately 2,760 acres in size, with all of the area located within the MCB Camp Lejeune installation boundary (**Figure 6-10**). The subwatershed area encompasses part of the Intracoastal Waterway, Banks Channel, and Browns Inlet. A total of 5 RTAs and one identified MC loading area are located within the subwatershed.

The following RTAs are partially or fully located within the subwatershed of Intracoastal Waterway between Gillete Creek and Browns Creek:

- GA (768 acres)
- GD (1102 acres)
- GF (644 acres)
- GG (1413 acres)
- GH (856 acres)

All of these RTAs have been operational since 1941. No munitions use was recorded in RFMSS for RTA GF during 2004–2010, and only minimal use consisting of blasting charges was recorded for the other RTAs. A brief summary of the MC loading area located within this subwatershed is provided in **Table 6-1**.

Military Munitions

Various high explosive, small arms, and practice military munitions are allowed in the RTAs within the G-5 MC loading area to support the various primary uses of the ranges in this area. Data recorded in RFMSS for the years 2004–2010 indicate that G-5 is used but not extensively.

6.8.1. Conceptual Site Model

6.8.1.1. Estimated Munitions Constituents Loading

The G-5 MC loading area is shown in **Figure 6-10**. This MC loading area was delineated based on GIS shapefiles. The MC Loading Rate Calculator was used to estimate the amount of MC deposited within the MC loading area over time. **Table 6-70** provides the estimated annual MC loading by time period. Loading was calculated during the baseline assessment; however, MC loading areas were delineated differently. Therefore, a direct comparison is not possible. The G-5 MC loading area was included as part of the G-10 Impact Area MC loading area in the baseline assessment, and it is broken out for individual assessment during the five-year review.

Table 6-70: Estimated Annual MC Loading for the Subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
G-5	F (2005–2010)	2005	2010	1.01E-08	7.69E-08	2.28E-08	3.11E-11

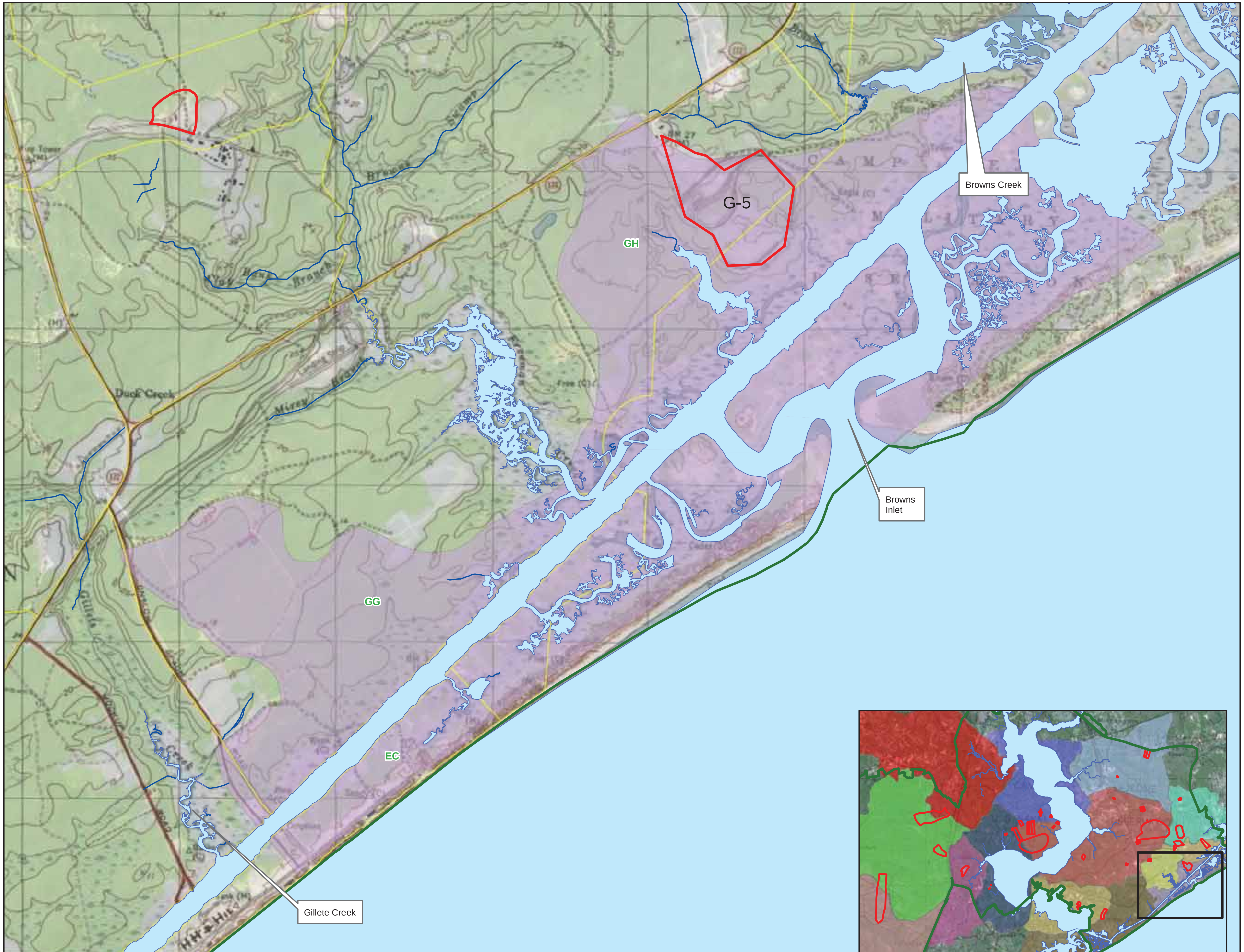
Annual lead deposition was estimated for the G-5 MC loading area and is provided in **Table 6-71**. It is estimated that only 41 lb/yr of lead are deposited on the G-5 MC loading area.

Table 6-71: Estimated Annual Lead Deposition for the Subwatershed of Intracoastal Waterway between Gillette Creek and Browns Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
G-5	4.11E+05	41

FIGURE 6-10
MC Loading Areas within the Subwatershed of Intracoastal Waterway between Gillete Creek and Browns Creek

MCB Camp Lejeune
Jacksonville, NC



Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- Intracoastal Waterway between Gillete Creek and Browns Creek

0 650 1,300 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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6.8.1.2. Geography and Topography

The subwatershed of Intracoastal Waterway between Gillete Creek and Browns Creek generally consists of level flat lands. Available elevation contour data indicate the elevation of the subwatershed area ranges from sea level at the Intracoastal Waterway to approximately 38 ft amsl at the northern boundary of the subwatershed area. Based on available topographic data, the slope within the subwatershed area ranges from nearly level to approximately 6%, with the majority of the subwatershed area having an average slope of less than 3% (MCB Camp Lejeune, 2010a).

6.8.1.3. Surface Water Features

The subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek does not contain perennial streams but contains tidal creeks that flow through riparian wetland areas to the Intracoastal Waterway and Banks Channel. Tidal creeks within the subwatershed flow in south and southeast directions into the Intracoastal Waterway. A small portion of the downstream segment of Freeman Creek, a major tributary of the Intracoastal Waterway, is located within the subwatershed.

Approximately 97% of the G-5 MC loading area located within the subwatershed drains south into an unnamed tidal creek that drains approximately 430 ft southwest of the MC loading area into the Intracoastal Waterway.

6.8.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek include Bohicket silty clay loam (Bo), WaB, and Pactolus fine sand (Pa). These soils are poorly to excessively well drained, and the acidity of the soils ranges from moderately alkaline to very strongly acidic. The organic contents of the soil map units range from 0.5% to 25% (USDA SCS, 1992). The Bo soil map unit has an organic content of 5% to 25%, the Pa soil map unit has an organic content of 0.5% to 2%, and the WaB soil map unit has an organic soil map unit of less than 1%. The soil map units have low inherent soil erodibility, with a soil erodibility factor ranging from 0.1 tons/acre to 0.28 tons/acre (USDA SCS, 1992). The G-5 MC loading area has some unvegetated areas. Other areas are covered predominantly with marshland, and some areas include forest plantations that have existed for less than 10 years.

6.8.1.5. Erosion Potential

The estimated soil erosion potential at the G-5 MC loading area is low due to the high vegetation cover and low topographic slope of the area.

6.8.1.6. Groundwater Characteristics

There are no environmental site data within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek that provide site-specific geologic and hydrogeologic information. However, based on the site investigation data presented for the closest IR site (IR site 12), the site geology and aquifer characteristics of the subwatershed area should be similar to the information presented in **Section 6.7.1.6**.

Based on measurements obtained from environmental site data closest to the G-5 MC loading area, the depth to groundwater at the MC loading areas is estimated to be approximately 4 ft bgs (CH2M Hill et al., 2001).

6.8.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek. Runoff coefficient at the G-5 MC loading area was assumed to be 0.2 due to the large vegetation cover, low slope, and a soil type with low runoff potential. As indicated in **Section 6.8.1.5**, the G-5 MC loading area within the subwatershed has low soil erosion potential, indicating that soil and sediment erosion may not be a significant pathway of MC into surface water runoff. MC transported in groundwater could discharge into surface water because the shallow groundwater is a known source of baseflow to surface water features. MC in a tidal creek would drain south into the Intracoastal Waterway, which is a receptor location.

Groundwater Pathways

MC at the G-5 MC loading area within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the MC loading area toward the unnamed tidal creek and the Intracoastal Waterway. Deeper groundwater, in the Castle Hayne aquifer, flows west toward the installation drinking water wells located west of the subwatershed area.

6.8.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within and downstream of the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek supports T/E species (including the green sea turtle, the loggerhead sea turtle, the leatherback sea turtle, the seabeach amaranth, and the piping plover). In addition, sensitive wetland habitats are present throughout the subwatershed. Although surface water is not a drinking water source, the Intracoastal

Waterway and the downstream Onslow Bay are used for recreational purposes. The Intracoastal Waterway is a toll-free boating channel. Recreational activities permitted in Onslow Bay include game and sport fishing, diving, sailing, and other recreational boating activities.

Groundwater Receptors

MC from the MC loading area within the subwatershed potentially can migrate to installation water supply wells located west of the subwatershed area; however, the significant distance between the loading area and drinking water wells reduces the potential MC impact on the wells (**Figure 4-3**). Shallow groundwater from the surficial aquifer discharges into the unnamed tidal creek and ultimately to the Intracoastal Waterway. Potential receptors in these surface waters include sensitive wetland habitats, T/E species, and humans (exposure by recreational use of the waters).

6.8.2. Surface Water and Sediment Analyses Results

Quantitative surface water and sediment screening-level analyses were not conducted for the G-5 MC loading area. This is because the MC loading area has a low MC loading rate, and MC from the loading area directly discharge into a tidal creek that undergoes tidal mixing that is expected to provide significant dilution of MC in the water. Very little MC are expected to be transported with sediment due to the overall low sediment erosion potential at the G-5 MC loading area. Therefore, based on these assessments, the G-5 MC loading area within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek is not considered an area of concern for MC migration in surface water and sediment, and no further analysis was warranted at this time. No surface water or sediment samples were collected from this subwatershed.

6.8.3. Groundwater Analysis Results

A quantitative groundwater screening analysis was not conducted for the G-5 MC loading area located within the subwatershed of the Intracoastal Waterway between Gillete Creek and Browns Creek. This is because MC loading rates at the G-5 MC loading area are low and there is significant distance between the loading area and the nearest drinking water well, indicating minimal MC impact to groundwater receptors. MC in the shallow groundwater discharge into a tidal environment where tidal mixing significantly reduces concentrations. Therefore, the G-5 MC loading area within the subwatershed of Intracoastal Waterway between Gillete Creek and Browns Creek is not considered an area of concern for MC migration in groundwater, and no further analysis was warranted at this time.

6.9. The subwatershed of Shelter Swamp Creek

The subwatershed of Shelter Swamp Creek is located on the western part of MCB Camp Lejeune, within the GSRA area of MCB Camp Lejeune. It is approximately 31,746 acres in size, with a large part of the area located within the MCB Camp Lejeune installation boundary (**Figure 6-11**). The subwatershed area encompasses Shelter Swamp Creek, an unnamed tributary, and the Great Sandy Run Pocosin. A total of 17 RTAs and three identified MC loading areas are located within the subwatershed.

The following RTAs are partially or fully located within the subwatershed of Shelter Swamp Creek:

- LE (818 acres)
- ME (1727 acres)
- SA through SP (total of 32516 acres)

RTAs LE and ME became operational in 1941, while SA through SP became operational in 1992 after acquisition of the GSRA. No munitions use was recorded in RFMSS for any of the RTAs from 2004–2010. A brief summary of MC loading areas partially or fully located in the subwatershed of Shelter Swamp Creek is provided in **Table 6-1**.

Military Munitions

Various high explosive, small arms, and practice military munitions are allowed in the RTAs within the subwatershed of Shelter Swamp Creek to support the various primary uses of the ranges in this area. These ranges are heavily used; however, RFMSS data from 2004 through 2010 show that much of the use is small arms ammunition.

6.9.1. Conceptual Site Model

6.9.1.1. Estimated Munitions Constituents Loading

The MC loading areas within the subwatershed of Shelter Swamp Creek are shown in **Figure 6-11**. The delineation of the areas was based on GIS shapefiles and the locations of fixed targets.

The MC Loading Rate Calculator was used to estimate the amount of MC deposited within the MC loading areas over time; the assumptions used to guide the estimates are detailed in **Section 5**. **Table 6-72** provides the estimated annual MC loading by time period. MC loading was not calculated for these MC loading areas during the baseline assessment; therefore, all historical loading was estimated during the five-year review.

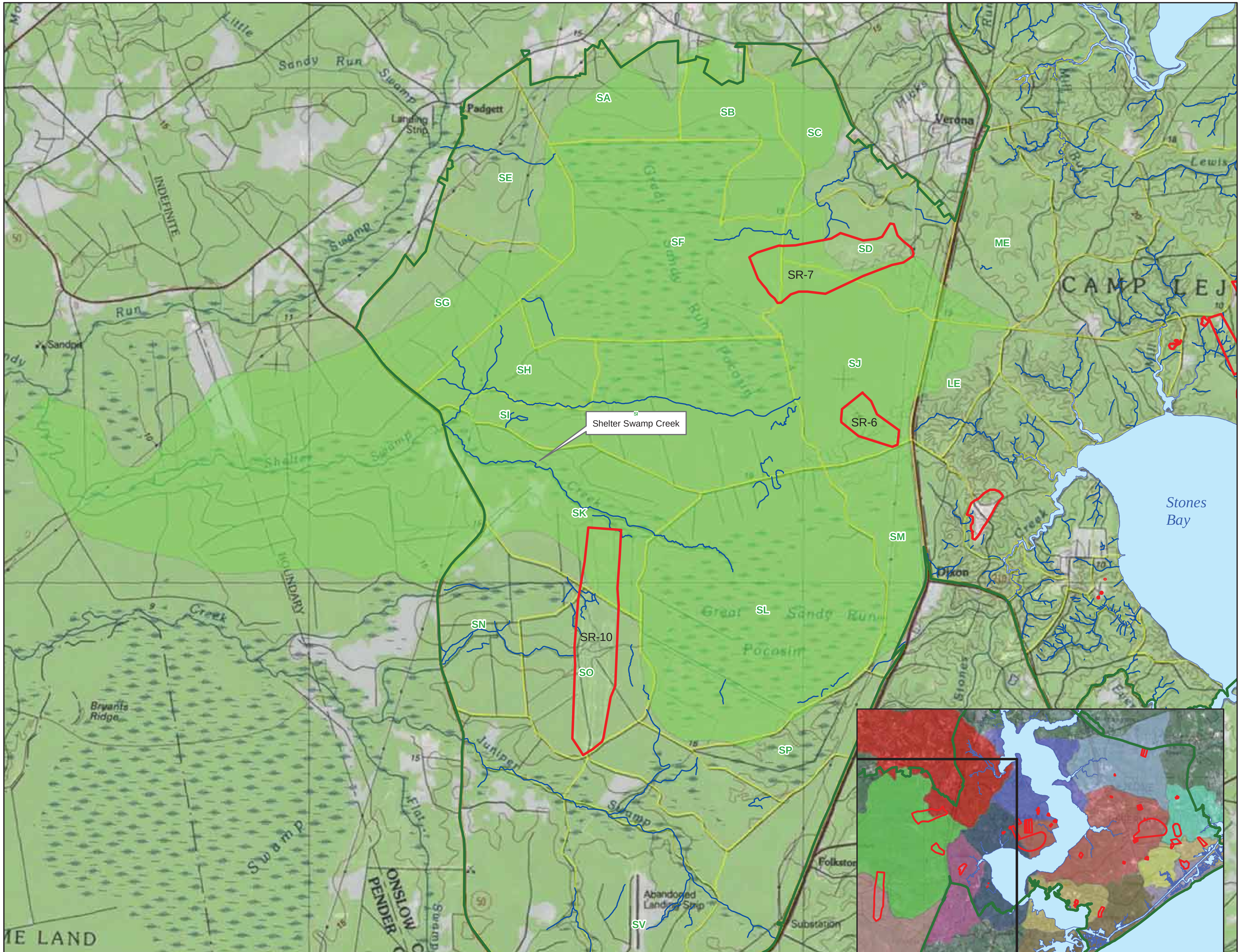

FIGURE 6-11
MC Loading Areas within the Subwatershed of Shelter Swamp Creek

MCB Camp Lejeune
Jacksonville, NC

Legend

- Installation Boundary
- MC Loading Area
- AA Training Area
- Stream
- Surface Water Body

Subwatershed Area

- Shelter Swamp Creek

0 2,050 4,100 Meters

Coordinate System: UTM
Zone: 18N
Datum: NAD83
Units: Meters

Date: April 2012

Source: Aerial - ESRI
MCB/NREA GIS Office 2005/2010

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Table 6-72. Estimated Annual MC Loading for the Subwatershed of Shelter Swamp Creek

MC Loading Area	Period	Begin Use	End Use	RDX (kg/m^2)	TNT (kg/m^2)	HMX (kg/m^2)	Perchlorate (kg/m^2)
SR-6	E (1989–2004)	1995	2004	6.07E-09	4.04E-10	2.57E-12	6.53E-08
	F (2005–2010)	2005	2010	4.04E-09	2.69E-10	1.71E-12	4.35E-08
SR-7	E (1989–2004)	1997	2004	1.55E-07	1.48E-07	7.52E-11	3.28E-08
	F (2005–2010)	2005	2010	1.03E-07	9.85E-08	5.01E-11	2.19E-08
SR-10	E (1989–2004)	1997	2004	6.84E-09	2.79E-09	2.89E-11	7.38E-09
	F (2005–2010)	2005	2010	4.56E-09	1.86E-09	1.92E-11	4.29E-09

Annual lead deposition estimates for the MC loading areas are provided in Table 6-73. Lead deposition at the three MC loading areas located in GSRA is similar, ranging from 8,030 lb/yr of lead deposited on the SR-6 MC loading area to 12,500 lb/yr of lead at the SR-7 MC loading area.

Table 6-73: Estimated Annual Lead Deposition for the Subwatershed of Shelter Swamp Creek

MC Loading Area	Size (m^2)	Lead (lb/yr)
SR-6	6.80E+05	8,032
SR-7	2.73E+06	12,529
SR-10	3.36E+06	10,252

6.9.1.2. Geography and Topography

The subwatershed of Shelter Swamp Creek consists of flat lands with very little topographic relief. Available elevation contour data indicate the elevation of the subwatershed area ranges from approximately 30 ft amsl on the western part of the subwatershed to approximately 84 ft amsl on the eastern part of the subwatershed. Based on available topographic data, the slope of the subwatershed area located within the installation boundary ranges from nearly level to approximately less than 4% (MCB Camp Lejeune, 2010a).

6.9.1.3. Surface Water Features

The subwatershed of Shelter Swamp Creek contains perennial streams and a tidal creek. Riparian wetlands fringe much of the streams and tidal creek. Shelter Swamp Creek flows west off the installation boundary into Holly Shelter Creek and ultimately into Northeast Cape Fear River (NAVFAC, 1997).

Table 6-74 describes the drainage characteristics of the MC loading areas within the subwatershed of Shelter Swamp Creek.

Table 6-74: Drainage Description for the MC Loading Areas within the Subwatershed of Shelter Swamp Creek

MC Loading Area	Drainage Description
SR-6	Drains west into the tributary of Shelter Swamp Creek, which drains approximately 3,000 ft west of the MC loading area.
SR-7	Approximately 60% of the loading area drains northwest into a short unnamed stream that drains into the Great Sandy Run Pocosin. Drainage from the Great Sandy Run Pocosin connects with Shelter Swamp Creek.
SR-10	Approximately 40% of the loading area drains north into Shelter Swamp Creek, which drains approximately 1,080 ft north of the loading area.

6.9.1.4. Soil Characteristics and Land Cover

The predominant soil map units within the subwatershed of Shelter Swamp Creek include Croatan muck (Ct), Torhunta fine sandy loam (To), Murville fine sand (Mu), Ln, and Woodington loamy fine sand (Wo). These soils are very poorly to poorly drained, and the acidity of the soils ranges from slightly acidic to very strongly acidic. The organic contents of the soil map units range from 0.5% to 60%. The Ct soil map unit has the highest organic content (25% to 60%), followed by the To (3% to 10%), the Mu (2% to 9%), the Wo (2% to 4%), and finally the Ln (0.5% to 4%). The soil map units have low inherent soil erodibility, with their soil erodibility factor ranging from 0.1 to 0.2 tons/acre (USDA SCS, 1992). MC loading areas within the subwatershed either are sparsely vegetated or have some unvegetated areas. Other areas of the subwatershed within the boundaries of MCB Camp Lejeune are covered predominantly with pine forest, bottomland and upland hardwood forest, and mixed pine and hardwood forest.

6.9.1.5. Erosion Potential

The estimated soil erosion potential at the MC loading areas identified within the subwatershed of Shelter Swamp Creek ranges from medium to high. The SR-7 and the SR-10 MC loading areas have medium soil erosion potential, while the SR-6 MC loading area has high soil erosion potential. The high and medium soil erosion potential estimated at the MC loading areas is a result of high rainfall, poor vegetation cover, and soil/sediment disturbance from range activities and maintenance within the areas. The SR-6 MC loading area is sparsely vegetated, while the SR-7 and the SR-10 MC loading areas are partially unvegetated.

6.9.1.6. Groundwater Characteristics

There are no environmental site data within the subwatershed of Shelter Swamp Creek or the GSRA area of MCB Camp Lejeune that provide site-specific geologic and hydrogeologic information. However, the major aquifers underlying this area are expected to be similar to what is discussed in **Section 4**. The surficial aquifer is most likely composed mainly of fine sand with silt (Baker Environmental, 1998). In the vicinity of the subwatershed area, the Castle Hayne aquifer is encountered at a depth of approximately 75 ft bgs, and the thickness of the aquifer is approximated to be 100 ft. The aquifer contains beds of fossilized shell or shell marl; due to the calcareous nature of this material, water from the aquifer is hard and contains a high amount of dissolved minerals (NAVFAC, 1997).

6.9.1.7. Potential Surface Water and Groundwater Pathways

Surface Water Pathways

Surface water runoff and sediment are important potential transport pathways of MC to streams and tidal creeks within the subwatershed of Shelter Swamp Creek. Runoff coefficient at MC loading areas within the subwatershed was assumed to range from 0.26 at the area with a larger vegetation cover to 0.69 at the area with sparse vegetation cover. As indicated in **Section 6.9.1.5**, MC loading areas within the subwatershed have high and medium soil erosion potential, making soil erosion an important potential mechanism for MC mobilization into surface water runoff. MC transported in groundwater could discharge into surface water because the shallow groundwater is a known source of baseflow to surface water features. MC in streams and tidal creek drain west into Shelter Swamp Creek and ultimately off the installation boundary into Holly Shelter Creek. Shelter Swamp Creek is a receptor location.

Groundwater Pathways

MC at MC loading areas within the subwatershed of Shelter Swamp Creek may migrate to the surficial aquifer via infiltration of rainwater. The potential shallow groundwater pathway is from the MC loading area toward Shelter Swamp Creek and its tributary. Deeper groundwater, in the Castle Hayne aquifer, flows northeast from the SR-7 MC loading area, south from the SR-6 MC loading area, and east from the SR-10 MC loading area (**Figure 4-3**).

6.9.1.8. Potential Surface Water and Groundwater Receptors

Surface Water Receptors

Surface water within the Shelter Swamp Creek subwatershed supports T/E species (including the red-cockaded woodpecker and the rough-leaved loosestrife). In addition, sensitive wetland habitats are present throughout the subwatershed. There is no information that suggests Shelter Swamp Creek is used for recreational purposes.

Groundwater Receptors

MC from MC loading areas within the subwatershed potentially can migrate to installation water supply wells located on the northeast part of MCB Camp Lejeune and off-installation water supply wells (County wells) located south of MCB Camp Lejeune; however, the significant distances between the loading areas and the water supply wells (approximately ranging from 2.6 to 3.6 miles) will reduce the potential MC impact on the wells (**Figure 4-3**). Shallow groundwater from the surficial aquifer discharges into Shelter Swamp Creek and its tributary. Potential receptors in these surface waters include sensitive wetland habitats and T/E species.

6.9.2. Surface Water and Sediment Analyses Results

Quantitative surface water and sediment screening-level analyses were not conducted for the MC loading areas located within the subwatershed of Shelter Swamp Creek because the estimated loading rates at the loading areas are low. These low MC loading rate values are expected to cause minimal impact to the potential ecological receptors of the water (the red-cockaded woodpecker and the rough-leaved loosestrife). Therefore, the MC loading areas within the subwatershed of Shelter Swamp Creek are not considered areas of concern for MC migration in surface water and sediment, and no further analysis was warranted at this time. No surface water or sediment samples were collected from this subwatershed.

6.9.3. Groundwater Analysis Results

A quantitative groundwater screening analysis was not conducted for the MC loading areas located within the subwatershed of Shelter Swamp Creek. This is because MC loading rates at the MC loading areas are low and there are significant distances between MC loading areas and drinking water wells, indicating minimal MC impact to groundwater receptors. MC in the shallow groundwater discharge into surface water where the low MC loading rates are expected to have minimal impact on the potential ecological receptors of the water. Therefore, MC loading areas within the subwatershed of Shelter Swamp Creek are not considered areas of concern for MC migration in groundwater, and no further analysis was warranted at this time.

7. Small Arms Range Assessments

The REVA indicator MC for SARs is lead because it is the most prevalent (by weight) potentially hazardous constituent associated with small arms ammunition. As described in previous sections, fate and transport parameters for lead at SARs are dependent on site-specific geochemical properties, which cannot be determined solely by physical observation. Therefore, ranges that solely use small arms ammunition (defined as nonexplosive ammunition, .50 cal or smaller) for training purposes are qualitatively assessed under the REVA program. Ranges that perform joint small arms and live-fire training with HE munitions are not assessed through this process; rather, they are assessed through the MC loading estimation and modeling processes previously described. Only operational SARs are addressed in this protocol; historical use SARs that are no longer used are not assessed due to lack of information to adequately perform an assessment.

The SARAP was developed as a qualitative approach to identify and assess factors that influence the potential for lead to migrate from an operational range. These factors include the following:

- Range design and layout, including any best management practices
- Physical and chemical characteristics of the area
- Past and present operation and maintenance practices

In addition, potential receptors and pathways are identified relative to the SAR being assessed. The potential for an identified receptor to be impacted by MC migration through an identified pathway is evaluated.

7.1. Summary of the Small Arms Range Assessment Protocol

The SARAP produces two scores: the sum of surface water elements and the sum of groundwater elements. These determine the overall environmental concern evaluation ratings for surface water and groundwater conditions. The scoring system assigns minimal, moderate, and high values for each environmental concern category:

- Minimal (0 to 29 points) – The SAR has minimal or no potential for lead migration, indicating minimal threat of environmental concern, but actions may be considered to maintain a minimal rating.

- Moderate (30 to 49 points) – The SAR may have the potential for lead migration, most likely indicating that there is no immediate environmental concern, but actions may be necessary to prevent a greater or future concern.
- High (50 to 65 points) – The SAR most likely has the potential for lead migration, creating the greatest level of environmental concern and requiring the recommendation of additional action(s).

Additional documentation describing the purpose, requirements, and supporting drivers for the performance of the SAR assessment is provided with the range-specific assessments in **Appendix A**, which contains the assessments of the operational SARs at MCB Camp Lejeune. Where warranted, key range-specific considerations not captured by the SARAP were taken into account during the assessments, and ratings were modified accordingly.

The locations of the SARs are shown in **Figure 3-2**. **Table 7-1** provides the results ofthe assessment completed for each range. Although a total of 44 SARs were identified at MCB Camp Lejeune, 5 of these contained no expenditure data and 2 are contained indoors; therefore, these 7 SARs were not evaluated. The remaining 37 SARs were evaluated, but only 27 SARAPs were completed; some of the SARs with similar characteristics in proximity to one another were grouped for the assessment. These results are discussed in the following sections.

Table 7-1: Summary of SAR Prioritizations

Range Name	Range Type	Surface Water Environmental Concern	Groundwater Environmental Concern
A-1	Pistol qualification range	Minimal	Minimal*
B-12	Pistol qualification range	Moderate	Moderate
D-29A and D-29B	Pistol qualification range	Minimal	Minimal*
D-30	Pistol qualification range	Moderate	Minimal*
F-4	Rifle familiarization range	Minimal*	Moderate*
F-11A and F-11B	Rifle BZO/pistol range	Minimal	Moderate
F-18	Machine gun field firing range	Moderate	Moderate
I-1	Small arms qualification range	Moderate	Moderate
K-302	BZO and machine gun 10-meter qualification range	Moderate	Moderate
K-309	Machine gun zeroing and live fire qualification range	Moderate	Moderate
K-315	Infantry familiarization firing range	Moderate	Moderate

Range Name	Range Type	Surface Water Environmental Concern	Groundwater Environmental Concern
K-317	Close combat pistol/rifle and EMP range	Moderate	Moderate
K-319	Fire and movement range	Moderate	Moderate
K-321 and K-321A	Squad automatic weapon and transition range	Moderate	Moderate
K-325	EMP range	Moderate	Moderate
K-402	Individual tactic training range	Moderate	Moderate
K-406A and K-406 B	Basic room clearing range, close combat/EMP range	Moderate	Moderate
MAC-1,2,3,5,6	MOUT Assault Courses	Moderate	Moderate
Alpha, Bravo, Charlie Ranges	Rifle marksmanship range	Moderate	High
Dodge City	Urban sniper training	Moderate	Moderate*
Hathcock Range	Sniper training	Moderate	Moderate
Mechanical Pistol	Pistol marksmanship range	Minimal	Moderate
Multi-Purpose	Rifle marksmanship, special operations rifle, pistol, and shotgun training	Minimal	Moderate
Walk-Down Pistol	Pistol marksmanship range	Minimal	Moderate
Square Bay	Live-fire pistol/rifle range	Moderate	Moderate
SR-8	Multi-purpose machine gun qualification firing range	Moderate*	Moderate
SR-11	Pistol qualification range	Minimal	Moderate

* Rating was modified based on professional judgment and consideration of additional range-specific factors.

Four SARs were evaluated in the five-year review that were not evaluated in the baseline assessment: MAC-6, Square Bay, SR-8, and SR-11. Ten ranges were evaluated as part of the K-2 Impact Area in the baseline assessment that were determined to be SARs in the five-year review (K-302, K-309, K-317, K-319, K-321, K-321A, K-325, K-402, K-406A, and K-406B). All 14 ranges were evaluated with the SARAP for this five-year review.

Range Control oversees the scheduling and administration of the SARs present at MCB Camp Lejeune. As discussed in **Section 3.2**, estimation of average annual lead loading at each SAR was based upon 6 years of expenditure data (FY05 to FY10); key assumptions are discussed in that section. All historical loading was estimated for the four SARs that were not evaluated in the baseline assessment.

7.2. Small Arms Ranges

SARs are located throughout MCB Camp Lejeune, as seen in **Figure 3-2**. For many of the SARs, the general information used to document soil characteristics, groundwater characteristics, fate and transport pathways, potential receptors, and T/E species are the same. Information applicable across the installation is further detailed in **Section 4.3**. Site-specific information regarding the soils at the different SARs was not available, but soils at MCB Camp Lejeune are composed primarily of sand and loam with low organic content (≤2%) and highly variable drainage characteristics. The low-lying pocosin areas contain poorly drained, mucky soils with very high organic content (25% to 60%). The topography at MCB Camp Lejeune consists of flat terraces underlain by unconsolidated sediments. Although most of the installation is relatively flat with slopes of less than 2%, steeper topography with slopes of 2% to 15% are present in some areas. Soil erodibility factors of the predominant soil series at MCB Camp Lejeune are low to moderate, with an estimated range of 0.1 to 0.3 tons/acre (USDA SCS, 1992). Vegetative cover at the SARs consists primarily of grasses, while the undeveloped parts of the installation are highly vegetated with forests. Groundwater typically contains a pH of 5.5–6.5 and is approximately 10–20 ft bgs and increasingly shallow closer to the surface water bodies. Surface water pH is typically in the range of 7.5–8.0. This information was used to complete the SARAPs for most of the SARs, except where site-specific information was available and differed. Additional site-specific data used to complete the qualitative evaluations of the SARs are provided in the site-specific SARAPs in **Appendix A**.

Surface water and groundwater receptors for the installation are discussed in **Section 4**. Surface waters around MCB Camp Lejeune are used for human recreation and fishing, and groundwater from the Castle Hayne aquifer is a drinking water source. Although there are no known current shallow groundwater users at MCB Camp Lejeune, the surficial aquifer is the principle source of recharge to the underlying Castle Hayne aquifer due to its semiconfined nature. In some locations, the confining unit is very limited to absent, providing a direct connection to the surficial aquifer.

A total of 37 SARs were evaluated as part of the five-year review, but some were grouped based on proximity and similar use and characteristics, resulting in a total of 28 assessments. Descriptions of each of the ranges follow, and ranges are grouped in the same manner in which they were assessed.

7.2.1. A-1

Range A-1 is a pistol qualification range located east of MCAS New River in the northern part of the installation. It has been operational since 1958 but currently is not heavily used. Approximately 2,042 lb/yr of lead were used at Range A-1 for the time period from 2005 through 2010 based on expenditure data. The range has 10 firing lanes, 14 targets, a horseshoe-shaped berm, and a steel bullet trap that was installed in 1999. It is fully baffled (walls and ceiling) and designed to prevent rounds from escaping under normal firing situations. The SDZ for Range A-1 extends over the New River.

Range Operations inspects and files an inspection report following each use of the range. In addition, it is Marine Corps policy to pick up any brass on the ground after a firing session. A contractor performs monthly inspections and quarterly maintenance and cleaning, including replacement of the high efficiency particulate air filter. The range is flat with very little vegetation but is surrounded by wooded area and is located adjacent to the New River.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for impacts to surface water and groundwater receptors. This range was assessed in the baseline assessment, and results indicated that MC loading at Range A-1 had moderate potential to impact surface water and groundwater; however, the potential impacts were likely to be reduced by the lead containment in the bullet traps and regular inspection and maintenance.

The decreased concern rating in the five-year review for both surface water and groundwater was due primarily to the rating for sensitive species habitat and threatened and endangered species. In the baseline, this criteria was given the highest score (most concern) for both surface water and groundwater based only on the location in a coastal environment. A more specific analysis was completed in the five-year review, and because of the range's location on the edge of the New River, it was assumed that runoff and groundwater discharge directly into the New River where mixing would dilute any concentrations, thus presenting little or no concern to species and/or habitat. Professional judgment was used to decrease the groundwater score from moderate to minimal in the five-year review based on the proximity of the range to the New River, where it is assumed that both surface water and groundwater quickly discharge.

7.2.2. B-12

Range B-12 is a pistol qualification range located at MCAS New River that has been operational since 1970 and is still in use today. It is 25 meters (m) long and consists of three firing lines, 10 targets, a horseshoe-shaped berm, and a steel bullet trap. A baffle with a metal bullet trap was added in 1985. This is currently a wooden baffle, but MCB

Camp Lejeune has plans to replace the wooden baffle with 2-inch steel plates with rubber. The bullet trap is inspected monthly and maintained and cleaned quarterly.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for impacts to surface water and groundwater receptors. Range B-12 was assessed in the baseline assessment, which also concluded that MC loading at Range B-12 had moderate potential to impact surface water and groundwater. However, the potential impacts are likely reduced by the lead containment of the bullet traps and regular inspection and maintenance.

7.2.3. D-29A and D-29B

Because of proximity and similar use, Ranges D-29A and D-29B were assessed together. These are pistol qualification ranges located in the MCB Camp Lejeune main cantonment area on the eastern bank of the New River. They have been used since 1958. The two ranges are adjacent to each other and consist of 34 firing lanes (17 at each range) and 28 pistol targets (14 at each range). The SDZ for each range extends over the New River. Ranges D-29A and D-29B each contain an earthen berm and a steel bullet trap with a vacuum to remove lead dust. The bullet traps were installed in June 1999. The bullet traps are inspected monthly and maintained and cleaned quarterly.

These ranges were rated using the SARAP during the five-year review and determined that there was a minimal concern for impacts to surface water and groundwater receptors. They were assessed in the baseline assessment, which concluded that MC loading at Ranges D-29A and D-29B had moderate potential to impact surface water and groundwater. However, the potential impacts are likely to be reduced by the lead containment of the bullet traps and regular inspection and maintenance.

7.2.4. D-30

Range D-30 is a pistol qualification range located in the MCB Camp Lejeune main cantonment area. It was first used in 1958 and is still in use today. The range consists of 32 firing lanes, 32 targets, and an earthen impact berm.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for impacts to surface water and groundwater receptors; however, because shallow groundwater quickly discharges to the New River and there are no groundwater receptors, the groundwater concern was decreased to minimal. This range was assessed in the baseline assessment, which concluded that MC loading at Range D-30 had moderate potential to impact surface water and a high potential to impact groundwater.

The decreased concern rating in the five-year review for both surface water and groundwater was due primarily to the ratings for sensitive species habitat and threatened and endangered species. In the baseline, this criteria was given the highest score (most concern) for both surface water and groundwater based only on the location in a coastal environment. A more detailed analysis was completed in the five-year review, and because of the range's location on the edge of the New River, it was assumed that runoff and groundwater discharge directly into the New River where mixing would dilute any concentrations, thus presenting little or no concern to species and/or habitat. Professional judgment was used to decrease the groundwater score from moderate to minimal in the five-year review based on the proximity of the range to the New River, where it is assumed that both surface water and groundwater quickly discharge.

Other factors that further decreased the scores were range maintenance and surface water pH. With the installation of the bullet trap between 2006 and 2007, maintenance increased to quarterly, whereas in the baseline, the berm was maintained as needed on a much less frequent basis. Surface water pH was determined based on groundwater sampling results in the baseline assessment (assumed pH <6.5), whereas surface water data was used in the five-year review to determine the pH is between 7.5-8. The more neutral pH limits the mobility of lead, thus decreasing the score.

7.2.5. F-4

Range F-4 is a rifle familiarization range located in the northeastern part of the installation just east of ranges F-11A and F-11B. It was constructed in 1960 and is still in use today. There are 11 PITS stations in which units provide their own targets. Each location has a backstop berm, but there are no designated firing points.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for impacts to surface water receptors and moderate concern for impacts to groundwater receptors. Range F-4 was included in the baseline assessment as an HE range because of the use of pyrotechnics; however, current use is almost entirely small arms. Therefore, this range was evaluated as a SAR in the five-year review.

7.2.6. F-11A and F-11B

Ranges F-11A and F-11B are located adjacent to each other in the northeastern part of the installation immediately east of the MCB Camp Lejeune main cantonment area. They were assessed together because of proximity to one another and similar usage. They have been in use since 1950, F-11A as a 30 m firing range and F-11B as a pistol qualification range. F-11A has 16 targets, and F-11B has 14 targets. The ranges contain earthen berms and have had steel bullet traps since October 1999. The bullet traps are inspected monthly and maintained and cleaned quarterly.

These ranges were rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors. These ranges were also assessed together in the baseline assessment, which concluded that MC loading at Ranges F-11A and F-11B had moderate potential to impact surface water and groundwater. However, the potential for impacts was reduced by the lead containment of the bullet traps.

The reduction in the surface water rating is due primarily to scoring of the sensitive species habitat and threatened or endangered species criteria. This was given the highest ranking in the baseline assessment based on its location in the coastal environment. A more specific analysis was compelted in the five-year review, and no sensitive species or habitat were identified in vicinity of the range. This was also true for groundwater receptors; however, this did not impact the overall rating of the groundwater environmental concern.

7.2.7. F-18

Range F-18 is a machine gun field firing range located immediately east of the MCB Camp Lejeune main cantonment area. It has been in use since 1970, but current plans are to close this range in 2011; a new machine gun range currently is under construction as a replacement. The operational range contains six targets and two firing areas. Targets on the left side are placed at 646 m, 720 m, and 912 m; targets on the right side are placed at 656 m, 720 m, and 912 m. Targets are backed by earthen backstops to trap bullets. The range has two earthen firing berms, with a forward berm approximately 1 m high and a rear berm approximately 2 m high. The designated firing line is on the berm or directly in front of the forward berm.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment, which concluded that MC loading at Range F-18 had moderate potential to impact surface water and high potential to impact groundwater. Three public supply wells (PSW-G, PSW-C, and PSW-D) were sampled near F-18 during the five-year review, and lead was not detected above the RL in groundwater samples.

The reduced concern rating for groundwater was due to the differences in scoring of groundwater pH, soil type, and groundwater receptors. The approach in the baseline was a more general look at the installation as a whole, whereas the individual range location was assessed in the five-year review. Groundwater wells sampled near the range indicate a pH of 6.5-8.5, whereas it was assumed to be less than 6.5 in the baseline assessment. The soil type of the installation as a whole is sand with some organic matter; however, the Onslow series identified at Range F-18 indicates the soil to be clayey sand/silt, which decreases infiltration to groundwater and thus lowers the score. The groundwater receptors were scored high in the baseline assessment based on the coastal environment; however, a closer analysis in the five-year review yielded no findings of sensitive species or habitat in the vicinity. The changes in scoring of these factors resulted in a lowering of the groundwater concern rating from high to moderate.

7.2.8. I-1

Range I-1 is a small arms qualification range, NLW range, and shotgun (non-lethal) range. It has been in use since 1960 and is located at Courthouse Bay. It contains 16 firing lanes and targets and a steel bullet trap, which was installed in July 1999. Wooden walls run along the length of the range for bullet containment.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was assessed in the baseline assessment, which concluded that MC loading at Range I-1 had minimal potential to impact surface water receptors and moderate potential to impact groundwater receptors. The potential for impacts was reduced by the lead containment of the bullet trap. The bullet trap is inspected monthly and maintained and cleaned quarterly.

The increased score for surface water from the baseline to the five-year review was based on the lead loading at the range. Loading was more accurately estimated due to increased tracking in RFMSS since the baseline. Whereas only 80 pounds of lead were estimated to be loaded annually at Range I-1 at the time of the baseline, approximately 3,800 pounds of lead were estimated annually in the five-year review. It is unclear if training has increased at this range, or if inadequate sources were used for estimations in the baseline assessment.

7.2.9. K-302

Range K-302 is a BZO / 10 m qualification range located near the center of the northern boundary of the K-2 Impact Area. The range first opened in 1970 and has been in use since that time. There are 50 target locations located in the first 100 m of the range, and direction of fire is south toward the K-2 Impact Area. There is no backstop berm, so ammunition likely is deposited in the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed. It was assessed in accordance with the SARAP for the five-year review.

7.2.10. K-309

Range K-309 is a machine gun zeroing and live-fire qualification range located near the center of the northern boundary of the K-2 Impact Area. A base order issued in 1970 indicates that the range has been in use since that time; however, rocket launchers and demolition charges previously were authorized. The range contains a tower, six fighting holes, and steel echo-type targets at 200 m, 400 m, 700 m, and 900 m, bunkers at 50 m, and armor targets at 1,000 m. A firing line is present, and all firing must occur from the berm or within 100 m forward of the berm. The range is wooded along the sides and at the back of the range.

All firing is toward the K-2 Impact Area, and there is no backstop berm. While many of the munitions are contained by the tree line, some may be deposited farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.11. K-315

Range K-315 is an infantry familiarization firing range located just east of K-309, which is near the center of the northern boundary of the K-2 Impact Area. A base order issued in 1970 indicates that it has been operational since at least that time. Permanent targets are not present; therefore, each unit must supply PITS or other type targets when using the range. A range tower and a firing line is present, and all firing must occur from the berm or within 80 m forward of the berm. The range is surrounded by a thin tree line; however, there is no backstop berm, so munitions are likely deposited farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.12. K-317

Range K-317 is a close combat / EMP range located immediately east of K-315. A base order issued in 1970 indicates that it has been operational since at least that time. Each unit using the range must provide PITS or other type target material and target holders, as permanent targets are not present. There are no designated firing points; however, a firing line is located at the range. All firing is directed toward the K-2 Impact Area. The range is wooded along the length of the range and at the back of the range. There is no backstop berm so, although the tree line contains many of the munitions, some may be deposited farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.13. K-319

Range K-319 is a 100 m fire and movement range located just east of K-317 on the northern boundary of the K-2 Impact Area. A base order issued in 1970 indicates that it has been operational since at least that time. Each unit using the range must provide PITS or other type target material and target holders, as permanent targets are not present. A range tower, a firing line, and assault firing lanes are located at the range, but there are no designated firing points. All firing is directed toward the K-2 Impact Area. The range is wooded along the length of the range and at the back of the range. There is no backstop berm so, while the tree line likely contains many of the munitions, some likely are deposited farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.14. K-321 and K-321A

Ranges K-321 and K-321A are M249 squad automatic rifle transition ranges located on the northeastern boundary of the K-2 Impact Area. A base order issued in 1986 indicates that the range has been active since that time. The range has 25 concrete PITS target stations (5 per lane for five lanes) located at 50 m, 100 m, 200 m, 300 m, and 400 m. A range tower, a firing line, and assault firing lanes are located at the range, but there are no designated firing points. All firing is directed toward the K-2 Impact Area, and there is no backstop berm. The range is wooded along the length of the range and at the back of the range; while the wooded area contains many of the rounds within the range footprint, some of the munitions likely are deposited within the SDZ farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.15. K-325

Range K-325 is a combat marksmanship program range located adjacent to the New River on the eastern part of the northern boundary of the K-2 Impact Area. A base order issued in 1970 indicates that the range has been used since that time, but it previously was used for rockets and large ammunition. It currently is used only for small arms ammunition. The range consists of a range tower and eight concrete firing bunkers within an earthen berm area. Firing is authorized from inside the bunkers, from the top of the berm, or forward of the berm within 100 m. PITS or BZO targets may be used within 100 m of the firing area. All firing is directed toward the K-2 Impact Area. The range is wooded along the length of the range and at the back of the range. There is no backstop berm so, while the tree line likely contains many of the munitions, some likely are deposited farther into the K-2 Impact Area.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. This range was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.16. K-402

Range K-402 is an individual tactical training range located on the western boundary of the K-2 Impact Area. A base order issued in 1970 indicates this range has been used since that time, but it was used previously for HE munitions and demolitions. Since the baseline assessment, automated targetry has been added to the range. K-402 has a 35 ft range tower, remoted engagement target system targets, two battlefield sound effect simulators, and two smoke generators. There are target lines with backstop berms at 50 m, 100 m, 150 m, 200 m, 250 m, and 300 m. Firing is toward the K-2 Impact Area, and the range is surrounded by trees. The target lines contain the following:

- 50 m target line: one row of 10 stationary infantry targets (SITs)
- 100 m target line: two 75 ft MITs and one SIT
- 150 m target line: nine SITs in three clusters of three targets and six are double target arm lifters
- 200 m target line: two 75 ft MITs at a 30- to 40-degree angle and one SIT
- 250 m target line: nine SITs in three clusters of three targets and six are double target arm lifters
- 300 m target line: one row of 10 SITs

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. Range K-402 was evaluated in the baseline assessment; however, it was included in the K-2 Impact Area MC loading area and no SARAP was completed.

Range K-402A is located beside K-402 but is an enclosed shoothouse that will not be evaluated in REVA because all potential impact is contained indoors.

7.2.17. K-406A and K-406B

Ranges K-406A and K-406B are located immediately beside each other on the western boundary of the K-2 Impact Area, just south of K-402. Range K-406A serves as an EMP range, and Range K-406B serves as an EMP range and a close combat range. A base order issued in 1970 indicates that the ranges have been in use since that time, but they were used previously for demolition training. Earthen separation berms are present between K-402 and K-406B and between K-406B and K-407, but firing into these berms is not authorized. There are no targets present at either range, but K-406B contains a concrete fiber mesh shooting structure with window and flanking targets. Direction of fire is toward the K-2 Impact Area, and the ranges are wooded along their lengths and at the back of the range. There are no backstop berms.

This range was rated using the SARAP during the five-year review, which determined that there was a moderate concern for potential impacts to surface water and groundwater receptors. Ranges K-406A and K-406B were evaluated in the baseline assessment; however, they were included in the K-2 Impact Area MC loading area and no SARAP was completed.

7.2.18. MAC Ranges

There are seven MAC ranges adjacent to one another that are part of the MCB Camp Lejeune MOUT complex located northeast of the G-10 Impact Area; MAC-3 is an indoor range and MAC-7 has no expenditure data at this time; as such, they are not included in the SARAP evaluation. The combined MAC ranges total 12.6 acres, and a 16-foot high earthen berm was installed in 2010 to cover the length of all MAC ranges.

- MAC-1: Live-fire urban quick kill range used for fire team– and squad-level urban training located northeast of the G-10 Impact Area. MAC-1 became operational in 1990 and contains five building facades, eight window targets, four door targets, and seven emplacement targets.
- MAC-2: Search-and-kill range used for fire team– and squad-level urban training located northeast of the G-10 Impact Area. MAC-2 opened in 1990 and contains three structures, five window targets, one door target, and 11 lights mounted on posts.

- MAC-4: Cover-and-clear range used for fire team– and squad-level urban training located northeast of the G-10 Impact Area. MAC-4 opened in 1990 and contains no targets.
- MAC-5: Basic squad MOUT range used for squad-level urban training located northeast of the G-10 Impact Area. MAC-5 opened in 1990 and contains eight PITS stations.
- MAC-6: Enhanced marksmanship range used for fire team– and squad-size units located northeast of the G-10 Impact Area. MAC-6 opened in 2005 and contains 15 PITS bunkers.

These ranges were combined for assessment using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors. The ranges were assessed individually using the SARAP during the baseline assessment, which determined that there was moderate concern at all MAC ranges for potential impacts to surface water and groundwater receptors.

The decreased scoring for surface water concern in the five-year review was based primarily on surface water pathway criteria and accessibility of media to sensitive species or habitat. The pH of surface water in the baseline was estimated as less than 6.5, whereas data collected in the five-year review indicated a pH in the range of 6.5-8.5. The more neutral pH limits the mobility of lead and thus receives a lower score. Vegetation covers the ranges and was estimated at greater than 50% cover in the five-year review; it was at 20-50% in the baseline. The greater vegetative cover decreases velocity of runoff and erosion. Due to the berm installed in 2010 that extends along the length of the ranges, the score was lowered due to partial controls for managing surface water runoff from the ranges. The last factor identified to lower the score from moderate to minimal concern was sensitive species and/or habitat. This criteria received the highest rating in the baseline due to the location in the coastal environment; it was given a score one step lower in the five-year review due to wetlands in vicinity, but no sensitive species identified nearby.

7.2.19. Stones Bay Range Complex

The ranges in the Stones Bay Range Complex were constructed in the mid-1980s and include the following operational SARs:

- Alpha Range
- Bravo Range
- Charlie Range
- Dodge City

- Hathcock Range
- Mechanical Pistol Range
- Multi-Purpose Range
- Walk-Down Pistol Range

The results of the SARAP assessment during the five-year review are summarized under the individual ranges described below. Each range was assessed separately in the baseline assessment, which concluded that MC loading at all the ranges had moderate potential to impact surface water and groundwater receptors.

A sediment study was conducted by the Georgia Institute of Technology – Savannah and University of South Carolina Beaufort at the Stone Bay Range Complex. Sediment samples were collected in uplands and within Stones Bay in May 2008 and April 2010, and were analyzed for lead, copper, antimony, manganese, iron, and zinc. Other parameters including bulk density, grain size distribution, total organic carbon, acid volatile sulfide, and simultaneously extracted metals were also analyzed. Results did not indicate metals in the sediment were bioavailable or migrating.

Alpha, Bravo, and Charlie Ranges

Alpha, Bravo, and Charlie Ranges are known distance rifle ranges (25–600 yards) located within the Stones Bay Complex. There are protective berms (used for bullet containment / safety purposes) located on both sides of each range. Direction of fire is south to north, and there are standard rifle range carriage and manual mover targets. In the 2006 to 2007 timeframe, maintenance was conducted at 5 acres of these ranges in which the top 4–5 inches of soil was sifted and residual bullets and fragments were removed.

These ranges were rated using the SARAP during the five-year review and determined that there was a moderate concern for potential impacts to surface water receptors and a high concern for potential impacts to groundwater receptors.

The higher concern in the five-year review versus the baseline was due to the frequency of maintenance. While it was assumed that lead was removed at least annually during the baseline assessment, it was scored on the assumption that lead is removed less than every three years in the five-year review. Lead was removed during 2006 to 2007, as noted above, but lead has not been removed since that time. These ranges are rated at the very low end of the high concern scoring range.

Dodge City

Dodge City is an urban sniper training range with 200 m multiple supported and elevated shooting positions. The range consists of buildings used to simulate urban warfare. Targets consist of a stationary wood frame or portable steel targets, as well as hard-wired stationary and moving targets.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for potential impacts to surface water and groundwater receptors.

Hathcock Range

Hathcock Range is a 50- to100-yard rifle and sniper range. Direction of fire is south to north. An observation tower is located on the range, and a pond is located adjacent to the range. The pond is bordered by berms on three sides, and pop-up targets are located in front of the berms. The earthen berms are designed to capture bullets that are fired; the berms are mined on an as-needed basis.

This range was rated using the SARAP during the five-year review and determined that there was a moderate concern for potential impacts to surface water and groundwater receptors.

Mechanical Pistol Range

The mechanical pistol range is a pistol marksmanship range with 50 firing points and automated turning targets located at 25 m and 50 m. Direction of fire is south to north. The range is bordered by berms on three sides; the berms were designed to capture bullets until a bullet trap was installed in 2006. The berms were mined after they were no longer used to capture bullets. The bullet trap is inspected monthly and maintained and cleaned quarterly.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors.

The decreased concern for surface water is due primarily to changes in scoring of surface water pathways criteria. The pH was determined to be less than 6.5 in the baseline, whereas surface water sampling in the five-year review confirmed pH to be between 6.5 and 8.5. The more neutral pH limits the mobility of lead. Additionally, the slope of the range was determind based on the slpe of the berm in the baseline assessment (>10% slope), whereas it was based on the overall slope of the range in the five-year review (<5%). The flatter surface slows surface water runoff and minimizes erosion. With the installation of the bullet trap in 2006, estimation of slope based on the berm is not as representative of current conditions.

Multi-Purpose Range

The multi-purpose range is a 100 m range used as a rifle marksmanship range, close quarters battle range, pistol and rifle range, and a shotgun range. Direction of fire is south to north. There is a small arms target system, a stationary wood frame, and portable steel targets / ballistic plates. Vulcanized rubber behind the targets captures bullets, and maintenance is performed on the rubber every 2 years. The range is bordered by berms on three sides; the berms were designed to capture bullets until a bullet trap was installed in 2006. The berms were mined after they were no longer used to capture bullets.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors.

The decreased concern for surface water is due primarily to changes in scoring of surface water pathways criteria. The pH was determined to be less than 6.5 in the baseline, whereas surface water sampling in the five-year review confirmed pH to be between 6.5 and 8.5. The more neutral pH limits the mobility of lead. Additionally, the slope of the range was determind based on the slpe of the berm in the baseline assessment (>10% slope), whereas it was based on the overall slope of the range in the five-year review (<5%). The flatter surface slows surface water runoff and minimizes erosion. With the installation of the bullet trap in 2006, estimation of slope based on the berm is not as representative of current conditions.

Walk-Down Pistol Range

Walk-Down Pistol Range (called Non-Mechanical Range in the baseline assessment) is a pistol marksmanship range with covered firing positions, 50 targets, and a bullet trap, which was installed in April 2004. It is unknown when the range first became operational. Mechanical turning targets are present at 25 m and 50 m. Prior to installation of the bullet trap, earthen impact berms were present on three sides of the range. During installation of the bullet trap, the berms were mined, and the portion of the berm behind the bullet trap was removed. The bullet trap is inspected monthly and maintained and cleaned quarterly.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors.

The decreased concern for surface water is due primarily to changes in scoring of surface water pathways criteria. The pH was determined to be less than 6.5 in the baseline, whereas surface water sampling in the five-year review confirmed pH to be between 6.5

and 8.5. The more neutral pH limits the mobility of lead. Additionally, the slope of the range was determind based on the slpe of the berm in the baseline assessment (>10% slope), whereas it was based on the overall slope of the range in the five-year review (<5%). The flatter surface slows surface water runoff and minimizes erosion. With the installation of the bullet trap in 2006, estimation of slope based on the berm is not as representative of current conditions.

7.2.20. Square Bay RR-227

Square Bay RR-227 is a live-fire pistol and rifle range located immediately south of the Stones Bay Complex. It is not clear when the range first became operational, but it continues to be used today. A bullet trap is present at the range. The bullet trap is inspected monthly and maintained and cleaned quarterly.

This range was rated using the SARAP during the five-year review and determined that there was moderate concern for potential impacts to surface water and groundwater receptors. This range was identified during research for the five-year review and was not assessed in the baseline.

7.2.21. SR-8

SR-8 is a 187-acre multipurpose machine gun qualification firing range that opened in 2009 and is located west of SR-6 in the GSRA. There are 10 firing lanes with 179 SITs and three MITs located at 300 m, 450 m, and 650 m. Impact berms are positioned behind the targets. There are several concrete machine gun positions on the firing line. A drainage system carries surface runoff to the back of the range.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors. Based on professional judgment, the surface water concern was increased to moderate due to the extremely high use (almost 17,000 pounds of lead per year); however, it should be noted that surface water pathways and receptors were not identified in the vicinity. This range opened in 2009 and, therefore, was not assessed during the baseline assessment.

7.2.22. SR-11

Range SR-11 is a pistol qualification range located in the southern part of the GSRA inside the boundary of SR-10. It has been operational since 2001. The range consists of 14 firing lanes, 14 targets, and a bullet trap, which was installed during construction of the range. The bullet trap is inspected monthly and maintained and cleaned quarterly.

This range was rated using the SARAP during the five-year review and determined that there was a minimal concern for potential impacts to surface water receptors and a moderate concern for potential impacts to groundwater receptors. This range was assessed in the baseline assessment, which also concluded that MC loading at Range SR-11 had minimal potential to impact surface water and moderate potential to impact groundwater. The bullet trap is expected to minimize potential for impact to groundwater.

7.3. Small Arms Range Assessment Protocol Surface Water Assessments

The surface water assessment is the sum of three component scores in the SARAP: range use and range management, surface water pathways, and surface water receptors. Of the 27 surface water assessments completed, no SARs were designated as a high concern, 17 received a score of moderate concern, and 10 received a score of minimal concern. SARAPs are provided in **Appendix A**.

7.3.1. Small Arms Ranges with Moderate Surface Water Concern

SARs designated as having a moderate concern are those in which the components in the surface water evaluation totaled 30–49 points. **Table 7-2** lists those ranges receiving this rating with a summary of the scores.

Table 7-2: Scores for SARs with Moderate Concern for Surface Water Receptors

Range Name	Annual Lead Use (lb)	Range Use/ Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
B-12	4,063	10	8	13	**31**
D-30	7,842	15	10	6	**31**
F-18	10,849	15	11	4	**30**
I-1	3,762	11	8	15	**34**
K-302	10,407	15	13	13	**41**
K-309	18,053	15	15	13	**43**
K-315	14,347	15	13	6	**34**
K-317	7,559	15	13	6	**34**
K-319	11,102	15	13	6	**34**
K-321 and K-321A	12,608	13	11	6	**30**
K-325	7,315	15	9	6	**30**
K-402	6,552	15	15	6	**36**
K-406A and K-406B	5,984	15	11	6	**32**

Range Name	Annual Lead Use (lb)	Range Use/ Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
Alpha Bravo Charlie	17,205 22,858 18,474	12	4	15	**31**
Dodge City	1,406	12	8	15	**35**
Hathcock Range	1,797	12	8	15	**35**
Square Bay	1,956	8	8	15	**31**
SR-8	16,992	8	5	13	**26**

Several ranges with moderate surface water concern received the maximum range use / range management score of 15 due to prolonged use, lack of bullet capture technology, and infrequent range maintenance. All of the ranges scoring in the moderate concern range receive more than 1,000 lb/yr of lead. All but five have been operational for more than 30 years, and most were operational for more than 30 years without bullet capture technology. Pistol ranges B-12 and I-1 now have bullet traps, but they were used over 30 years before the bullet traps were installed. The Hathcock Range and D-30 have impact berms, but it is unknown when they were installed. Dodge City, K321 and K-321A, and Alpha, Bravo, and Charlie ranges have not had bullet capture technology for the 25 years they have been operational. Bullet traps are inspected monthly and maintained and cleaned every three months. Ranges without bullet traps are maintained as needed, which is typically no more frequently than every 3 years. SR-8 has only been operational since 2009 and it does not have bullet capture technology. It does, however, have an impact berm, but this range sees extremely high use.

Surface water at MCB Camp Lejeune typically has a pH of 7.5–8, which helps in keeping lead bound to sediments; however, the installation has a relatively high annual precipitation with approximately 54 in/yr. Almost all of the ranges with moderate surface water concern are flat (slope less than 5%) and have a sand/gravel subsurface, thus decreasing potential for surface water runoff. Five ranges were classified as having some parts of the range or an impact berm with a slightly higher slope (5%–10%): D-30, K-309, K-402, Hathcock Range, and SR-8. Three ranges also were classified as having a subsurface that is primarily clayey sand/silt: F-18, K-302, and K-309. The range of surface water pathways scores is due primarily to differences in vegetative cover on the ranges and engineered controls to help manage runoff and minimize erosion. Vegetation helps manage storm water runoff; ranges with vegetation covering more than 50% of the range include F-18, K-325, and the Alpha, Bravo, and Charlie Ranges. Ranges with less than 20% vegetation on the range include B-12, I-1, K-315, K-317, K-319, K-402, and

Dodge City. Square Bay was conservatively assumed to contain less than 20% vegetation since the status of the vegetation is unknown. D-30, K-321 and K-321A, and SR-8 contain 20% to 50% vegetation. Ranges on which no engineered controls for managing storm water runoff were identified include F-18 and the K-ranges. Although the intended purpose of the design is to contain bullets, the sidewalls, baffled ceilings, and vegetated berms on other ranges help manage storm water and erosion. While many of the pistol ranges have a gravel or dirt floor with little or no vegetation, they have walls and baffled ceilings, which help control storm water runoff and erosion in addition to their intended purpose of containing the bullets. Drainage ditches are located long the length of the SR-8 range and divert drainage to the back of the range. Furthermore, targets are backed by vegetated impact berms at this range.

SARs located near Stones Bay scored higher than other ranges for surface water receptors due to jurisdictional wetlands located nearby and proximity to Stones Bay, where recreational users may be present. These SARs include Alpha, Bravo, and Charlie Ranges; Dodge City; Hathcock Range; and Square Bay. Other ranges scored higher for the surface water receptor component due to nearby wetlands and/or T/E or protected species in the vicinity, such as the bald eagle, red-cockaded woodpecker, and American alligator. Ranges near sensitive habitat or species include B-12, I-1, K-302, and K-309. Surface water at MCB Camp Lejeune is not used as a drinking water source; however, it is used recreationally and, thus, has potential for being a receptor location for fishing activities and recreational users. Ranges on drainage pathways to the New River were scored higher for this potential exposure to recreational users. These include I-1, K-315, K-317, K-319, K-321 and K-321A, K-325, K-402, K-406A, and K-406B.

Ranges K-309, K-315, K-321 and K-321A, SR-8, and Alpha, Bravo, Charlie are used most heavily; therefore, maintaining vegetation on these ranges is an important consideration in minimizing surface water runoff, erosion, and sediment migration off the range. Vegetation should be permitted to grow to the extent that it does not interfere with the mission at the range. Mowing frequency should be established to allow maximum allowed growth of vegetation.

7.3.2. Small Arms Ranges with Minimal Surface Water Concern

SARs designated as having a minimal concern are those in which the components in the surface water evaluation totaled 0–29 points. **Table 7-3** lists the 10 ranges (or groups of ranges) receiving this rating with a summary of the scores.

Table 7-3: Scores for SARs with Minimal Concern for Surface Water Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Surface Water Pathways	Surface Water Receptors	Total Score
A-1	2,042	11	8	6	**25**
D-29A and D-29B	8,786	11	8	10	**29**
F-4	496	13	11	13	**37***
F-11A and F-11B	7,405	11	8	4	**23**
MAC Ranges	5,325	12	6	8	**26**
Mechanical Pistol	1,371	8	6	15	**29**
Multi-Purpose	5,553	8	6	15	**29**
Walk Down	4,200	8	4	15	**27**
SR-11	779	2	8	13	**23**

* Professional judgment was used to decrease the concern of F-4 from moderate to minimal due to the low use of only 496 lb annually and the presence of a backstop berm for bullet capture.

All of these SARs receive more than 1,000 lb/yr of lead, except for Ranges F-4 and SR-11. Ranges A-1, D-29A and D-29B, and F-11A and F-11B are pistol qualification ranges with bullet traps, but the ranges were operational for more than 30 years without bullet traps. Berms are located behind these ranges, but it is unknown when the berms were installed so it was conservatively assumed in the scoring that the ranges operated for more than 30 years without berms. Range SR-11 is also a pistol qualification range with a bullet trap, but the bullet trap was installed when the range opened in 2001; the range has never operated without a bullet trap. Bullet traps are inspected monthly and maintained and cleaned every three months. The MAC ranges opened in 1990, and a 16 ft high impact berm was installed in 2010. Ranges K-321 and K-321A, SR-8, and the MAC Ranges are maintained as needed, and lead is removed less frequently than once every 3 years.

Surface water at MCB Camp Lejeune has a pH of 7.5–8, and annual rainfall is relatively high with approximately 54 in/yr. Ranges A-1, D-29A and D-29B, F-11A and F-11B, and SR-11 contain sand or gravel floors with no vegetation; however, each has a baffled ceiling, sidewalls, and a bullet trap, which would provide partial control on managing storm water runoff in addition to their intended purpose of containing the bullets. Ranges F-4, MAC Ranges, Mechanical Pistol, Multi-Purpose, and Walk Downare 20%–50% vegetated and, thus, have decreased capability to slow surface water runoff. Ranges F-4 and K-321 and K-321A have no engineered controls for storm water; the MAC Ranges, Mechanical Pistol, Multi-Purpose, and Walk Down ranges have berms that help control surface water runoff.

Surface water is not a drinking water source at MCB Camp Lejeune, but the New River is used for recreation and fishing, so this is a potential receptor point. Ranges F-4, MAC Ranges, SR-11, and F-11A and F-11B are considered to have no direct surface water pathway to the New River. No sensitive habitat or species were near A-1 or F-11A and F-11B. Jurisdictional wetlands are in the area immediately surrounding D-29A and D-29B, MAC Ranges, Mechanical Pistol, Multi-Purpose, Walk Down, and SR-11, but all of these ranges have bullet traps or berms that minimize the opportunities for bullets to land in the nearby wetlands. The American alligator and the red-cockaded woodpecker inhabit areas near Range F-4. These sensitive species and habitats near these ranges increase concern for lead transport via surface water; however, bullet capture technology, engineered controls, and/or decreased loading minimize the concern.

7.4. Groundwater Assessments

The groundwater assessment is the sum of three component scores in the SARAP: range use and range management, groundwater pathways, and groundwater receptors. Of the 27 surface water assessments completed, one grouping of SARs was designated as a high concern, 23 received a score of moderate concern, and 3 received a score of minimal concern. SARAPs are provided in **Appendix A**.

7.4.1. Small Arms Ranges with High Groundwater Concern

SARs designated as having a high concern are those in which the components in the groundwater evaluation totaled 50–65 points. **Table 7-4** lists those ranges receiving this rating with a summary of the scores.

Table 7-4: Scores for SARs with High Concern for Groundwater Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
Alpha, Bravo, Charlie	17,205 22,858 18,474	12	30	8	**50**

The Alpha, Bravo, and Charlie Ranges are rifle marksmanship ranges that are among the most heavily used ranges at the installation. The ranges have been used for approximately 25 years and do not currently have bullet capture technology. The ranges are maintained as needed, and lead is removed less frequently than every 3 years. The ranges were cleared of lead and landscaped during 2006 and 2007.

The groundwater pathway is a potential concern due to the shallow water table, high precipitation, and a sand and gravel subsurface. Although there is potential for lead to reach groundwater, no receptors are nearby and lead does not tend to be very mobile. The closest drinking water well is approximately 2.5 miles west, and groundwater is not known to be used for agricultural use. Shallow groundwater may discharge to jurisdictional wetlands just south of the ranges. No groundwater samples were collected during the five-year review in vicinity of this MC loading area.

7.4.2. Small Arms Ranges with Moderate Groundwater Concern

SARs designated as having a moderate concern are those in which the components in the groundwater evaluation totaled 30–49 points. **Table 7-5** lists those ranges receiving this rating with a summary of the scores.

Table 7-5: Scores for SARs with Moderate Concern for Groundwater Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
B-12	4,063	10	30	8	**48**
F-4	496	13	30	16	**59***
F-11A and F-11B	7,405	11	26	4	**41**
F-18	10,849	15	22	4	**41**
I-1	3,762	11	30	8	**49**
K-302	10,407	15	26	8	**49**
K-309	18,053	15	26	8	**49**
K-315	14,347	15	30	4	**49**
K-317	7,559	15	30	4	**49**
K-319	11,102	15	30	4	**49**
K-321 and K-321A	12,608	12	30	4	**46**
K-325	7,315	15	30	4	**49**
K-402	6,552	15	30	4	**49**
K-406A and K-406B	5,984 6,496	15	30	4	**49**
MAC Ranges	5,325	12	30	6	**48**
Dodge City	1,406	12	30	8	**50***
Hathcock	1,797	12	30	6	**48**
Mechanical Pistol	1,371	8	30	8	**46**
Multi-Purpose	5,533	8	30	8	**46**
Walk Down	4,200	8	30	8	**46**
Square Bay	1,956	8	30	8	**46**
SR-8	16,992	8	30	8	**46**

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
SR-11	779	2	30	8	**40**

* Professional judgment was used to decrease the concern of Ranges F-4 and Dodge City from high to moderate. This was primarily due to the relatively low lead loading of only 496 and 1,406 lb/yr of lead, respectively.

Twenty-three SARs were rated as having a moderate surface water concern. These ranges expend more than 1,000 pounds of lead annually (except for F-4 and SR-11 which expend approximately 500 and 800 pounds, respectively). Most of the ranges rated as moderate concern have berms or bullet traps for bullet containment. Those ranges without bullet capture technology include the K-Ranges and Dodge City. Approximately one-half of the ranges rated as having a moderate surface water concern have been operational more than 30 years.

The moderate groundwater concern score is attributed largely to the groundwater pathway; infiltration to groundwater may be elevated due to the sand and gravel subsurface, shallow water table, and high annual precipitation. A low pH in the groundwater and soil at MCB Camp Lejeune inhibits lead from binding to sediments. The groundwater pathway score for four ranges was slightly lower than for the other SARs due to the following reasons:

- A well near ranges F-11A and F-11B and F-18 indicated groundwater near these ranges has a pH greater than 6.5.
- The subsurface at Ranges F-18, K-302, and K-309 is considered to be clayey sand and silt rather than sand and gravel.

Although the groundwater pathway is evident, few receptors are present in the area and, given the nature of lead, it is unlikely to be significantly mobile. Only Range F-4 is located near a public supply well (approximately 1,000 ft away), and it is also the only range identified as being near potential agricultural or beneficial use. Since it is located near the range boundary, there is potential for a private well nearby but off installation. Several ranges are located near wetlands where shallow groundwater likely discharges. These include ranges B-12, I-1, K-302, K-309, MAC Ranges, Dodge City, Hathcock, Mechanical Pistol, Multi-Purpose, Walk Down, Square Bay, SR-8, and SR-11. Shallow groundwater discharging to surface water also could impact sensitive species, such as the American alligator, bald eagle, and red-cockaded woodpecker located near Ranges B-12, F-4, and I-1.

7.4.3. Small Arms Ranges with Minimal Groundwater Concern

SARs designated as having a minimal concern are those in which the components in the groundwater evaluation totaled 0–29 points. **Table 7-6** lists those ranges receiving this rating with a summary of the scores.

Table 7-6: Scores for SARs with Minimal Concern for Groundwater Receptors

Range Name	Annual Lead Use (lb)	Range Use / Range Management	Groundwater Pathways	Groundwater Receptors	Total Score
A-1	2,042	11	30	4	**45***
D-29A and D-29B	8,786	11	30	6	**47***
D-30	7,842	15	30	4	**49***

* Professional judgment was used to decrease the scores for three ranges from moderate to minimal concern. The rating was modified because these ranges are located beside the New River, and shallow groundwater is assumed to discharge to the New River. No groundwater or surface water receptors were identified.

The higher scores for these SARs are attributed to the groundwater pathway score, which is high due to a shallow water table, high annual precipitation, low soil and groundwater pH, and a sand and gravel subsurface. All of these ranges expend more than 1,000 lb/yr of lead; however, A-1, D-29A, and D-29B have bullet traps and berms behind the ranges. D-30 has an impact berm. The bullet traps are inspected monthly and maintained and cleaned every 3 months, whereas the impact berm is maintained as needed. It was last mined for lead in 2003. These three ranges are over 1.5 miles from the nearest public supply wells, and groundwater is not known to be used for any agricultural uses in the vicinity. Ranges D-29A and D-29B are near wetlands and, although groundwater likely discharges to the New River, it is possible that some could discharge into the nearby wetlands. No other sensitive species or habitats were identified near these three ranges. The groundwater score for these ranges was lowered primarily because they are located on the bank of the New River, and shallow groundwater quickly discharges to the New River.

8. Field Data Collection Results

The initial surface water and groundwater sampling events associated with the baseline REVA at MCB Camp Lejeune were performed in November 2007 and April 2008. The results of these sampling events did not indicate a current MC release, but low-level detections of lead, perchlorate, and explosives led the REVA team to recommend additional sampling to monitor conditions.

As part of the five-year review, additional sampling was performed to build upon previous REVA documentation and further evaluate the potential for off-range migration of MC at MCB Camp Lejeune. This section summarizes the results of the 2010 and 2011 sampling efforts, as described below:

- A sampling event was conducted on 20–24 September and 20 December 2010 to replicate the REVA baseline sampling. This event included the sampling of surface water, groundwater, and a portion of the public supply wells.
- A monitoring well screened in the Castle Hayne aquifer was installed on 3–6 October 2011. This monitoring well is located to the south and immediately down gradient of loading area L-5. The location was selected based on the results of groundwater modeling, which predicted perchlorate from this MC loading area could reach a groundwater receptor at concentrations exceeding the REVA trigger value.
- A sampling event was conducted on 21 and 23 October 2011. This event included the sampling of groundwater collected from the newly installed monitoring well and the collection of three additional surface water samples. Two of the surface water samples were collected because no previous sampling had been conducted in these subwatersheds, and the other sample was collected to assess concentrations in the New River down gradient of many of the subwatersheds on the installation.

8.1. Field Activities

The deep monitoring well installed in October 2011 near L-5 (identified as L-5 MW-01D) was installed into the Castle Hayne aquifer. The surface casing was cemented in place from the ground surface into the Castle Hayne confining unit, which was encountered at approximately 30 ft bgs. The monitoring well then was installed inside this casing using mud rotary drilling techniques. The well screen was set from 82 to 92 ft bgs.

Samples were collected from 11 surface water locations, 22 groundwater monitoring wells, and 9 public supply wells located near the G-10 and K-2 Impact Areas. All samples were submitted for analysis of the full explosives suite, perchlorate, lead (total and dissolved), and total hardness (samples collected in October 2011 were not analyzed for total hardness). **Table 8-1** lists the samples, associated impact area, and media.

Table 8-1: MC Loading Areas and Corresponding Sample Identification Labels

Type of Sample	Associated Impact Area	Sample Identification Label
Surface Water	G-10 Impact Area	SW-1 (and duplicate)
		SW-2
		SW-6
		SW-7
	K-2 Impact Area	SW-2 (and duplicate)
		SW-4
		SW-5
	Background	SW-Background
	ETA-, F-2 and F-5	Wallace Creek (upper and bottom)
	EOD-2, K-510	EOD-2
	New River Watershed	M-17 (upper and bottom)
Groundwater	G-10 Impact Area	MW-3
		MW-4
		MW-5
		MW-5d
		MW-6
		MW-7
		MW-9
		MW-10
		MW-11
		MW-12
		MW-14
		MW-15
		MW-17
		MW-19 (and duplicate, resample)
	K-2 Impact Area	MW-1 (and duplicate)
		MW-2
		MW-4
		MW-6

Type of Sample	Associated Impact Area	Sample Identification Label
		MW-7
		MW-8
		MW-9
	L-5 MC Loading Area	L-5 MW-01D (and duplicate)
Public supply wells	G-10 Impact Area	PSW-A
		PSW-B (and duplicate)
		PSW-C
		PSW-D (and resample)
		PSW-E
		PSW-F
		PSW-G
		PSW-H
		PSW-BB

Sampling activities were coordinated with installation range management and collected in accordance with methodologies described in the Sampling and Analysis Plan (SAP) / Quality Assurance Project Plan (QAPP) (Malcolm Pirnie, 2010; ARCADIS/Malcolm Pirnie, 2011), except when field conditions required modifications, as described below:

- Some proposed surface water sample locations contained no water in September 2010 or drained only a small portion of the associated areas; therefore, these sample locations were moved or eliminated.
- Surface water samples collected in September 2010 were collected using a peristaltic pump, as opposed to the proposed method using a bailer or dipping the sample bottle directly into the stream. This allowed collection of the sample near the stream floor without disturbing it. Surface water samples collected in October 2011 were collected using a Pegasus pump.

Field duplicate and matrix spike / matrix spike duplicate (MS/MSD) samples were collected for quality control purposes. Field parameters were recorded in the field at each sample location, including pH, temperature, specific conductance, turbidity, and dissolved oxygen (DO) of surface water or groundwater. These were measured in the field with a portable meter (Horiba U-10 in 2010, Horiba W22 in 2011), and the oxidation-reduction potential (ORP) was measured in the field with a separate portable meter (Barnant 20).

All samples were shipped on ice by express courier to TestAmerica Laboratories, Inc., located in Arvada, Colorado, and Savannah, Georgia, for analysis. The surface water samples were analyzed for the full explosives suite and perchlorate at the Arvada laboratory and for lead (total and dissolved) at the Savannah laboratory. Analytical sampling results were compared to the DoD RMUS screening levels (**Appendix B**) and North Carolina groundwater protection standards.

8.2. Water Quality and Analytical Results

8.2.1. Surface Water

Following methodologies described in the SAP/QAPP (Malcolm Pirnie, 2010; ARCADIS/Malcolm Pirnie, 2011), a total of 13 field samples and 2 field duplicate samples were collected from surface water using a peristaltic or Pegasus pump. Field duplicate sample results closely replicated the field sample results, which are summarized in **Table 8-2**. No surface water analytical results exceeded RMUS or state of North Carolina screening values. A brief summary of results follows:

- Explosives were not detected in any surface water samples.
- Perchlorate was detected at SW-07 (located near the G-10 Impact Area) and SW-04 and SW-05 (both located near the K-2 Impact Area) at estimated concentrations ranging from 0.013 to 0.017 µg/L. The background sample contained perchlorate at an estimated concentration of 0.024 µg/L. All detections are below the RMUS surface water screening value of 9,300 µg/L.
- Total lead was detected in two samples near the K-2 Impact Area (SW-02 and SW-05) at an estimated concentration of 1.2 µg/L and in the bottom sample at Wallace Creek at a concentration of 0.71 µg/L. All of these results are below the RMUS surface water screening value of 2.5 µg/L and the North Carolina standard of 25 µg/L.
- Dissolved lead was detected in two samples near the K-2 Impact Area (SW-02 and SW-05) at concentrations of 0.46 and 0.94 µg/L. These detections are below the RMUS surface water screening value of 2.5 µg/L and the North Carolina standard of 25 µg/L.

Table 8-2
REVA Surface Water Sampling Results
September and December 2010, October 2011

			G-10					K-2				2011 Samples					Background
Impact Area / Sample ID	Screening Value		SW-01		SW-02	SW-06	SW-07	SW-02		SW-04	SW-05	Wallace Creek (upper)	Wallace Creek (bottom	EOD-2	M17 (surface)	M17 (bottom)	SW-Background
Constituent / Sample Date	DoD RMUS Surface Water[a]	NC Protection Standard[b]	20-Sep-10	20-Sep-10 (Duplicate)	20-Sep-10	20-Sep-10	21-Sep-10	24-Sep-10	24-Sep-10 (Duplicate)	24-Sep-10	20-Dec-10	21-Oct-11	21-Oct-11	21-Oct-11	21-Oct-11	21-Oct-11	24-Sep-10
Explosives (ug/L)																	
1,3,5-Trinitrobenzene	11	---	*0.40 U*	*0.39 U*	*0.39 UJ*	*0.39 U*	*0.40 U*	*0.38 U*	*0.39 U*	*0.38 U*	*0.40 U*	*0.43 U*	*0.45 UQ*	*0.41 U*	*0.43 U*	*0.44 U*	*0.43 U*
1,3-Dinitrobenzene	20	---	*0.15 U*	*0.15 U*	*0.15 U*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
2,4,6-Trinitrotoluene	90	---	*0.15 U*	*0.15 U*	*0.15 U*	*0.150 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 UJ*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
2,4-Diamino-6-nitrotoluene	---	---	*0.39 U*	*0.38 U*	*0.4 U*	*0.4 U*	*0.4 U*	*0.37 U*	*0.38 U*	*0.38 U*	*0.39 U*	*0.97 U*	*1 UQ*	*0.93 U*	*0.96 U*	*0.98 U*	*0.42 U*
2,4-Dinitrotoluene	44	---	*0.15 U*	*0.15 U*	*0.15 U*	*0.150 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
2,6-Diamino-4-nitrotoluene	---	---	*0.35 U*	*0.34 U*	*0.3 U*	*0.3 U*	*0.4 U*	*0.33 U*	*0.34 U*	*0.34 U*	*0.35 U*	*0.97 U*	*1 UQ*	*0.93 U*	*0.96 U*	*0.98 U*	*0.38 U*
2,6-Dinitrotoluene	42	---	*0.15 U*	*0.15 U*	*0.15 U*	*0.150 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
2-Amino-4,6-dinitrotoluene	20	---	*0.15 UJ*	*0.15 UJ*	*0.15 UJ*	*0.15 UJ*	*0.15 UJ*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
4-Amino-2,6-dinitrotoluene	---	---	*0.15 U*	*0.15 U*	*0.15 UJ*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 UJ*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
HMX	150	---	*0.15 U*	*0.15 U*	*0.15 UJ*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
3-Nitrotoluene	750	---	*0.15 U*	*0.15 U*	*0.15 UJ*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 UJ*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
Nitrobenzene	270	---	*0.15 U*	*0.15 U*	*0.15 UJ*	*0.15 U*	*0.2 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
Nitroglycerin	138	---	*1.5 U*	*1.5 U*	*1.5 U*	*1.5 U*	*1.5 U*	*1.4 U*	*1.4 U*	*1.4 U*	*1.5 UJ*	*1.6 U*	*1.7 UQ*	*1.6 U*	*1.6 U*	*1.6 U*	*1.6 U*
2-Nitrotoluene	---	---	*0.15 U*	*0.15 U*	*0.15 U*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
PETN	85,000	---	*1.5 UJ*	*1.5 UJ*	*1.5 UJ*	*1.5 UJ*	*1.5 UJ*	*1.4 U*	*1.4 U*	*1.4 U*	*1.5 U*	*1.6 U*	*1.7 UQ*	*1.6 U*	*1.6 U*	*1.6 U*	*1.6 U*
4-Nitrotoluene	1,900	---	*0.40 U*	*0.39 U*	*0.39 U*	*0.39 U*	*0.4 U*	*0.38 U*	*0.39 U*	*0.38 U*	*0.40 U*	*0.43 U*	*0.45 UQ*	*0.41 U*	*0.43 U*	*0.44 U*	*0.43 U*
RDX	190	---	*0.15 U*	*0.15 U*	*0.15 UJ*	*0.15 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 UJ*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
Tetryl	---	---	*0.15 U*	*0.15 U*	*0.2 U*	*0.2 U*	*0.2 U*	*0.14 U*	*0.14 U*	*0.14 U*	*0.15 U*	*0.16 U*	*0.17 UQ*	*0.16 U*	*0.16 U*	*0.16 U*	*0.16 U*
Perchlorate (ug/L)																	
Perchlorate	9,300	2	*0.020 UJ*	*0.02 UJ*	*0.02 UJ*	*0.02 UJ*	0.013 J	*0.020 UJ*	*0.020 UJ*	0.017 J	0.014 J	*0.2 U*	*0.2 U*	*0.2 U*	*0.2 U*	*0.2 U*	0.024 J
Metals (ug/L)																	
Total Lead	2.5	25	*0.50 U*	*0.5 U*	*0.5 U*	*0.5 U*	*0.5 U*	*1.0 U*	1.2 J	*1.0 U*	1.2 J	*0.5 U*	0.71 J	*0.5 U*	*0.5 U*	*0.5 U*	*1.0 U*
Dissolved Lead	2.5	25	*0.20 U*	*0.2 U*	*0.2 U*	*0.2 U*	*0.2 U*	0.46 J	0.40 J	*0.20 U*	0.94 J	*0.2 U*	*0.2 U*	*0.2 U*	*0.2 U*	*0.2 U*	*0.20 U*
Field Parameters																	
Temperature (^oC)	---	---	23.35	-	24.96	25.21	20.87	-	-	27.33	4.51	*U*	*U*	*U*	*U*	*U*	28.28
Conductivity (mS/cm)	---	---	0.005	-	3.862	0.002	0.248	-	-	45.59	35.2	*U*	*U*	*U*	*U*	*U*	42.60
DO (mg/L)	---	---	7.21	-	6.03	7.42	5.88	-	-	6.42	11.27	*U*	*U*	*U*	*U*	*U*	6.93
pH	---	---	7.92	-	7.46	7.42	7.97	-	-	8.24	8.02	*U*	*U*	*U*	*U*	*U*	8.13
ORP (mV)	---	---	185.4	-	157.2	170.2	171.7	-	-	-	-19.7	*U*	*U*	*U*	*U*	*U*	-
Turbidity (NTU)	---	---	8.4	-	52.1	13.4	2.9	-	-	7.6	1.1	*U*	*U*	*U*	*U*	*U*	4.2

Notes:

--- = Not listed in standards

J - Estimated result

U - Not detected; reporting limit provided

UJ - Analyte was not detected; however, the result is considered estimated due to low laboratory recovery (MS/MSD or surrogate)

Q - One or more quality control criteria failed

Bold = above North Carolina screening value

Bold = above DoD RMUS screening level

Detected concentration

a.) DoD RMUS operational range assessment screening values for protection of freshwater ecological receptors. Obtained from "Protocol for Choosing Screening Values for Range and Munitions Use Subcommittee Operational Range Assessment Matrix"

b.) North Carolina protection standards obtained from North Carolina Administrative Code for surface water (15A NCAC 02B)

^oC = Degrees Celcius
mS/cm = milliSiemens per centimeter
mg/L = milligrams per Liter
DO = Dissolved Oxygen
ORP = Oxidation-Reduction Potential
mV = milliVolts
NTU = Nephelometric Turbidity Units
PETN = Pentaerythritol Tetranitrate

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A summary of the field parameters measured at the surface water sample locations is presented in **Table 8-2**. Observed pH measurements ranged from 7.42 to 8.48 and did not vary significantly between areas around the G-10 and K-2 Impact Areas or the additional surface water locations. DO ranged from 5.88 to 11.27 mg/L, with an average of 7.16 mg/L and a median of 7.02 mg/L. ORP ranged from -19.7 to 185.4 mV. Conductivity measurements recorded at SW-04, SW-05, SW-Background, and the 2011 locations collected along or in the New River ranged from 23.2 to 46.5 mS/cm and were significantly higher than other surface water measurements, which averaged 1.03 mS/cm. These higher conductivity values are attributed to brackish waters in the New River estuary. Turbidity ranged from 1.1 to 138 NTU, with an average of 40.4 NTU and a median of 8.4 NTU.

Data validation was performed on the analytical data, and data sets meet the data quality objectives (DQOs) and are considered usable. Minor data quality issues were observed in some analyses related to low MS/MSD percent recovery.

8.2.2. Monitoring Wells

A total of 22 groundwater samples were collected from monitoring wells during the 2010 and 2011 sampling events. One was collected using a monsoon pump, and the others were collected with a peristaltic pump and low-flow purge methods. Fourteen of the monitoring wells sampled were located near the G-10 Impact Area, seven of the monitoring wells were located near the K-2 Impact Area, and one was located south of Range L-5. Of the 14 monitoring wells located near the G-10 Impact Area, 9 are screened in the surficial aquifer and 5 are screened in the Castle Hayne aquifer. The monitoring wells around the K-2 Impact Area are screened in the surficial aquifer, and the monitoring well located south of L-5 is screened in the Castle Hayne aquifer. Three field duplicate samples were collected and closely replicated the field samples.

There were no RMUS screening criteria exceedances in groundwater around the G-10 Impact Area, but one sample result exceeded the North Carolina groundwater protection standard. The results of samples collected near the G-10 Impact Area are presented in **Table 8-3** and summarized below.

- Explosives were detected only in MW-19, which is screened in the Castle Hayne aquifer. This well was sampled on 2 days to assess temporal variability and the effect of collection method / purge volume. 2,4-Dinitrotoluene was detected only on the first day of sampling (0.19 µg/L), and 2-amino-4,6-dinitrotoluene was detected only on the second day of sampling (0.093 µg/L). Both were qualified as estimated concentrations because they were detected below their respective RLs. Concentrations did not exceed RMUS screening values of 0.22 and 73 µg/L, respectively; however, 2,4-dinitrotoluene did exceed the North Carolina IMAC of 0.1

µg/L. This was an estimated concentration, and it was not detected in the sample collected from this well the following day.

- Perchlorate was detected in 8 of 14 monitoring wells near the G-10 Impact Area at concentrations (six estimated concentrations) ranging from 0.013 to 0.85 µg/L, with a median concentration of 0.051 µg/L. One of these detections was in a deep well screened in the Castle Hayne aquifer. These detections did not exceed the RMUS screening value of 15 µg/L or the North Carolina IMAC of 2 µg/L.
- Total lead was detected in two monitoring well samples (MW-7 and MW-17) at a maximum estimated concentration of 1.3 µg/L. Total lead detections were well below the RMUS and North Carolina screening value of 15 µg/L.
- Dissolved lead was detected in three monitoring well samples (MW-6, MW-9, and MW-17) at estimated concentrations ranging from 0.29 to 0.99 µg/L, below the RMUS and North Carolina screening value of 15 µg/L.

One detection of total lead near the K-2 Impact Area exceeded the RMUS value and North Carolina protection standard of 15 µg/L. No other exceedances occurred in groundwater samples. Results of the seven samples collected near the K-2 Impact Area are presented in **Table 8-3** and summarized below.

- Explosives were detected only in MW-08. Nitroglycerin was detected at an estimated concentration of 2.6 µg/L, which is below the RMUS screening value of 138 µg/L (no North Carolina screening value available).
- Perchlorate was detected in MW-02, MW-06, and MW-07 at concentrations of 0.05, 0.051, and 0.13 µg/L, respectively. These detections were below the RL, the RMUS screening value of 15 µg/L, and the North Carolina IMAC of 2 µ/L.
- Total lead was detected in five monitoring well samples (MW-01, MW-02, MW-04, MW-06, and MW-07) at concentrations ranging from 0.52 to 18 µg/L. Maximum detected total lead concentrations were 18 µg/L in MW-01 and 14 µg/L in MW-07. The MW-01 detection exceeds the RMUS screening value and North Carolina protection standard of 15 µg/L.
- Dissolved lead was detected in four monitoring wells (MW-02, MW-04, MW-06, and MW-07) at estimated concentrations ranging from 0.24 to 0.81 µg/L. No detections exceed the RMUS screening value and North Carolina protection standard of 15 ug/L.

One monitoring well was sampled south of the L-5 MC loading area and analyzed for total and dissolved lead, perchlorate, and explosives. No constituents were detected.

Table 8-3
REVA Monitoring Well Sampling Results
September 2010 and October 2011

Impact Area			G-10															
Sample ID	Screening Value		MW-3	MW-4	MW-5	MW-5d	MW-6	MW-7	MW-9	MW-10	MW-11	MW-12	MW-14	MW-15	MW-17	MW-19		
Sample Date / Constituent	DoD RMUS Drinking Water[a]	NC Protection Standard[b]	22-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	21-Sep-10	21-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	23-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10	22-Sep-10 (Duplicate)	23-Sep-10 (Re-sample)
Explosives (ug/L)																		
1,3,5-Trinitrobenzene	1,100	---	0.39 U	0.39 U	0.39 U	0.38 U	0.39 U	0.39 U	0.38 U	0.38 U	0.39 U	0.4 U	0.38 U	0.38 U	0.38 U	0.39 U	0.39 U	0.40 U
1,3-Dinitrobenzene	3.7	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
2,4,6-Trinitrotoluene	2.2	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
2,4-Diamino-6-nitrotoluene	---	---	0.38 UJ	0.38 UJ	0.38 U	0.37 U	0.38 UJ	0.38 UJ	0.37 UJ	0.38 UJ	0.38 U	0.39 U	0.38 U	0.37 U	0.38 UJ	0.38 U	0.38 U	0.39 U
2,4-Dinitrotoluene	0.22	0.1	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	**0.17 J**	**0.19 J**	0.15 U
2,6-Diamino-4-nitrotoluene	---	---	0.34 U	0.34 U	0.35 U	0.34 U	0.34 U	0.34 U	0.33 U	0.34 U	0.34 U	0.35 U	0.34 U	0.33 U	0.34 U	0.34 U	0.34 U	0.35 U
2,6-Dinitrotoluene	37	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
2-Amino-4,6-dinitrotoluene	73	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 UJ	0.14 U	0.093 J
4-Amino-2,6-dinitrotoluene	73	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
HMX	1,800	---	0.15 U	0.15 UJ	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
3-Nitrotoluene	3.7	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
Nitrobenzene	0.12	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
Nitroglycerin	138	---	1.5 U	1.5 U	1.5 U	1.4 U	1.5 U	1.5 U	1.4 U	1.4 U	1.4 U	1.5 U	1.4 U	1.4 U	1.4 U	1.4 U	1.4 U	1.5 U
2-Nitrotoluene	0.31	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
PETN	---	---	1.5 U	1.5 UJ	1.5 U	1.4 U	1.5 U	1.5 U	1.4 U	1.4 U	1.4 U	1.5 U	1.4 U	1.4 U	1.4 U	1.4 U	1.4 U	1.5 U
4-Nitrotoluene	4.2	---	0.39 U	0.39 U	0.39 U	0.38 U	0.39 U	0.39 U	0.38 U	0.38 U	0.39 U	0.4 U	0.38 U	0.38 U	0.38 U	0.39 U	0.39 U	0.40 U
RDX	0.61	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
Tetryl	150	---	0.15 U	0.15 U	0.15 U	0.14 U	0.15 U	0.15 U	0.14 U	0.14 U	0.14 U	0.15 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.15 U
Perchlorate (ug/L)																		
Perchlorate	15	2	0.015 J	0.030 J	0.36 J	0.020 UJ	0.020 UJ	0.10 J	0.060	0.013 J	0.020 UJ	0.85	0.042 J	0.020 UJ	0.020 U	0.020 U	0.020 U	0.020 UJ
Metals (ug/L)																		
Total Lead	15	15	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	1.3 J	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U	0.62 J	0.50 U	0.50 U	0.50 U
Dissolved Lead	15	15	0.20 U	0.20 U	0.20 U	0.20 U	0.99 J	0.20 U	0.29 J	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.63 J	0.20 U	0.20 U	0.20 U

Notes:

--- = Not listed in standards

J - Analyte is present but detected below reporting limit. Value may not be accurate or precise (estimated)

M - Manually integrated compound

Q - One or more quality control criteria failed

U - Not detected; reporting limit provided

UJ - Analyte was not detected; however, the result is considered estimated due to low laboratory recovery (MS/MSD or surrogate)

Bold = above NC screening value

Bold = above DoD RMUS screening level

Detected concentration

a.) DoD RMUS operational range assessment screening values for human drinking water. Obtained from "Protocol for Choosing Screening Values for Range and Munitions Use Subcommittee Operational Range Assessment Matrix"

b.) North Carolina protection standards obtained from North Carolina Administrative Code for groundwater (15A NCAC 02L .0202)

Table 8-3
REVA Monitoring Well Sampling Results
September 2010 and October 2011

Impact Area			K-2																L-5			
Sample ID	Screening Value		MW-01				MW-02		MW-04		MW-06		MW-07		MW-08		MW-09		MW-01			
Constituent / Sample Date	DoD RMUS Drinking Water[a]	NC Protection Standard[b]	24-Sep-10		24-Sep-10 (Duplicate)		24-Sep-10		24-Sep-10		24-Sep-10		24-Sep-10		24-Sep-10		24-Sep-10		23-Oct-11		23-Oct-11 (duplicate)	
Explosives																						
1,3,5-Trinitrobenzene	1,100	---	*0.40*	*UJ*	*0.39*	*UJ*	*0.42*	*U*	*0.42*	*U*	*0.39*	*U*	*0.40*	*UJ*	*0.39*	*UJ*	*0.39*	*U*	*0.43*	*U*	*0.42*	*U*
1,3-Dinitrobenzene	3.7	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
2,4,6-Trinitrotoluene	2.2	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
2,4-Diamino-6-nitrotoluene	---	---	*0.39*	*UJ*	*0.38*	*UJ*	*0.41*	*UM*	*0.41*	*UJ*	*0.38*	*U*	*0.39*	*U*	*0.38*	*UJ*	*0.38*	*UJ*	*0.97*	*UJ*	*0.94*	*UJ*
2,4-Dinitrotoluene	0.22	0.1	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.160*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
2,6-Diamino-4-nitrotoluene	---	---	*0.35*	*UJ*	*0.34*	*UJ*	*0.36*	*U*	*0.37*	*U*	*0.34*	*U*	*0.35*	*U*	*0.34*	*UJ*	*0.34*	*U*	*0.97*	*U*	*0.94*	*U*
2,6-Dinitrotoluene	37	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
2-Amino-4,6-dinitrotoluene	73	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
4-Amino-2,6-dinitrotoluene	73	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
HMX	1,800	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UM*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
3-Nitrotoluene	3.7	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
Nitrobenzene	0.12	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
Nitroglycerin	138	---	*1.5*	*UJ*	*1.5*	*UJ*	*1.6*	*U*	*1.6*	*U*	*1.5*	*U*	*1.5*	*U*	2.6	J	*1.5*	*U*	*1.6*	*U*	*1.6*	*U*
2-Nitrotoluene	0.31	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
PETN	---	---	*1.5*	*UJ*	*1.5*	*UJ*	*1.6*	*U*	*1.6*	*U*	*1.5*	*U*	*1.5*	*UQ*	*1.5*	*UJ*	*1.5*	*U*	*1.6*	*U*	*1.6*	*U*
4-Nitrotoluene	4.2	---	*0.40*	*UJ*	*0.39*	*UJ*	*0.42*	*U*	*0.42*	*U*	*0.39*	*U*	*0.40*	*UM*	*0.39*	*UJ*	*0.39*	*U*	*0.43*	*U*	*0.42*	*U*
RDX	0.61	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
Tetryl	150	---	*0.15*	*UJ*	*0.15*	*UJ*	*0.16*	*U*	*0.16*	*U*	*0.15*	*U*	*0.15*	*U*	*0.15*	*UJ*	*0.15*	*U*	*0.16*	*U*	*0.16*	*U*
Perchlorate																						
Perchlorate	15	2	*0.020*	*U*	*0.02*	*UJ*	0.05	J	*0.02*	*UJ*	0.051	J	0.13	J	*0.020*	*U*	*0.02*	*UJ*	*0.2*	*U*	*0.2*	*U*
Total Metals																						
Total Lead	15	15	**18**		14		0.52	J	0.57	J	2.2		14		*0.50*	*U*	*0.50*	*U*	*0.50*	*U*	*0.50*	*U*
Dissolved Lead	15	15	*0.20*	*U*	*0.20*	*U*	0.55	J	0.24	J	0.65	J	0.81	J	*0.20*	*U*	*0.20*	*U*	*0.20*	*U*	*0.20*	*U*

Notes:

--- = Not listed in standards

J - Analyte is present but detected below reporting limit. Value may not be accurate or precise (estimated)

M - Manually integrated compound

Q - One or more quality control criteria failed

U - Not detected; reporting limit provided

UJ - Analyte was not detected; however, the result is considered estimated due to low laboratory recovery (MS/MSD or surrogate)

Bold = above North Carolina screening value

Bold = above DoD RMUS screening level

Detected concentration

a.) DoD RMUS operational range assessment screening values for human drinking water. Obtained from "Protocol for Choosing Screening Values for Range and Munitions Use Subcommittee Operational Range Assessment Ma

b.) North Carolina protection standards obtained from North Carolina Administrative Code for groundwater (15A NCAC 02L .0202)

Well yield was poor at MW-4 and MW-8 (both screened in the surficial aquifer) but was adequate to collect samples in accordance with low-flow protocol. The measured pH in the Castle Hayne aquifer was slightly higher than that measured in the surficial aquifer. The pH in the surficial aquifer ranged from 5.17 to 7.54 and averaged 5.95, while pH in the Castle Hayne aquifer ranged from 7.06 to 9.54 and averaged 7.96. DO was also slightly higher in the surficial aquifer, with concentrations ranging from 0.19 to 8.9 mg/L and averaging 3.02 mg/L, while DO in the Castle Hayne aquifer ranged from 0.06 to 5.16 mg/L and averaged 1.02 mg/L. Conductivity was higher in the surficial aquifer, ranging from 0.055 to 15.84 mS/cm and averaging 1.3 mS/cm, whereas conductivity in the Castle Hayne aquifer ranged from 0.259 to 0.458 mS/cm and averaged 0.358 mS/cm. Turbidity varied between wells but tended to be higher in the surficial aquifer.

Parameters in the Castle Hayne aquifer measured at L-5 MW-01D were in the same range as parameters measured in wells at the impact areas, except for ORP, which measured133 mV. Other parameters measured included a pH of 7.52, conductivity of 0.541 mS/cm, and DO of 0.12. Turbidity was less than 1 NTU.

Data validation was performed on the analytical data. Based on the result of this validation, data sets were deemed usable and to meet the DQOs. Minor data quality issues were observed in some analyses related to low surrogate and MS/MSD percent recovery, and the affected results are consequently qualified.

8.2.3. Public Supply Wells

Nine water supply wells screened in the Castle Hayne aquifer were sampled by collecting groundwater directly from the sampling port of the well. One field duplicate sample was collected, which closely replicated the field sample result. The only RMUS screening value and North Carolina groundwater standard exceeded was in a total lead detection in PSW-D. Results are summarized below and provided in **Table 8-4**.

- Explosives were not detected in any public supply wells.
- Perchlorate was not detected in any water supply wells.
- Total lead was detected in four water supply wells (PSW-F, PSWBB, PSW-G, and PSW-D) at concentrations of 4.0, 4.1, 4.3, and 38 µg/L, respectively. PSW-D contained a concentration of 38 µg/L, which exceeded the RMUS value and North Carolina groundwater protection standard of 15 µg/L. This well was resampled in December 2010, and lead was not detected. Dissolved lead was not detected in this well.
- Dissolved lead was detected in five water supply wells at concentrations ranging from 0.25 to 2.1 µg/L, which are below the RMUS screening value and North Carolina groundwater protection standard of 15 µg/L.

Field parameters were recorded prior to collecting any samples. Measurements were similar for all the public supply wells. DO ranged from 1.48 to 5.86 mg/L, with an average of 4.06 mg/L; pH ranged from 7.98 to 8.19; turbidity ranged from 1.7 to 53.9 NTU, with an average of 10.89 NTU and a median of 2.8 NTU; and ORP was not measured due to malfunctions with the meter.

Data validation was performed on the analytical data. Based on the results of the validation step, data sets are considered usable and to meet the DQOs. Two lead results were qualified as "estimated" due to a result above the sample detection limit but lower than the method quantitation limit.

8.3. Conclusions

Sample results do not indicate a current MC release to groundwater or that MC above applicable regulatory screening criteria are migrating to off-range receptors. Three explosives constituents were detected in two wells at estimated concentrations; one of these constituents, 2,4-dinitrotoluene, exceeded the North Carolina IMAC in one well (MW-19). MW-19 was resampled the following day, and 2,4-dinitrotoluene was not detected.

Perchlorate concentrations less than 1 μg/L were detected in the surficial aquifer, with one estimated concentration detected in the Castle Hayne aquifer. Results indicate that perchlorate is not reaching receptor exposure points, and all detected concentrations were below the RMUS and North Carolina screening values.

Lead exceeded its screening value in one monitoring well (MW-01 near K-2 Impact Area) and one public supply well (PSW-D). It was just above the screening value in the MW-01 sample, and it was not detected when PSW-D was resampled. No pathway to receptor exposure points is apparent from MW-01. Lead appears to be associated to sediments in the surficial and Castle Hayne aquifers, as evidenced by the fact that dissolved lead results were consistently lower than total lead results. This binding action of sediments largely immobilizes the lead and prevents it from migrating to receptor exposure points.

Although perchlorate was detected in three surface water samples, it was below RMUS screening values and was detected at a slightly higher concentration in the background sample. This indicates that surface water perchlorate concentrations are within background levels. Lead was detected at three surface water locations surrounding the K-2 Impact Area and in the Wallace Creek sample collected at the bottom of the vertical profile, but all concentrations were below screening values. Total lead results in surface water tended to be higher than dissolved lead, indicating a fraction bound to sediments.

The field sampling was a continuation of the five-year review assessment, and the sampling results provide a general confirmation of the modeling results, which were based on conservative assumptions. Because of exceedances, MW-01 and MW-19 will be resampled annually for lead and explosives, respectively. Results will be used to determine if annual sampling will continue. Groundwater and surface water monitoring should be continued in the next REVA five-year review process in addition to the semi-annual sampling of all public supply wells conducted by MCB Camp Lejeune. **Table 8-5** presents conclusions of the five-year review for MCB Camp Lejeune and summarizes the screening-level modeling and field results as they relate to MC loading areas.

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Table 8-4
REVA Water Supply Well Sampling Results
September 2010

Sample ID	Screening Value		PSW-584	PSW-585		PSW-611	PSW-612			PSW-628	PSW-648	PSW-652	PSW-708	PSWBB-280
Sample / Date	DoD RMUS Drinking Water[a]	NC Protection Standard[b]	23-Sep-10	23-Sep-10	23-Sep-10 (Duplicate)	23-Sep-10	23-Sep-10	20-Dec-10	20-Dec-10 (Duplicate)	23-Sep-10	23-Sep-10	23-Sep-10	23-Sep-10	23-Sep-10
Explosives (ug/L)														
1,3,5-Trinitrobenzene	1,100	---	*0.39 U*	*0.44 U*	*0.39 U*	*0.38 U*	*0.38 U*	-	-	*0.38 U*	*0.39 U*	*0.38 U*	*0.38 U*	*0.39 U*
1,3-Dinitrobenzene	3.7	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
2,4,6-Trinitrotoluene	2.2	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.140 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
2,4-Diamino-6-nitrotoluene	---	---	*0.38 U*	*0.43 U*	*0.38 U*	*0.37 UJ*	*0.37 UJ*	-	-	*0.37 U*	*0.38 UJ*	*0.38 U*	*0.37 U*	*0.38 U*
2,4-Dinitrotoluene	0.22	0.1	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
2,6-Diamino-4-nitrotoluene	---	---	*0.34 U*	*0.4 U*	*0.34 U*	*0.3 U*	*0.3 U*	-	-	*0.34 U*	*0.34 U*	*0.34 U*	*0.33 U*	*0.34 U*
2,6-Dinitrotoluene	37	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
2-Amino-4,6-dinitrotoluene	73	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
4-Amino-2,6-dinitrotoluene	73	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
HMX	1,800	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
3-Nitrotoluene	3.7	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
Nitrobenzene	0.12	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.1 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
Nitroglycerin	3.7	---	*1.5 U*	*1.7 U*	*1.4 U*	*1.4 U*	*1.4 U*	-	-	*1.4 U*	*1.5 U*	*1.4 U*	*1.4 U*	*1.5 U*
2-Nitrotoluene	0.31	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
PETN	---	---	*1.5 U*	*1.7 U*	*1.4 U*	*1.4 U*	*1.4 U*	-	-	*1.4 U*	*1.5 U*	*1.4 U*	*1.4 U*	*1.5 U*
4-Nitrotoluene	4.2	---	*0.39 U*	*0.44 U*	*0.39 UJ*	*0.38 U*	*0.38 U*	-	-	*0.38 U*	*0.39 U*	*0.38 U*	*0.38 U*	*0.39 U*
RDX	0.61	---	*0.15 U*	*0.17 U*	*0.14 U*	*0.14 U*	*0.14 U*	-	-	*0.14 U*	*0.15 U*	*0.14 U*	*0.14 U*	*0.15 U*
Perchlorate (ug/L)														
Perchlorate	15	2	*0.020 U*	*0.02 U*	*0.02 U*	*0.02 U*	*0.02 U*	-	-	*0.020 U*	*0.020 U*	*0.02 U*	*0.02 U*	*0.02 U*
Metals (ug/L)														
Total Lead	15	15	*0.50 U*	*0.50 U*	*0.50 U*	*0.50 U*	**38**	*0.50 U*	*0.50 U*	*0.50 U*	4.0	4.3	*0.5 U*	4.1
Dissolved Lead	15	15	*0.20 U*	*0.20 U*	0.25 J	0.93 J	1.7	*0.20 U*	*0.20 U*	*0.20 U*	*0.20 U*	1.9	*0.20 U*	2.1

Notes:

--- = Not listed in standards

J - Analyte is present but detected below reporting limit. Value may not be accurate or precise (estimated)

U - Not detected; reporting limit provided

UJ - Analyte was not detected; however, the result is considered estimated due to low laboratory recovery (MS/MSD or surrogate)

Bold = above North Carolina screening value

Bold = above DoD RMUS screening level

Detected concentration

a.) DoD RMUS operational range assessment screening values for human drinking water. Obtained from "Protocol for Choosing Screening Values for Range and Munitions Use Subcommittee Operational Range Assessment Matrix"

b.) NC protection standards obtained from North Carolina Administrative Code for groundwater (15A NCAC 02L .0202)

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Table 8-5: Conclusions of the Five-Year Review

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
G-10 Impact Area	Indicates RDX and TNT potentially will exceed REVA trigger values at edge of MC loading area but will not reach surface water receptor location.	Indicates TNT potentially will exceed REVA trigger values at edge of MC loading area but not at point where sediment enters the New River.	Indicates RDX, TNT, HMX, and perchlorate potentially will reach the Castle Hayne aquifer above REVA trigger values, but indicates only perchlorate will potentially exceed REVA trigger value at drinking water well.	Surface water samples collected in vicinity include SW-1, SW-6, and SW-07. Perchlorate detected below screening value in SW-07. Groundwater wells and public supply wells around G-10 Impact Area were sampled. Perchlorate detected in 2 shallow monitoring wells and 6 monitoring wells screened in Castle Hayne aquifer. None exceeded screening levels. Lead detected in 4 shallow wells below screening values. 2 explosive compounds detected in MW-19 (deep well). The detection of 2,4-dinitrotoluene exceeded the North Carolina IMAC. The well was resampled the following day and this constituent was not detected.	Will resample MW-19 due to the North Carolina IMAC exceedance of 2,4-dinitrotoluene. Surface water and groundwater will be resampled in the next REVA five-year review, or sooner if a significant change occurs that could affect determinations made during the five-year review. Will include the public supply well immediately west of the G-10 Impact Area in the next REVA five-year review sampling event.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
F-6	Indicates RDX, TNT, and perchlorate potentially will exceed REVA trigger values at edge of MC loading area; indicates perchlorate potentially will exceed REVA trigger value at surface water receptor location.	Indicates TNT potentially will exceed REVA trigger values at edge of MC loading area but not at point where sediment enters the New River.	Indicates RDX, HMX, and perchlorate potentially will reach the Castle Hayne aquifer above REVA trigger values, but indicates only perchlorate will potentially exceed REVA trigger value at drinking water well.	Surface water sample collected in vicinity includes SW-7. Perchlorate detected below screening value. PSW-G in vicinity was sampled. Lead detected below screening value.	No further action in conjunction with this five-year review. The public supply well located immediately west of the F-6 MC loading area should be considered for sampling in the next REVA sampling event. The range is expected to move south of the G-10 Impact Area by FY2015. Reassess in the next five-year review to determine if use from 2010-2015 warrants further evaluation, and which wells and surface water, if any, should be sampled.
G-8 and G-9	Indicates RDX and HMX potentially will exceed REVA trigger values at edge of MC loading area but not at downstream receptor location.	No predicted migration	Indicates HMX and RDX will potentially reach the Castle Hayne aquifer above REVA trigger values but will not reach a drinking water well.	Surface water samples collected in vicinity include SW-1 and SW-7. Only perchlorate detected, and it was below screening value. MW-7, MW-9, MW-19, and PSW-E collected in vicinity. Lead and perchlorate detected in shallow groundwater at MW-7 and MW-9 below screening value. Two explosive compounds detected in MW-19 (Castle Hayne aquifer) below screening values.	Training is not conducted at these ranges. No further action in condjunction with this five-year review.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
K-211 and K-212	Indicates RDX, TNT, and perchlorate potentially will reach edge of MC loading area; indicates perchlorate potentially will reach a downstream receptor location above REVA trigger values in 2 subwatersheds.	No predicted migration	Indicates HMX, RDX, TNT, and perchlorate will potentially reach the water table above REVA trigger values. No drinking water well is in vicinity.	Surface water samples collected in vicinity SW-2 and SW-4. Lead detected in SW-2, and perchlorate detected in SW-4; all below screening values. Groundwater samples in vicinity collected from shallow groundwater in wells MW-1, MW-2, and MW-8. Perchlorate detected below screening in MW-2; lead detected in MW-1 and MW-2. Detection of 18 µg/L in MW-1 (shallow well) exceeded RMUS and North Carolina IMAC screening value of 15 µg/L.	Will resampled MW-01 due to total lead screening value exceedance. Sampling results will determine if annual sampling should continue. Will reassess in the next five-year Review.
K-405	Indicates RDX and TNT potentially will reach the edge of MC loading area above REVA trigger values; indicates perchlorate potentially will reaches a downstream receptor location above REVA trigger value.	Indicates RDX and TNT potentially will exceed REVA trigger values at edge of MC loading area.	Indicates RDX, TNT, and perchlorate potentially will reach the water table above REVA trigger values; no drinking water wells are in vicinity.	Surface water sample collected at SW-2. Lead detected below screening value. Shallow groundwater sample collected at MW-2. Lead and perchlorate detected below screening value.	Training is no longer conducted at Range-405. No further action in conjunction with this five-year review.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
K-510	Indicates RDX, TNT, and perchlorate potentially will reach edge of loading area above REVA trigger values; indicates perchlorate potentially will reach a downstream receptor location above REVA trigger value.	Indicates TNT potentially will exceed REVA trigger value at edge of MC loading area.	Indicates RDX, TNT, and perchlorate potentially will reach the water table above REVA trigger values; no drinking water wells in vicinity.	Surface water sample collected at SW-EOD2. No detections were made. Shallow groundwater samples collected in vicinity include MW-6 and MW-7. Lead and perchlorate were detected in both wells below screening values.	Reassess in the next five-year review. No further action in conjunction with this five-year review.
L-5	Indicates RDX, TNT, and perchlorate potentially will exceed REVA trigger values at edge of MC loading area; indicates perchlorate potentially will exceed REVA trigger value at receptor location.	No predicted migration	Indicates RDX, TNT, and perchlorate potentially will reach the Castle Hayne aquifer above REVA trigger values; indicates perchlorate will exceed REVA trigger values at drinking water well.	No surface water samples were collected in vicinity. Groundwater from the Castle Hayne aquifer was sampled in L-5 MW-01D and no detections were made.	Re-evaluate in the next five-year review. The well south of L-5 (L-5 MW-01D) should be included in the sampling event in next five-year review to be protective of county supply wells south of the installation. No further action in conjunction with this five-year review.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
F-2 and F-5	Indicates RDX potentially will exceed REVA trigger values at edge of MC loading area; indicates it will not exceed at downstream receptor location.	No predicted migration	Indicates RDX potentially will reach Castle Hayne aquifer and a drinking water well above REVA trigger value.	Surface water was sampled in vicinity at SW-Wallace Creek. Lead was detected below its screening value. Groundwater in the Castle Hayne aquifer was sampled in vicinity at PSWs H, C, D, and G. Lead was detected at PSWs C, D, and G. It exceeded its screening value of 15 µg/L at PSW D with a concentration of 38 µg/L. The well was resampled in December 2010, and lead was not detected.	The public supply well located within the F-2 and F-5 MC loading area should be included in the next REVA sampling event. The ranges are expected to move south of the G-10 Impact Area by FY2015. Reassess in the next five-year review to determine if use from 2010-2015 warrants sampling in vicinity. No further action in conjunction with this five-year review.
ETA-1	Indicates RDX, TNT, and perchlorate potentially will exceed REVA trigger values at edge of MC loading area; Indicates perchlorate potentially will exceed REVA trigger value at downstream receptor location.	Indicates TNT potentially will exceed REVA trigger value at edge of MC loading area.	Indicates RDX, TNT, and perchlorate will potentially reach the Castle Hayne aquifer above REVA trigger values; indicates perchlorate will potentially exceed REVA trigger value at drinking water well.	A surface water sample was collected in Courthouse Bay, and no constituents were detected. PSW-BB was sampled in vicinity. Lead was detected below its screening value.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
ETA-3	Indicates RDX, TNT, and perchlorate potentially will exceed REVA trigger values at edge of MC loading area; indicates perchlorate potentially will exceed REVA trigger value at downstream receptor location.	Indicates RDX and TNT potentially will exceed REVA trigger values at edge of MC loading area.	Indicates RDX, TNT, and perchlorate will potentially reach the Castle Hayne aquifer above REVA trigger values; indicates perchlorate will potentially exceed REVA trigger values at drinking water well.	Surface water samples collected in vicinity include SW-Wallace Creek. Lead was detected below screening value. PSW-G, PSW-C, and PSW-D were sampled in vicinity. Lead was detected in all three wells. One detection in PSW-D exceeded screening criteria. This well was resampled in December 2010, and lead was not detected.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.
ETA-4	Indicates RDX and TNT will potentially exceed REVA trigger values at edge of MC loading area but will not reach downstream receptor location.	No predicted migration	Indicates RDX and TNT will potentially reach the Castle Hayne aquifer above REVA trigger values but not reach a drinking water well.	Surface water was collected in vicinity at SW-2. No detections were made. Shallow groundwater was sampled in MW-11, and groundwater from the Castle Hayne aquifer was sampled in MW-17 and PSW-B. No detections in MW-11; lead was detected below its screening value in MW-17 and PSW-B.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.
ETA-7	Indicates RDX and TNT potentially will exceed REVA trigger values at edge of MC loading area but will not reach downstream receptor location.	Indicates TNT potentially will exceed REVA trigger values at edge of MC loading area but not at point where sediment enters the New River.	Indicates RDX and TNT will potentially reach the Castle Hayne aquifer above REVA trigger values but not reach a drinking water well.	No surface water or groundwater samples were collected in vicinity.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.

MC Loading Area	Surface Water Screening-Level Analysis Result	Sediment Screening-Level Analysis Result	Groundwater Screening-Level Analysis Result	Field Sampling Result	Conclusion
Stones Bay Area	Indicates RDX, TNT, HMX, and perchlorate potentially will exceed REVA trigger values at edge of MC loading area; indicates perchlorate potentially will reach a downstream receptor location above REVA trigger values.	No predicted migration	Indicates RDX and TNT will potentially reach the Castle Hayne aquifer above REVA trigger values but will not reach a drinking water well.	No surface water samples or groundwater samples were collected in vicinity. A surface water sample was taken down gradient in Courthouse Bay, and no constituents were detected.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.
EOD-2	Indicates RDX, TNT, HMX, and perchlorate potentially will reach downstream receptor location above REVA trigger values.	Indicates TNT potentially will exceed REVA trigger value at edge of MC loading area.	Indicates RDX, TNT, HMX, and perchlorate potentially will reach the water table above REVA trigger values, and all will discharge to the New River above REVA trigger values.	Surface water was sampled at SW-EOD2, and no detections were made. Shallow groundwater was sampled in vicinity at MW-6. Lead and perchlorate were detected below screening values.	Re-evaluate in the next five-year review. No further action in conjunction with this five-year review.

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APPENDIX B – Protocol for Choosing Screening Values for Range and Munitions Use Subcommittee Operational Range Assessment Matrix

HQMC has indicated that results of environmental sampling for munitions constituents (MC) should be reviewed against the applicable federal and state regulatory standards and guidelines to determine the next step in the assessment process. The United States (U.S.) Air Force, U.S. Army, U.S. Marine Corps, and U.S. Navy developed informal guidelines jointly in November 2007. These guidelines for drinking water and surface water are presented in the following sections.

Background

Department of Defense (DoD) Directive 4715.11 and DoD Instruction (DODI) 4715.14 require each service to assess its operational ranges within the continental United States. Each service has developed its own Operational Range Assessment Program and provides its own direction and guidance for conducting its range assessments. The operational range assessment programs determine whether there has been a release or substantial threat of release of MC from an operational range to off-range areas that creates an unacceptable risk to human health and/or the environment. This document provides screening-level values to assist the operational range assessment programs in determining if there may be an unacceptable risk to human health and/or the environment. As provided in the individual services' range assessment programs and guidance, sampling may be warranted during the range assessment process.

To promote consistency across the services' range assessment programs, the DoD Range and Munitions Use Subcommittee (RMUS) has developed screening values presented in this document to which all services will compare their surface water, groundwater, and sediment sampling data. The RMUS involved toxicologists and the Tri-Service Environmental Risk Assessment Work Group (TSERAWG) in the development and review of these procedures and screening values. Screening values have been selected from a hierarchy of sources with recognized authority, acceptance, and applicability. This list of screening values has been developed as a general list of commonly found MC used in various range training activities. This list is not intended to be inclusive of all munitions types nor is it intended that the entire list be monitored for all ranges to be investigated. The specific list of MC to be evaluated will be determined on a site-by-site basis during the range assessment process, based on the munitions used and source, pathway, and receptor characteristics.

To promote defensibility, the methodology and scientific basis of collecting and analyzing samples should be as rigorous as the process used to comply with standards associated with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) risk screening and analysis as provided in the individual services' program direction and guidance.

Sampling data will be compared to the appropriate media screening values presented here to determine if further assessment is appropriate. MC concentrations less than these conservative screening values will be considered to have no adverse impacts on human health and/or the environment and, therefore, would not require any further action.

Sampling data with MC concentrations exceeding these screening values do not necessarily indicate the presence of an unacceptable risk or that cleanup or other mitigation measures will be necessary. Results above these conservative screening values indicate that a more detailed evaluation of the existing data is required. An initial assessment of data exceeding screening values would consider such things as review and update of the conceptual site model, additional data collection, site-specific screening evaluations, and potential cumulative health risk effects from multiple parameters.

Supplemental actions and/or investigations may be conducted as part of the data assessment. These additional actions may include, but are not limited to, more sophisticated modeling (three-dimensional modeling), data refinement, weight-of-evidence determination, and additional sampling and analysis. If indicated by this initial screening, a site-specific risk assessment may be conducted as well. Any site-specific risk assessments conducted should comply with regulations and guidance associated with CERCLA. Since the range assessments are internal to DoD and are not a regulatory requirement, involvement with regulators is not part of the data assessment process. Regulatory involvement in the range assessment process is described in the DODI 4715.14 *Operational Range Assessments* (30 November 2005) and in the DoD memorandum "DoD-Regulator Interactions for Operational Range Assessments" (15 August 2006).

If the conclusion of the range assessment is, or most likely is, that an off-range release has occurred or is likely to occur, creating an unacceptable risk, the assessor should follow the appropriate services' program direction and guidance.

Approach

The services will only use these screening values for the appropriate exposure scenarios identified for the site location. To facilitate development of uniform values, the most prevalent and significant exposure scenarios were selected. These scenarios include groundwater, surface water, and sediment migration pathways from on-range to off-range areas occupied by human and/or ecological receptors. For human health, the most significant exposure scenario is consumption of either surface water or groundwater. For ecological receptors, direct contact with surface water and sediment by aquatic organisms (e.g., fish, algae) was selected as the most significant exposure scenario. Generally, aquatic organisms are considered a conservative representative for other ecological receptors because they will have continuous exposure to the water and sediment through their entire lifecycle. Ecological screening values are provided for both fresh and marine surface water and sediments. The ecological values are not appropriate for determining human exposure from consumption of ecological receptors exposed to potentially impacted water and/or sediments.

Multiple agencies have developed drinking water, surface water, and sediment values indicating levels that should not cause adverse effects to consumers and aquatic organisms using a variety of processes and assumptions. The RMUS developed a hierarchy of sources for each of the identified exposure scenarios to guide the selection of screening values for this protocol. The hierarchies are prioritized lists of screening value sources in order of recognized authority and applicability and are described in the Drinking Water and Surface Water Systems sections. From the prioritized list, the first and most appropriate screening value found for each MC was selected for use in this protocol. Where there were multiple values for the same MC from the same hierarchy source, the RMUS selected the most conservative value.

Other Considerations

- The screening values presented here are the default values. If there are appropriate state or local regulatory standards that are more stringent, they take precedence and will be used on a site-specific basis. Assessors will investigate state and local regulations to determine if they are appropriate.
- The screening values were selected assuming a chronic exposure to the receptors. The assessor should verify that a specific species/MC acute value is not lower than the identified chronic value.
- These screening values are based on current existing information. The range assessments will be based upon the information available at the time of the assessment. As U.S. EPA or other federal agencies develop new standards, regulations, or guidance or new information affecting MC tables is published, the screening values will be re-evaluated and, where appropriate, updated. A designated RMUS member will be responsible for reviewing screening values and sources at least biennially. The RMUS and TSERAWG will be involved with any updates to the screening values.
- Sampling results for metals and perchlorate will be compared to background sampling data, if available. The range will not be considered a source of MC migration when the sampling results are less than or equivalent to background concentrations.
- The statistical analyses used by each service to compare sampling data to screening values and/or background values will be described in individual sampling plans and are not discussed further in this document.
- In exposure scenarios where surface water has potential to impact human health and ecological receptors, both drinking water and ecological surface water screening values need to be considered. The more conservative value should be selected for comparison with analytical results.

Drinking Water

Drinking water values are usually appropriate for an exposure scenario where humans are using the water (surface water or groundwater) as a drinking water source. These screening values may not be appropriate if humans are both drinking the water and consuming aquatic organisms from that source. The RMUS recognized the samples may be collected from raw sources such as wells or other sampling locations and not necessarily from finished drinking water supply wells or surface water intakes to which most screening values are applicable. Therefore, while it is appropriate to use the drinking water standards as screening values only, note they are not directly enforceable regulatory standards. When collecting samples from these raw sources, these values will be evaluated technically on a case-by-case basis to determine the appropriateness of the drinking water values. Table E-1 presents the human health drinking water screening values.

The hierarchy for human health drinking water screening values:

1. Applicable standards or benchmarks that have been recognized or released by the U.S. EPA.
    a. Regional screening levels (RSLs) - The values from the RSL table were used as the default U.S. EPA value for drinking water.
    b. Other U.S. EPA drinking water values (maximum contaminant levels)
2. When no U.S. EPA values are available, values from other government agencies will be considered (e.g., National Oceanic and Atmospheric Administration, Department of Energy).
3. If none of those are available, scientifically peer reviewed published literature will be researched.

Other Considerations

- The DoD memorandum "Perchlorate Release Management Policy" (22 April 2009) identifies a level of concern for managing perchlorate at 15 parts per billion. That value will be used for drinking water in the absence of more stringent state or local standards.
- Toxicity studies have indicated that 2,4-dinitrotoluene (2,4-DNT) and 2,6-DNT may be carcinogenic when present together. When both compounds are detected at a site, the screening level for the 2,4-DNT, 2,6-DNT mixture should be used instead of the individual screening levels.

Surface Water Systems; Fresh and Marine

For surface water systems, the RMUS considered the scenarios of ecological receptors being exposed to surface water and sediment from either fresh or marine waters. For brackish waters, state guidance on the use of fresh or marine screening levels for the specific water bodies (bays, estuaries, rivers, etc.) should be followed. Due to the sensitivity of some of the ecological receptors, these values are not intended to be applicable for every possible type of species. These values were selected as a conservative screening tool protective of a majority of species. Therefore, when sampling, the specific species type should be taken into consideration when comparing screening values and evaluating whether there is a potential unacceptable risk.

The overall hierarchy of sources for determining surface water system impacts on the ecological receptor is the same whether the focus is on freshwater or marine water. The appropriate sections and values must be selected for the exposure scenario being assessed. Ecological screening values are presented in Table E-2 for freshwater surface water systems and Table E-3 for marine surface water systems.

The hierarchy for ecological surface water and sediment for both fresh and marine environments is listed below:

1. Applicable standards or benchmarks recognized or released by the U.S. EPA
    a. National Recommended Ambient Water Quality Criteria developed by the U.S. EPA Office of Water
    b. Ecotox Thresholds developed by U.S. EPA Office of Solid Waste and Emergency Response
    c. Ecological Screening Values developed by U.S. EPA regions
2. When no U.S. EPA values are available, values developed by other government agencies will be considered.
3. If none of those are available, scientifically peer reviewed published literature will be researched.

Other Considerations

- These values are not relevant for recreational contact with surface water by human receptors. This scenario can be evaluated if appropriate for a site-specific circumstance.

Operational Range Assessment Screening Value Tables

Table E-1 - Human Drinking Water Values

MC	CAS #	Screening Value Value (µg/L)	Source
Antimony	7440-36-0	6	EPA RSL Table[a]
Arsenic	7440-38-2	10	EPA RSL Table[a]
Barium	7440-39-3	2000	EPA RSL Table[a]
Cadmium	7440-43-9	5	EPA RSL Table[a]
Chromium[1]	7440-47-3	100	EPA RSL Table[a]
Copper	7440-50-8	1300	EPA RSL Table[a]
Lead	7439-92-1	15	EPA RSL Table[a]
Manganese	7439-96-5	880	EPA RSL Table[a]
Mercury[2]	7439-97-6	2	EPA RSL Table[a]
Molybdenum	7439-98-7	180	EPA RSL Table[a]
Nickel	7440-02-0	730	EPA RSL Table[a]
Silver	7440-22-4	180	EPA RSL Table[a]
Vanadium	7440-62-2	180	EPA RSL Table[a]
Zinc	7440-66-6	11000	EPA RSL Table[a]
HMX	2691-41-0	1800	EPA RSL Table[a]
RDX	121-82-4	0.61	EPA RSL Table[a]
TNT	118-96-7	2.2	EPA RSL Table[a]
1,3,5-TNB	99-35-4	1100	EPA RSL Table[a]
1,3-DNB	99-65-0	3.7	EPA RSL Table[a]
Tetryl	479-45-8	150	EPA RSL Table[a]
NB	98-95-3	0.12	EPA RSL Table[a]
2A-4,6-DNT	35572-78-2	73	EPA RSL Table[a]
4A-2,6-DNT	19406-51-0	73	EPA RSL Table[a]
DNT-mixture 2,4/2,6	25321-14-6	.099	EPA RSL Table[a]
2,6-DNT	606-20-2	37	EPA RSL Table[a]
2,4-DNT	121-14-2	73	EPA RSL Table[a]
2-NT (o-)	88-72-2	0.31	EPA RSL Table[a]
3-NT (m-)	99-08-1	730	EPA RSL Table[a]
4-NT (p-)	99-99-0	4.2	EPA RSL Table[a]
Nitroglycerin	55-63-0	3.7	EPA RSL Table[a]
PETN	78-11-5	NA	
Perchlorate	14797-73-0	15	DoD[b]

Notes:
These values are default values. Local standards may be more stringent and take precedence.
A – Amino
CAS – Chemical Abstracts Service registry
DNB – Dinitrobenzene
HMX – Cyclotetramethylene Tetranitramine
NB – Nitrobenzene
NT – Nitrotoluene
PETN – Pentaerythritol Tetranitrate
RDX – Cyclotrimethylene Trinitramine
TNB – Trinitrobenzene
TNT – Trinitrotoluene

NA – not available (Screening levels were not developed due to the lack of scientific data on the specific constituents.)

[1] Screening value is for total chromium.
[2] Screening value is for elemental mercury.

Sources:
[a] "Regional Screening Levels for Chemical Contaminants at Superfund Sites" which is an update for Region 3 RBCs, Region 6 MSSLs, and Region 9 PRGs. From: http://www.epa.gov/region09/superfund/prg/ (April 2009).
[b] DoD" 22 Apr 2009 memorandum, subject: Perchlorate Release Management Policy.

Table E-2 – Ecological Freshwater Surface Water System Values

		Freshwater Surface Water		Freshwater Sediment	
MC	**CAS #**	**Value (µg/L)**	**Source**	**Value (mg/kg)**	**Source**
Antimony	7440-36-0	30	EPA Region 3[a]	12	EPA Region 4[d]
Arsenic	7440-38-2	150	EPA NRWQC[2,b]	8.2	EPA OSWER*[,c]
Barium	7440-39-3	3.9	EPA OSWER[c]	20	EPA Region 6[f]
Cadmium	7440-43-9	0.25	EPA NRWQC[2,3,b]	1.2	EPA OSWER[c]
Chromium (VI)	7440-47-3	11	EPA NRWQC[2,b]	81	EPA OSWER[c]
Copper	7440-50-8	9	EPA NRWQC[2,3,b]	34	EPA OSWER[c]
Lead	7439-92-1	2.5	EPA NRWQC[2,3,b]	47	EPA OSWER[c]
Manganese	7439-96-5	80	EPA OSWER[c]	460	Ontario Guidelines[i]
Mercury	22967-92-6	0.77	EPA NRWQC[2,b]	0.15	EPA OSWER[c]
Molybdenum	7439-98-7	240	EPA OSWER[c]	4	D.D.MacDonald et al., 1994[g]
Nickel	7440-02-0	52	EPA NRWQC[2,3,b]	21	EPA OSWER[c]
Silver	7440-22-4	3.2	EPA NRWQC[2,3,b]	2	EPA Region 4[d]
Vanadium	7440-62-2	19	EPA OSWER[c]	50	NOAA Screening Tables[h]
Zinc	7440-66-6	120	EPA NRWQC[2,3,b]	150	EPA OSWER[c]
HMX	2691-41-0	150	EPA Region 3[a]	.0047-.47	EPA Region 4[1,d]
RDX	121-82-4	190	EPA Region 4[d]	.013-1.3	EPA Region 4[1,d]
TNT	118-96-7	90	EPA Region 4[d]	.092-9.2	EPA Region 4[1,d]
1,3,5-TNB	99-35-4	11	EPA Region 4[d]	.0024-.24	EPA Region 4[1,d]
1,3-DNB	99-65-0	20	EPA Region 4[d]	.0067-.67	EPA Region 4[1,d]
Tetryl	479-45-8	NA		53.4	Nipper et al., 2002[j] (fine grain sediment)
NB	98-95-3	270	EPA Region 4[d]	0.488	EPA Region 4[d]
2A-4,6-DNT	35572-78-2	20	EPA Region 4[d]	NA	
4A-2,6-DNT	1946-51-0	NA		NA	
2,6-DNT	606-20-2	42	EPA Region 4[d]	0.0206	EPA Region 4[d]
2,4-DNT	121-14-2	44	EPA Region 3[a]	0.0751	EPA Region 4[d]
2-NT (o-)	88-72-2	NA		NA	
3-NT (m-)	99-08-1	750	EPA Region 3[a]	NA	
4-NT (p-)	99-99-0	1900	EPA Region 3[a]	NA	
Nitroglycerin	55-63-0	138	EPA Region 3[a]	NA	
PETN	78-11-5	85000	EPA Region 3[4,a]	NA	
Perchlorate	14797-73-0	9300	Dean et al.[e]	NA	

Note:
mg/kg –
NA – not available (Screening levels were not developed due to the lack of scientific data on the specific constituents.)
* - Arsenic values for sediment will be compared to background sampling data, if available. The range will not be considered a source of MC migration when the sampling results are less than or equivalent to background concentrations.

[1] These values are dependent on the sediment total organic carbon (TOC). The lower bound is for 1% TOC. Upper bound is for 100% TOC. To determine the site-specific value, multiply the % TOC by the lower bound. For example, for TNT in sediment with 5% TOC, it would be 0.46 (5*0.092=0.46).
[2] Value applies to dissolved metals.
[3] The value is dependent on the hardness of the water; provided value is for a water hardness of 100 milligrams per liter as $CaCO_3$.
[4] For PETN, U.S. EPA Region III values came from TNRCC 2001 & 2000, which are documented sources k and l below.

Sources:
[a] - EPA Region 3. Ecological Risk Assessment Freshwater Screening Benchmarks. 2007.

[b] EPA, Office of Water, Office of Science and Technology (4304T). National Recommended Water Quality Criteria. 2006.
[c] EPA Office of Solid Waste and Emergency Response. Ecotox Thresholds. 1996.
[d] EPA Region 4. Ecological Risk Assessment Bulletins – Supplement to RAGS. 2001.
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[f] EPA Region 6. Screening Level Ecological Risk Assessment Protocol. 1999.
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[j] Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Porewaters. Marine Pollution Bulletin, 44: 789-806. 2002.
[k] TNRCC. Guidance for Conducting Ecological Risk Assessment and Remediation Sites in Texas, Toxicology and Risk Assessment Section. 2001.
[l] TNRCC. Texas Surface Water Quality Standards, Texas Administrative Code, Title 30, Chapter 307, Effective 17, 2000.

Table E-3 – Ecological Marine Surface Water System Values

		Marine Surface Water		Marine Sediment	
MC	**CAS #**	**Value (µg/L)**	**Source**	**Value (mg/kg)**	**Source**
Antimony	7440-36-0	30	Suter and Tsao, 1996[e]	2	NOAA 1990[g]
Arsenic	7440-38-2	36	USEPA, 2004[b]	7.24	MacDonald et al., 2000*[,h]
Barium	7440-39-3	4	Suter and Tsao, 1996[e]	NA	
Cadmium	7440-43-9	8.8	USEPA, 2004[b]	0.68	MacDonald et al., 2000[h]
Chromium (VI)	7440-47-3	50	USEPA, 2004[b]	52.3	MacDonald et al., 2000[h]
Copper	7440-50-8	3.1	USEPA, 2004[b]	18.7	MacDonald et al., 2000[h]
Lead	7439-92-1	8.1	USEPA, 2004[b]	30.2	MacDonald et al., 2000[h]
Manganese	7439-96-5	120	Suter and Tsao, 1996[e]	460	Ontario Guidelines[i]
Mercury	22967-92-6	0.94	USEPA, 2004[b]	0.14	
Molybdenum	7439-98-7	370	Suter and Tsao, 1996[e]	NA	
Nickel	7440-02-0	8.2	USEPA, 2004[b]	15.9	MacDonald et al., 2000[h]
Silver	7440-22-4	1.9	USEPA, 2004[b]	0.73	MacDonald et al., 2000[h]
Vanadium	7440-62-2	20	Suter and Tsao, 1996[e]	NA	
Zinc	7440-66-6	81	USEPA, 2004[b]	124	MacDonald et al., 2000[h]
HMX	2691-41-0	330	Talmage et al., 1999[o]	.0047-.47	EPA Region 4[1,a]
RDX	121-82-4	5000	Nipper et al., 2001[k]	.013-1.3	EPA Region 4[1,a]
TNT	118-96-7	180	Nipper et al., 2001[k]	.092-9.2	EPA Region 4[1,a]
1,3,5-TNB	99-35-4	25	Nipper et al., 2001[k]	.0024-.24	EPA Region 4[1,a]
1,3-DNB	99-65-0	180	Nipper et al., 2001[k]	.0067-.67	EPA Region 4[1,a]
Tetryl	479-45-8	NA	NA	53.4	Nipper et al., 2002[l] (fine grain sediment)
NB	98-95-3	66.8	USEPA, 2002[c]	27	Talmage and Opresko, 1995[j]
2A-4,6-DNT	35572-78-2	1480	TNRCC, 2001[m] and TNRCC, 2000[n]	NA	
4A-2,6-DNT	1946-51-0	NA	NA	NA	
2,6-DNT	606-20-2	1000	Nipper et al., 2001[k]	0.55	Nipper et al., 2002[l]
2,4-DNT	121-14-2	480	Nipper et al., 2001[k]	0.23	Talmage and Opresko, 1995[j]
2-NT (o-)	88-72-2	NA	NA	NA	
3-NT (m-)	99-08-1	NA	NA	NA	
4-NT (p-)	99-99-0	NA	NA	NA	
Nitroglycerin	55-63-0	138	TNRCC, 2001[m] and TNRCC, 2000[n]	NA	
PETN	78-11-5	85000	EPA Region 3[2,d]	NA	
Perchlorate	14797-73-0	9300	Dean et al., 2004[f]	NA	

		Marine Surface Water		Marine Sediment	
MC	**CAS #**	**Value (µg/L)**	**Source**	**Value (mg/kg)**	**Source**

Note:
NA – not available (Screening levels were not developed due to the lack of scientific data on the specific constituents.
* - Arsenic values for sediment will be compared to background sampling data, if available. The range will not be considered a source of MC migration when the sampling results are less than or equivalent to background concentrations.

[1] These values are dependent on the sediment TOC. The lower bound is for 1% TOC. Upper bound is for 100% TOC. To determine the site-specific value, multiply the % TOC by the lower bound (e.g., for TNT in sediment with 5% TOC, it would be 0.46)(5*0.092=0.46).
[2] EPA Region III for PETN marine water refers to U.S. EPA Region III's Freshwater Screening Benchmark table for a value. These values came from TNRCC 2001 & 2000, which are documented sources m and n below.

Sources:
[a] EPA Region 4. Ecological Risk Assessment Bulletins - Supplement to RAGS. 2001.
[b] EPA – USEPA 2004 National Recommended Water Quality Criteria Office of Water and Office of Science and Technology.
[c] EPA – USEPA 2002 Ecological Risk Assessment Bulletin 2/11/2002. Waste Management Division, Freshwater Surface Screening Values for Hazardous Waste Sites, February.
[d] EPA Region 3, Ecological Risk Assessment Freshwater Screening Benchmarks, March 2007
[e] Suter and Tsao, 1996 Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 196 Revision. ES/ER/Tm-96/R2.
[f] Dean, K.E., R.M. Palachek, J.L. Noel, R. Warbritton, J. Aufderheide, and J. Wireman. 2004. Development of Freshwater Water-Quality Criteria for Perchlorate. Environmental Toxicology and Chemistry 23(6):1441-1451.
[g] The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Technical Memorandum NOS OMA 52. Long, E.R. and L.G. Morgan. 1990.
[h] MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology, 39: 20-31.
[i] Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario. Persaud, D., R. Jaagumagi, and A. Hayton. 1993.
[j] Talmage, S.S., and D.M. Opresko. 1995. Draft Ecological Criteria Documents for Explosives, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
[k] Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, K. Miller, and S. Saepoff, 2001. Development of Marine Toxicity Data for Ordnance Compounds, Archives of Environmental Contamination and Toxicology, 41:308-31.
[l] Nipper, M., R.S. Carr, J.M. Biedenbach, R.L. Hooten, and K. Miller. 2002. Toxicological and Chemical Assessment of Ordnance Compounds in Marine Sediments and Porewaters. Marine Pollution Bulletin, 44: 789-806.
[m] TNRCC 2001 Guidance for Conducting Ecological Risk Assessment and Remediation Sites in Texas, Toxicology and Risk Assessment Section, December.
[n] TNRCC 2000 Texas Surface water Quality Standards, Texas Administrative Code, Title 30, Chapter 307, Effective 17, 2000.
[o] Talmage, S.S., D.M. Opresko, C.J. Maxwell, J.E. Welsh, M. Cretelia, P.H. Reno, and F.B. Daniel. 1999. Nitroaromatic munition compounds: Environmental effects and screening values. Reviews in Environmental Contamination and Toxicology, 161: 1-156.

Appendix A. Small Arms Range Assessment Protocol

Small Arms Ranges

A-1

B-12

D-29A and D-29B

D-30

F-4

F-11A and F-11B

F-18

I-1

K-302

K-309

K-315

K-317

K-319

K-321 and K-321A

K-325

K-402

K-406A and K-406B

MAC 1,2,4,6 and 6

Alpha, Bravo, Charlie Ranges

Dodge City

Hathcock Range

Mechanical Pistol

Multi-Purpose Range

Walk Down Pistol

Square Bay

SR-8

SR-11

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
A-1

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1958.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1958, and a bullet trap was installed in July 1999. A bullet trap was not present for 41 years of operational use. It also has a horseshoe-shaped berm behind the range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 2,042 lbs per year at Range A-1.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	During installation of the bullet trap system, the previous impact berm was remediated. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			11
Notes:			

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range contains no vegetation and has a gravel floor. The range is surrounded on 2 sides by forest, and the New River is on the east and southern side of the range.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand. The floor of the range is gravel.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has a berm behind the bullet trap on the south and a thin line of trees to the east. These 2 controls lie between the range and the New River. Thick forests are to the north and west. The range has a baffled ceilings and walls on two sides with a bullet trap in forming a wall on the south end.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
A-1

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
pH of Soil	Baymeade series soils found at the installation are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand. The floor of the range is gravel.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
A-1

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used for drinking water.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located on the edge of the New River where these activities are occurring, but current data does not indicate migration of lead off the range.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	The range is located on the bank of the New River and most runoff would be highly diluted. No T&E species or sensitive habitats have been identified nearby.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2 miles east and west of the nearest water supply wells and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Groundwater at Range A-1 is assumed to discharge to the New River due to its proximity. No T&E species or sensitive habitats have been identified in the area.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
A-1

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Surface Water Pathways	2	8
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**25**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**45**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal**
Groundwater Environmental Concern Evaluation Ranking		**Minimal***
Notes: Although the ranking score reflected a moderate concern for groundwater, shallow groundwater is assumed quickly to discharge into the New River. No potential groundwater or surface water receptors were identified, and since surface water ranking is minimal where groundwater is assumed to discharge, the groundwater ranking was lowered.		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
B-12

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1960.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1960; a bullet trap was installed in 1985. The range was operational for 25 years without a bullet trap. An earthen horseshoe-shaped berm is present behind the range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 4,063 lbs per year at Range B-12.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	During installation of the bullet trap system, the previous impact berm was mined. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			10
Notes:			

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	There is no vegetation on the range, but the surrounding area is thick forest.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has a berm behind the bullet trap, 2 walls, and a baffled ceiling.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
pH of Soil	Baymeade series soils located on the installation are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
B-12

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used for drinking water.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	The range is not in immediate proximity to a drainage pathway or to the New River where fishing and recreational activities occur. No agricultural plots are nearby.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	Surface water runoff leaving the range could enter nearby Southwest Creek which used by American alligators. The range is directly adjacent to jurisdictional wetlands.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1,000 feet north of the nearest water supply well and outside of the 10-year maximum radius of influence	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Some shallow groundwater does discharge to surface water and jurisdictional wetlands are in the immediate vicinity. The American alligator uses southwest creek located nearby and could potentially use the wetlands as well.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	10
Surface Water Pathways	2	8
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**31**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	10
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**48**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-29A and D-29B

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The ranges have been in use since 1958.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The ranges have been in use since 1958; bullet traps were installed in July 1999. The ranges were operational 41 years without a bullet trap. Earthen berms are present behind the ranges.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 8,786 lbs per year at D-29A and D-29B.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	During installation of the bullet trap systems, the previous impact berms were remediated. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			11
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-29A and D-29B

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The ranges are flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The ranges contain no vegetation and have a gravel floor. The surrounding area is primarily developed with interspersed plots of trees.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The ranges have berms behind the bullet traps, 2 walls, and baffled ceilings. The ranges have poor drainage.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-29A and D-29B

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	The range is located on the bank of the New River. Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-29A and D-29B

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. Due to the proximity of the ranges to the New River, there is a possibility of contamination moving to an exposure point for a recreational user.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	The ranges are on the bank of the New River but no T&E species have been identified in the vicinity. Jurisdictional wetlands are located just south of the ranges, and while it is assumed that runoff would primarily flow east into the New River, surface water runoff is conservatively considered a possibility of entering wetlands.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	5
Surface Water Receptor Score			10
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas. No other beneficial use of groundwater is known.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	It is assumed that groundwater at the ranges discharges directly into the New River because of its proximity; however, it is conservatively assumed that some potential MC-impacted groundwater could discharge into the wetlands located immediately south of the ranges.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	3
Groundwater Receptor Score			6
Notes			

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Surface Water Pathways	2	8
Surface Water Receptors	4	10
Sum of Surface Water Element Scores		**29**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Groundwater Pathways	3	30
Groundwater Receptors	5	6
Sum of Groundwater Element Scores		**47**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal**
Groundwater Environmental Concern Evaluation Ranking		**Minimal***
Notes: Although the score indicated groundwater concern should be moderate, professional judgment was used to decrease the concern to minimal. Conditions promote infiltration to groundwater, but shallow groundwater likely discharges to the New River because of its proximity. Although wetlands are located south of the ranges, groundwater discharge is likely to the New River, and with minimal surface water concern, groundwater concern should also be minimal.		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-30

Table 1: Range Use and Range Management (*Source*) Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1958.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1958 and does not have a bullet trap. An earthen impact berm is present behind the range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 7,842 lbs per year at Range D-30	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	Lead was removed from the impact berm in 2003 and now done as needed with no regular maintenance schedule. During the 2003 lead removal, a portion of the New River was also remediated for lead.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
D-30

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The slope of the berm is >10%.	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	5
Vegetation	The range has no vegetation and a sand floor. The surrounding area is largely developed with interspersed plots of trees.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand. The floor of the range is also sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has a partially vegetated berm separating it from the New River. It also has 2 walls and a baffled ceiling.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			10
Notes: Slope of range determined using topographic contours in GIS.			

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	The range is located on the eastern bank of the New River. Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
pH of Soil	Baymeade series soils located on the installation are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 ≤ pH ≤ 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. Because of the ranges proximity to the New River, there is a possibility of recreational users to be exposed to MC-contaminated runoff.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No identified T&E species are in vicinity. A very narrow strip of jurisdictional wetlands are <0.25 miles to the east and south, but it is not believed that surface water runoff would enter these wetlands from the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1.6 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	The range is located on the bank of the New River where it is assumed that shallow groundwater discharges. No identified T&E species are in vicinity.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	10
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**31**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Minimal***

Notes: Although the score indicated groundwater concern should be moderate, professional judgment was used to decrease the concern to minimal. Conditions promote infiltration to groundwater, but shallow groundwater likely discharges to the New River because of its proximity. No surface water or groundwater receptors were identified, and the groundwater concern was reduced to minimal since it quickly discharges to surface water.

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-4

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1960.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1960. There is a backstop berm, but it is not known how long it has been present. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 496 lbs per year at Range F-4	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	3
Range Maintenance	The area is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-4

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	Impact area is sparsely vegetated with the remainder of the range covered in short grass. The surrounding area is mostly forested.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the rifle range is the Leon-Murville-Kureb series, which is mostly fine sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	There are no identified runoff/engineering controls.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			11
Notes: Slope of range determined using topographic contours in GIS.			

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Leon fine sand series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Leon-Murville-Kureb series, which is mostly fine sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Leon-Murville-Kureb series, which is mostly fine sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. However, the range is removed enough from the recreational use of surface water that it is less likely for MC-contaminated runoff to reach the exposure point.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	The range is located in the upper reaches of Wallace Creek where the American alligator is known to inhabit. There are also red cockaded woodpeckers in the immediate vicinity.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-4

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1,000 feet east and west of the nearest water supply wells and within the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	10
Wells Identified for Agricultural or Other Beneficial Usage	The range is located just inside the installation boundary but no agricultural areas have been identified in vicinity of the range. Private well use has not been assessed; however, it is possible that private users outside the installation boundary have private wells.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	3
Sensitive Species Habitat and Threatened and Endangered Species	Because some shallow groundwater does discharge to surface water, there is a possibility for T&E species to be exposed to MC-impacted groundwater.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	3
Groundwater Receptor Score			16
Notes			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-4

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	11
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**37**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	30
Groundwater Receptors	5	16
Sum of Groundwater Element Scores		**59**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal***
Groundwater Environmental Concern Evaluation Ranking		**Moderate***
Notes: Professional judgment was used to decrease the surface water and groundwater environmental rankings because only an estimated 496 pounds of lead are deposited annually on the range, and bullet capture technology is in place.		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-11A and F-11B

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1950.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1950; a bullet trap was installed in October 1999. The range was operational for 49 years without a bullet trap.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 7,405 lbs per year at F-11A and F-11B.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	During installation of the bullet trap system, the previous impact berm was remediated. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			11
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-11A and F-11B

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The ranges contain no vegetation, but the surrounding area wooded with a developed area just to the east.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand. The range itself has a gravel floor.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has berm behind the bullet trap, 2 walls, and a baffled ceiling.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-11A and F-11B

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 2 (Site 8) were above 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			26
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-11A and F-11B

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range has no direct path to surface water used for recreation or commercial fishing.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	No identified T&E species or jurisdictional wetlands are in vicinity.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			4
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-11A and F-11B

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1,500 feet north of the nearest water supply well and just outside the 10-year maximum radius of influence boundary. To date, no data indicating MC migration has been found. General groundwater flow direction from the wells is away from the public supply wells.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas. There is no observable direct drainage channel from the range to the New River where recreational and commercial fishing activities occur.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	No T&E species or jurisdictional wetlands have been identified in vicinity.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Surface Water Pathways	2	8
Surface Water Receptors	4	4
Sum of Surface Water Element Scores		**23**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Groundwater Pathways	3	26
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**41**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Minimal**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
F-18

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970. There are earthen backstop berms, but it is unknown how long the backstop berms have been present. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 10,849 lbs per year at Range F-18.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range maintenance program was not provided during the site visit.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirmed these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The area is mostly vegetated with tall grass and is surrounded by wooded areas	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	1
Soil Type / Runoff Conditions	The primary soil type located at the range is the Onslow series, which is a sand and silt mixture.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	3
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			11
Notes: Slope of range determined using topographic contours in GIS.			

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 2 (Site 8) were above 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
pH of Soil	The Onslow series soils are strongly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Onslow series, which is a sand and silt mixture.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Clay Content in Soil	The primary soil type located at the range is the Onslow series, which is a sand and silt mixture.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Groundwater Pathway Score			22
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	The New River is used for recreational and commercial fishing activities, but no direct drainage pathway was identified connecting the range to the New River.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	No identified T&E species or jurisdictional wetlands are in vicinity.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			4
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1,500 feet north of the nearest water supply well and just outside the 10-year maximum radius of influence boundary. To date, no data indicating MC migration has been found.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater discharges to surface water, but no receptors were identified in vicinity.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	11
Surface Water Receptors	4	4
Sum of Surface Water Element Scores		**30**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	22
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**41**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
I-1

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1960.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1960; a bullet trap was installed in 1999. The range operated 39 years without a bullet trap.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 3,762 lbs per year at Range I-1.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The impact berm was mined when the bullet trap was installed. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			11
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
I-1

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling results on the installation confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range has a sand and gravel floor with no vegetation. The surrounding area is forested with the New River located only 400 feet to the south and 600 feet to the east.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Pactolus series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has a berm behind the bullet trap, 2 walls, and baffled ceilings.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
I-1

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	The range is located on the bank of the New River. Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby SWMU 474 were below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Pactolus series soils are strongly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Pactolus series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Pactolus series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located on the bank of the New River where these activities occur, but evidence does not show MC migrating from the range.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	The range is located in vicinity of bald eagle nests and several jurisdictional wetlands.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 1 mile south of the nearest water supply well and outside of the 10-year maximum radius of influence. Given proximity to the New River and wetlands, it is assumed that most shallow groundwater would discharge directly to the New River and/or wetlands.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater likely discharges to the New River and jurisdictional wetlands located immediately beside the range. Bald eagle nests are located in the vicinity and could be exposed to discharged groundwater.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Surface Water Pathways	2	8
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**34**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-302

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970; a bullet trap has not been installed and there are no backstop berms.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 10,407 lbs per year at Range K-302.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The area is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-302

Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling data confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range has some short grass, but has many bare areas that are worn down to dirt, or are mulched.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Pantengo series, which is a mixture of sand and silt.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	3
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			13
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-302

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Pantengo series soils are strongly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Pantengo series, which is a mixture of sand and silt.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Clay Content in Soil	The primary soil type located at the range is the Pantengo series, which is a mixture of sand and silt, containing little to no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Groundwater Pathway Score			26
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is not on any direct drainage pathways to the New River such that the likelihood of MC reaching the New River at detectable concentrations is low.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	The range is located on jurisdictional wetlands and in vicinity of red cockaded woodpecker nests.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

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MCB Camp Lejeune
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Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4.5 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas. It is not in a direct drainage path to the New River where recreational and commercial fishing activities occur.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	The range is located within jurisdictional wetlands and it is assumed that shallow groundwater discharges to these wetlands.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	13
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**41**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	26
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

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MCB Camp Lejeune
K-309

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970; a bullet trap has not been installed and there are no backstop berms.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 18,053 lbs per year at Range K-309.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	Area is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range has some areas with steeper slopes (5-10%).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	3
Vegetation	The area is vegetated with short grass but has some sandy, bare areas near target areas, as well as areas worn down to dirt.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Marvyn series, which is a mixture of sand and silt.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	3
Runoff/ Erosion Engineering Controls	No runoff/engineering controls.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			15
Notes: Slope of range determined using topographic contours in GIS.			

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Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, jurisdictional wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Marvyn series soils are slightly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Marvyn series, which is a mixture of sand and silt.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Clay Content in Soil	The primary soil type located at the range is the Marvyn series, which is a mixture of sand and silt.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	3
Groundwater Pathway Score			26
Notes:			

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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is far enough upgradient of the New River that MC is not expected to reach the river at detectable concentrations	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	The range is not in direct contact with sensitive habitat or T&E species but is conservatively scored to possibly impact the wetlands located just to the west, as well as the red cockaded woodpecker nests to the north and the American alligator which inhabits Town Creek located north of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	It is conservatively assumed that shallow groundwater discharges to the jurisdictional wetlands located to the west of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	15
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**43**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	26
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-315

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970; a bullet trap has not been installed and there is no backstop berm.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 14,347 lbs per year at Range K-315.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-315

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The area is mostly bare near target areas and covered with sand and mulch.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			13
Notes: Slope of range determined using topographic contours in GIS.			

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K-315

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand. It contains little to no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is at the upper reaches of Whitehurst Creek which discharges to the New River.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No sensitive species or habitat has been identified in vicinity of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

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Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4.1 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater discharges to surface water; however, no sensitive habitat or species were identified.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

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Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	13
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**34**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-317

Table 1: Range Use and Range Management (*Source*) Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970. A tree line at the back of the range prevent rounds from moving further into the K-2 Impact Area, but there is no backstop berm or bullet capture device in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 7,559 lbs per year at Range K-317.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

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MCB Camp Lejeune
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Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range has some short grass but the central part of the range is mostly a sandy bare area.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls have been identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			13
Notes: Slope of range determined using topographic contours in GIS.			

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K-317

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand. It has little to no clay content.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is at the upper reach of Whitehurst creek which discharges into the New River where recreational and commercial fishing activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No T&E species or jurisdictional wetlands were located in vicinity of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4.1 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater is assumed to discharge to surface water but no sensitive species or habitat were identified.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	13
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**34**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-319

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970. A tree line present at the back of the range likely prevents some rounds from moving further into the K-2 Impact Area, but there is no backstop berm or bullet capture device in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 11,102 lbs per year at Range K-319.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-319

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The area contains some vegetated areas (short grass), but is mostly bare.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			13
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contain little or no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located in the upper reaches of Whitehurst Creek which discharges into the New River where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No T&E species or sensitive habitat was identified in proximity to the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 5: Groundwater Receptors Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Although shallow groundwater discharges to surface water, no sensitive species or habitat was identified.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	13
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**34**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-321 and K-321A

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1986.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since 1986. A tree line at the back of the range likely captures some of the rounds, but there is no backstop berm or bullet capture device in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years, or range contains no bullet capture technology	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 12,608 lbs per year at the range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-321 and K-321A

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The area is vegetated with short grass but has many sandy bare areas near targets.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			11
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-321 and K-321A

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contains little or no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-321 and K-321A

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is near the upper reaches of Whitehurst Creek which discharges into the New River where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No sensitive species or habitat was identified near the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 3.8 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	No sensitive species or habitat was identified near the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	11
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**30**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**47**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-325

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970. A tree line at the back of the range likely captures some of the rounds, but there is no backstop berm or bullet capture device in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 7,315 lbs per year at Range K-325.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	Range is maintained as needed. Range clearance was completed in 2004.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range is vegetated almost entirely with short grass.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	1
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			9
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-325

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contains little or no clay content.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is close to the bank of the New River and there is a high potential for surface water runoff from the range to enter the river. Data does not indicate that contamination from the range has reached the river.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No T&E species or sensitive habitat has been identified in vicinity of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-325

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.75 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	No sensitive species or habitat has been identified in vicinity of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	9
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**30**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-402

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The range has been in use since 1970. Target lines have backstop berms but it is unknown how long these have been in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 6,552 lbs per year at Range K-402.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-402

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range has some steep areas (5-10% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	3
Vegetation	Some of the range is vegetated with short grass but contains many sandy bare areas.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Alpin series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has three berms behind the target areas, but these do not appear to control runoff from the range.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	0
Surface Water Pathway Score			15
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-402

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Alpin series soils are strongly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Alpin series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Alpin series, which is mostly sand and contains little or no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-402

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located near Mill Creek which discharges into Stone's Bay where these activities occur. Sampling data does not indicate that MC has migrated from the range.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No T&E species or sensitive habitat is located in vicinity.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-402

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4.2 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater discharges to surface water but no T&E species or sensitive habitat was identified.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	15
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**36**

Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-406A and K-406B

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The ranges have been in use since 1970.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	5
Bullet-Capturing Technology	The ranges have been in use since 1970; bullet traps have not been installed and there are no backstop berms.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 5,984 lbs per year at Range K-406A, and 6,496 lbs per year at Range K-406B.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The ranges are maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-406A and K-406B

Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The ranges are vegetated with short grass but contain some sandy bare areas.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The ranges have earthen separation berms but they do not appear to control surface water runoff.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-0
Surface Water Pathway Score			11
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-406A and K-406B

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were below 6.5 at monitoring wells sampled at the K-2 impact area	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contains little or no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
K-406A and K-406B

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is in proximity to Mill Creek which discharges into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	No T&E species or sensitive habitat was identified in vicinity of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	1
Surface Water Receptor Score			6
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4.3 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater discharges to surface water but no T&E species or sensitive habitat was identified in vicinity of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	1
Groundwater Receptor Score			4
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Surface Water Pathways	2	11
Surface Water Receptors	4	6
Sum of Surface Water Element Scores		**32**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	15
Groundwater Pathways	3	30
Groundwater Receptors	5	4
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
MAC 1,2,4,5, and 6

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The ranges have been in use since 1990.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The ranges have been in use since 1990, and a 16-foot high earthen berm was installed in 2010 to cover the length of the MAC ranges. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years, or range contains no bullet capture technology	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at up to 5,325 lbs per year combined for all MAC Ranges.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The ranges are maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes: The loading for MAC-1 is 1210 lbs per year with a resulting score of 13. The loading for MAC-2 is estimated at 1851 lbs per year with a resulting score of 13. The loading rate at MAC-4 is estimated at 64 lbs per year with a resulting score of 9. The loading at MAC-5 is estimated at 179 lbs per year with a resulting score of 11. MAC-6 has been in use since 2005 and the loading rate is estimated at 2,021 lbs per year. The resulting score for MAC-6 is 13. The score of 13 was used since this is the most conservative score.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
MAC 1,2,4,5, and 6

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The ranges are level (<5%).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	At MAC 1-4, the range is vegetated with short grass but contains many bare areas.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil types located at the range are Baymead and Onslow series, which are mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	A 16' backstop berm is present and covers width of MAC ranges.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			6

Notes: At MAC-5 and MAC-6, the range is mostly vegetated with short grass. The resulting score at MAC-5 & MAC-6 is 4.

Slope of range determined using topographic contours in GIS.

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
MAC 1,2,4,5, and 6

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values were generally below 6.5 at monitoring wells sampled at the G-10 impact area	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Onslow and Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil types located at the ranges are Onslow and Baymeade, which are mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil types located at the ranges are Onslow and Baymeade, which are mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
MAC 1,2,4,5, and 6

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	The range has no direct surface water path to the New River which is used for recreation and commercial fishing.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	Wetlands are in vicinity of the ranges.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	5
Surface Water Receptor Score			8
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The ranges are located approximately 3.3 miles east of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The ranges are located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge to nearby wetlands.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	3
Groundwater Receptor Score			6
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	6
Surface Water Receptors	4	8
Sum of Surface Water Element Scores		**27**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	30
Groundwater Receptors	5	6
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Minimal**
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes: Individual surface water scores for MAC-1, -2, -4, -5, and -6 are 27, 27, 23, 25, and 27, respectively.

Individual groundwater scores for MAC-1, -2, -4, -5, and -6 are 49, 49, 45, 47, and 49, respectively.

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Alpha, Bravo, Charlie Ranges

Table 1: Range Use and Range Management (*Source*) Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The ranges have been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The ranges have been in use since mid-1980s. Protective berms are located on both sides of the ranges, but there are not impact berms in the direction of fire. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years, or range contains no bullet capture technology.	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 17,205 lbs per year at Alpha Range, 22,858 lbs/year at Bravo Range, and 18,474 lbs per year at Charlie Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	Range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes: Portions of Alpha, Bravo, and Charlie ranges (total of 5 acres) was recently cleared, sifted, and landscaped between 2006-2007. This was completed to a depth of approximately 5 inches.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Alpha, Bravo, Charlie Ranges

Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The ranges are flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The ranges are heavily vegetated with short grass and shrubs.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	1
Soil Type / Runoff Conditions	The primary soil type located at the ranges is the Baymeade and/or Goldsboro series, both of which are mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The ranges have berms and a thin layer of heavy vegetation on two sides. A thin layer of trees separates each range from the neighboring ranges. There are vegetated berms behind each line of targets, including at the back of the range.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			4
Notes: Slope of ranges determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Alpha, Bravo, Charlie Ranges

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic, and Goldsboro series soils are slightly acidic to acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil types located at the ranges is the Baymeade and/or Goldsboro series, which are mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil types located at the ranges is the Baymeade and/or Goldsboro series, which are mostly sand and contain little or no clay content.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Alpha, Bravo, Charlie Ranges

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source at the installation.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The ranges are close to Stone's Bay and drainage pathways that discharge into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located immediately south of the ranges.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Alpha, Bravo, Charlie Ranges

Table 5: Groundwater Receptors Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The ranges are located approximately 2.5 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The ranges are located on the installation and are not near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into jurisdictional wetlands located just south of the ranges.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	4
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**32**

Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**51**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**High**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Dodge City

Table 1: Range Use and Range Management (*Source*) Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid 1980s; a bullet trap has not been installed and no berms are present.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 1,406 lbs per year at Dodge City Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			12
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Dodge City

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range has many sandy bare areas but is surrounded by thick forests.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has berms on two sides. Thick vegetation exists between the range and nearby stream; however, the nearest stream draining to Stone's Bay is only 1000 feet to the northwest.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Dodge City

Table 3: Groundwater Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contains little no to clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located near Stone's Creek which discharges into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located northwest of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Dodge City

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.8 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into the wetlands located to the northwest of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	12
Surface Water Pathways	2	8
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**35**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	12
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**50**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate**
Groundwater Environmental Concern Evaluation Ranking	**High**

Notes:

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 1: Range Use and Range Management (*Source*) Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid 1980s. Earthen berms are located behind targets to capture bullets. It is unknown how long the berms have been in place. A bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years, or range contains no bullet capture technology	0
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 1,797 lbs per year at Hathcock Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			13
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range has some sloped areas (5-10%).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	3
Vegetation	The area has many sandy bare areas and vegetation consists of short grass.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Goldsboro series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has berms on two sides and thick vegetation between the range and Stone's Bay.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Goldsboro series soils are slightly to medium acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Goldsboro series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Goldsboro series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is right next to Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located immediately south of the ranges.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 5: Groundwater Receptors Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.9 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into jurisdictional wetlands located just south of the ranges.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	3
Groundwater Receptor Score			6
Notes			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Hathcock Range

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Surface Water Pathways	2	8
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**36**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	13
Groundwater Pathways	3	30
Groundwater Receptors	5	6
Sum of Groundwater Element Scores		**49**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Mechanical Pistol

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid 1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid-1980s; a bullet trap was installed in 2006. Impact berms were present prior to installation of the bullet trap, but it is unknown when they were constructed. It is conservatively assumed the range was operational 10-30 years before a bullet trap was installed.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 1,371 lbs per year at Mechanical Pistol Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			8
Notes: The berms were mined after they were no longer used to capture bullets.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Mechanical Pistol

Table 2: Surface Water Pathways Characteristics Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range is vegetated with short grass but contains many bare areas, including a sandy area at the target line.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has three berms behind the bullet trap. Thick vegetation exists between the range and nearby stream; however, the nearest stream draining to Stone's Bay is only 1000 feet to the northwest.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			6
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Mechanical Pistol

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located near Stone's Creek which discharges into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located west and northwest of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.3 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into the wetlands located to the northwest of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Surface Water Pathways	2	6
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**29**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**46**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Multi-Purpose Range

Table 1: Range Use and Range Management (*Source)* Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid-1980s; a bullet trap was installed in 2006. Impact berms were present prior to installation of the bullet trap, but it is unknown when they were constructed. It is conservatively assumed the range was operational 10-30 years before a bullet trap was installed.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 5,533 lbs per year at the Multi-Purpose Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed and according to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			8
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Multi-Purpose Range

Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range is covered in short grass with some sandy areas worn bare from use.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has three berms behind the bullet trap. Thick vegetation exists between the range and nearby stream; however, the nearest stream draining to Stone's Bay is only 1500 feet to the northwest.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			6
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Multi-Purpose Range

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand and contains little or no clay.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Multi-Purpose Range

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located near Stone's Creek which discharges into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located west and northwest of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Multi-Purpose Range

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.3 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into the wetlands located to the northwest of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Surface Water Pathways	2	6
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**29**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**46**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 1: Range Use and Range Management (*Source*) Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid-1980s. Earthen impact berms were present on three sides of the range prior to installation of the bullet trap, but it is not known how long these were present. A bullet trap was installed in April 2004. Therefore, it is conservatively assumed that the range was operational 10-30 years without bullet capture technology.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 4,200 lbs per year at the Walk-Down Pistol Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed and according to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			8
Notes: During installation of the bullet trap, the berms were mined and the portion of the berm behind the bullet trap was removed.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range is vegetated with short grass.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	1
Soil Type / Runoff Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has three berms behind the bullet traps and thick vegetation behind the bullet trap. A narrow line of thick trees separates the range from the 2 neighboring ranges.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			4
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 3: Groundwater Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Baymeade series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Baymeade series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is located near Stone's Creek which discharges into Stone's Bay where these activities occur.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	A narrow strip of jurisdictional wetlands are located southeast of the range.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.3 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater may discharge into the wetlands located to the southeast of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Walk Down Pistol

Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Surface Water Pathways	2	4
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**27**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**46**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Square Bay

Table 1: Range Use and Range Management (*Source*) Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since the mid-1980s.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	3
Bullet-Capturing Technology	The range has been in use since mid-1980s; bullet traps have been installed at all pistol ranges since 2007, according to Range Control. Impact berms were in place prior to the bullet trap installation, but it is unknown how long these berms were in place, so it is conservatively assumed the range was operational 10-30 years without bullet capture.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-1
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 1,956 lbs per year at the Square Bay Range.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The rifle range is maintained as needed. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			8
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Square Bay

Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The composition of the floor of the range is unknown, and is conservatively scored as a 5.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Marvyn series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	No runoff/engineering controls were identified. The range has a baffled ceiling, 2 sidewalls, and a bullet trap.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Square Bay

Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	pH values at the nearby OU 14 (Site 69) were generally below 6.5 in site monitoring wells.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Marvyn series soils are slightly acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Marvyn series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Marvyn series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
Square Bay

Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. These activities occur in Stone's Bay, which is located 2,000 feet to the east.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	3
Sensitive Species Habitat and Threatened or Endangered Species	Jurisdictional wetlands are located in the immediate vicinity of the range..	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			15
Notes:			

Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.5 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater likely discharges into the wetlands located to in the immediate vicinity of the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Surface Water Pathways	2	8
Surface Water Receptors	4	15
Sum of Surface Water Element Scores		**31**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	8
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**46**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: Environmental Concern Evaluation Ranking* — Score Range High — 50-65 Moderate — 30-49 Minimal — 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Moderate**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Small Arms Range Protocol Evaluation Forms
MCB Camp Lejeune
SR-8

Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 2009.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	1
Bullet-Capturing Technology	Range has been in use since 2009. Impact berms are positioned behind the targets, but a bullet trap has not been installed at this range.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years, or range contains no bullet capture technology	0
MC Loading Rates	Expenditure data was collected for 2009-2010 and the annual lead loading rate is estimated at 16,992 lbs per year at Range K-402.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	5
Range Maintenance	The range is maintained as needed.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	5
Source Element Score			11
Notes:			

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Table 2: Surface Water Pathways Characteristics Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope) but the slope of the impact berm is • 10%.	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	5
Vegetation	The range is covered with short grass but has several worn bare areas.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	3
Soil Type / Runoff Conditions	The primary soil type located at the range is the Leon series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	Drainage ditches are located along the length of the range and divert drainage to the back of the range. The targets are backed by vegetated impact berms.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-10
Surface Water Pathway Score			5
Notes: Slope of range determined using topographic contours in GIS.			

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Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Leon series soils are extremely acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Leon series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Leon series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is adequately removed from the New River that potential MC in runoff is not expected to reach the New River at detectable concentrations.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	The range is surrounded by jurisdictional wetlands.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

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Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 2.6 miles southwest of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater likely discharges to the wetlands surrounding the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

Table 6: Relative Environmental Concern Evaluation
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Surface Water Pathways	2	5
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**29**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	11
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**49**

The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium:

Environmental Concern Evaluation Ranking*	Score Range
High	50-65
Moderate	30-49
Minimal	0-29

*Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.

Surface Water Environmental Concern Evaluation Ranking	**Moderate***
Groundwater Environmental Concern Evaluation Ranking	**Moderate**

Notes: Because of the extremely high use of this range (almost 17,000 pounds lead/year), professional judgment was used to increase the surface water concern ranking from minimal to moderate.

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Table 1: Range Use and Range Management (*Source)* Element **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Duration of Range Use	The range has been in use since 2001.	5 if usage > 30 years 3 if usage is 10 to 30 years 1 if usage < 10 years	1
Bullet-Capturing Technology	Range has been in use since 2001; a bullet trap was installed during range construction in 2001.	-3 if range usage duration = bullet capture duration -1 if [range usage duration – bullet capture duration] = 10 to 30 years 0 if [range usage duration – bullet capture duration] > 30 years	-3
MC Loading Rates	Expenditure data was collected for 2005-2010 and the annual lead loading rate is estimated at 779 lbs per year at Range SR-11.	5 if MC loading > 1000 pounds/year 3 if MC loading = 100 to 1000 pounds/year 1 if MC loading < 100 pounds/year	3
Range Maintenance	The range is maintained as needed. According to range control, bullet traps are inspected monthly and maintained and cleaned every 3 months.	5 if lead is removed less than once every three years 3 if lead is removed more than once every three years but less than annually 1 if lead is removed at least annually	1
Source Element Score			2
Notes:			

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Table 2: Surface Water Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
pH of Water	U.S. Geological Survey (USGS) RealTime Stream data for the New River at Hwy 17 and multi-location monitoring performed by the University of North Carolina Wilmington Center for Marine Science in 2007 indicates a pH of 7.5-8.0, varying by location. REVA September 2010 surface water sampling confirms these results.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	1
Precipitation	The State Climate Office of North Carolina states that the average annual rainfall is 54 inches based on data from 1971 through 2000.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
Slope of Range	The range is flat (<5% slope).	5 if slope > 10% 3 if slope = 5% to 10% 1 if slope < 5%	1
Vegetation	The range floor is covered in gravel and contains no vegetation.	5 if vegetation cover < 20% 3 if vegetation cover = 20% to 50% 1 if vegetation cover > 50%	5
Soil Type / Runoff Conditions	The primary soil type located at the range is the Stallings series, which is mostly sand.	5 if soil type is clay / silty clay 3 if soil type is clayey sand / silt 1 if soil type is sand/gravel	1
Runoff/ Erosion Engineering Controls	The range has a baffled ceiling, 2 sidewalls, and a bullet trap at the back of the range.	0 if no engineering controls -5 if partial engineering controls -10 if effective engineering controls	-5
Surface Water Pathway Score			8
Notes: Slope of range determined using topographic contours in GIS.			

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Table 3: Groundwater Pathways Characteristics Element
(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)

Criteria	Evaluation Justification	Score Criteria	Site Score
Depth to Groundwater	Groundwater is shallow as evidenced by the low elevation and proximity to the New River, wetlands, and the coast.	5 if depth to groundwater < 20 feet 3 if depth to groundwater = 20-99 feet 1 if depth to groundwater = 100-300 feet 0 if depth to groundwater > 300 feet	5
Precipitation	U.S. Department of Agriculture (USDA) Soil Survey for Onslow County (1992) states that the average annual rainfall is 56 inches based on data from 1951 through 1979.	5 if precipitation > 40 inches/year 3 if precipitation = 20-40 inches/year 1 if precipitation < 20 inches/year	5
pH of Groundwater	Site data is not available but is likely below 6.5, similar to conditions observed at the K-2 and G-10 impact areas.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
pH of Soil	Stallings series soils are acidic.	5 if pH < 6.5 3 if pH > 8.5 1 if pH 6.5 • pH • 8.5	5
Soil Type / Infiltration Conditions	The primary soil type located at the range is the Stallings series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Clay Content in Soil	The primary soil type located at the range is the Stallings series, which is mostly sand.	5 if soil type is sand/gravel 3 if soil type is clayey sand / silt 1 if soil type is clay / silty clay	5
Groundwater Pathway Score			30
Notes:			

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Table 4: Surface Water Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Drinking Water Usage	Drinking water is obtained from water supply wells throughout the installation. Surface water is not used as a drinking water source.	10 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has a reasonable potential to move toward a surface water body used as a potable water supply or if a designation as a potable water source is unknown 5 if contamination in the media has moved or is expected to move only slightly beyond the source (tens of feet) or could move, but is not moving appreciably, toward surface water body used as a potable water supply or if a designation as a potable water source is unknown 2 if low possibility for contamination in the media to be present at or migrate to a point of exposure	2
Agricultural or Other Beneficial Usage	Surface water in the area is used for shellfish harvesting, fishing, and boarding activities. The range is adequately removed from the New River that potential MC in runoff is not expected to reach the New River at detectable concentrations.	5 if analytical data or observable evidence indicates that contamination in the media is present at, is moving toward, or has moved to a point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if contamination in the media has moved only slightly beyond the source (tens of feet) or could move but is not moving appreciably. 1 if low possibility for contamination in the media to be present at or migrate to a point of exposure	1
Sensitive Species Habitat and Threatened or Endangered Species	The range is surrounded by jurisdictional wetlands.	10 if identified receptors have access to possibly contaminated media and/or are located adjacent to the range boundary 5 if potential for receptors to have access to possibly contaminated media 1 if little or no potential for receptors to have access to possible contaminated media	10
Surface Water Receptor Score			13
Notes:			

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Table 5: Groundwater Receptors Element (These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)			
Criteria	**Evaluation Justification**	**Score Criteria**	**Site Score**
Wells Identified as Potable Water Sources	The range is located approximately 4 miles west of the nearest water supply well and outside of the 10-year maximum radius of influence.	10 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as a potable water source is unknown 5 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 2 if low possibility for MC to be present at or migrate to within a reasonable radius of influence or point of exposure	2
Wells Identified for Agricultural or Other Beneficial Usage	The range is located on the installation and is not located near agricultural areas.	5 if analytical data or observable evidence or site conditions indicate that MC may be within or moving toward a reasonable radius of influence of a well or other point of exposure or if a designation as agricultural or other beneficial usage is unknown 3 if analytical data or observable evidence or site conditions indicate that MC have moved only slightly beyond the source (tens of feet) or could move toward a reasonable radius of influence of a well or other point of exposure, but are not moving appreciably 1 if low possibility for MC to be present at or migrate to within a reasonable radius of influence of a well or point of exposure	1
Sensitive Species Habitat and Threatened and Endangered Species	Shallow groundwater likely discharges to the wetlands surrounding the range.	5 if identified receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 3 if potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources 1 if little or no potential for receptors exposed to potentially MC-impacted water from groundwater or groundwater sources	5
Groundwater Receptor Score			8
Notes			

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Table 6: Relative Environmental Concern Evaluation **(These definitions only apply for the purposes of the Small Arms Range Assessment Protocol.)**		
Surface Water		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	2
Surface Water Pathways	2	8
Surface Water Receptors	4	13
Sum of Surface Water Element Scores		**23**
Groundwater		
Element	**Table**	**Score**
Range Use and Range Management (Source)	1	2
Groundwater Pathways	3	30
Groundwater Receptors	5	8
Sum of Groundwater Element Scores		**40**
The relative environmental concern evaluation ranking for each medium is determined by selecting the appropriate score based on the data elements for that medium: <u>Environmental Concern Evaluation Ranking* Score Range</u> High 50-65 Moderate 30-49 Minimal 0-29 *Use the Environmental Concern Evaluation Ranking to determine if further actions are warranted based on the guidelines for recommended actions, as defined in Table 7.		
Surface Water Environmental Concern Evaluation Ranking		**Minimal**
Groundwater Environmental Concern Evaluation Ranking		**Moderate**
Notes:		

Heavy Metals and Sediment Analyses: Stone Bay Rifle Range, U.S. Marine Corps Base Camp Lejeune, NC

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Final Report

December 2011

1. INTRODUCTION

Since 2007, a team of engineers and scientists from the University of South Carolina Beaufort (USCB) and The Georgia Institute of Technology – Savannah have been working under contract to the U.S. Marine Corps to identify and quantify munitions constituents in water and sediments near several small arms firing and bombing ranges in South and North Carolina. At Parris Island, SC, Camp Lejeune, NC and Cherry Point, NC, sediment samples were acquired and analyzed for chemico-physical properties and munitions constituents including lead and copper, and in the case of Cherry Point, a suite of explosives compounds (Figure 1). The work at Cherry Point also included water sampling and analysis.

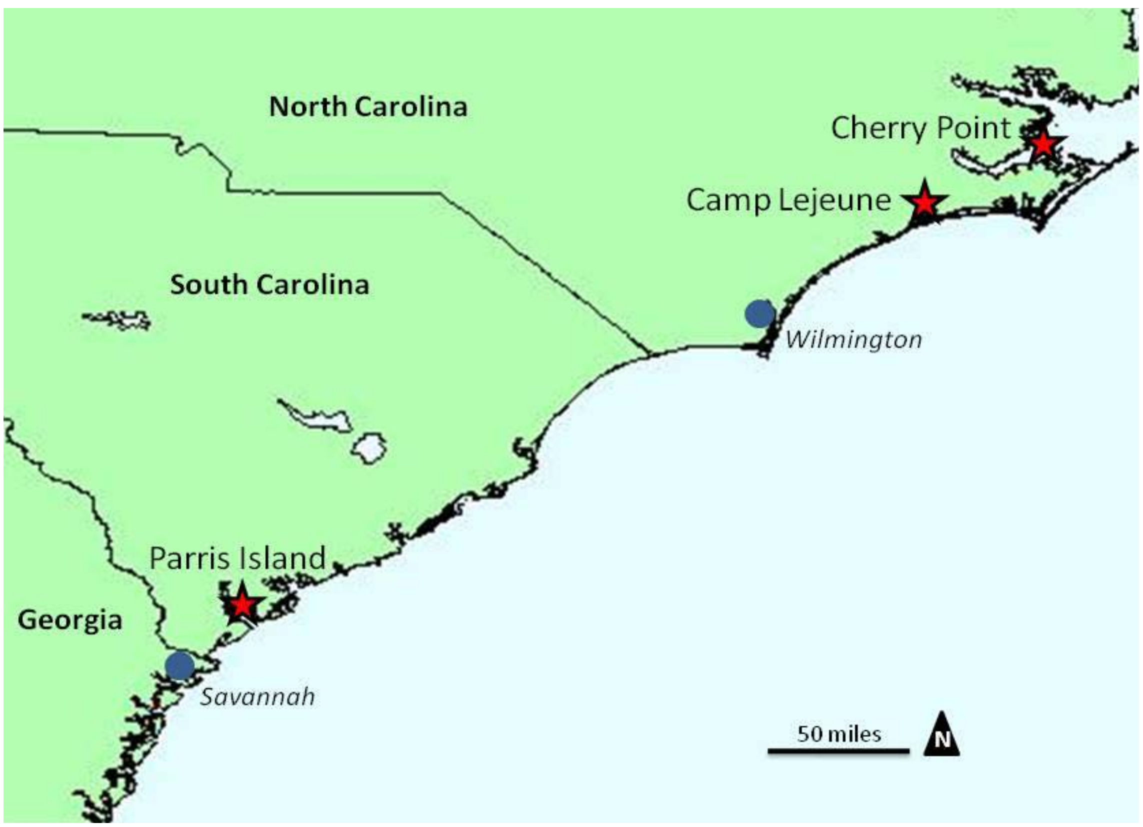

Figure 1. Locations of Parris Island, SC, Camp Lejeune, NC and Cherry Point, NC.

The MCB Camp Lejeune study site is located in a coastal/estuarine environment in North Carolina, and includes a portion of Stone Bay to the east, intertidal marshland, and several small creeks. The rifle ranges are located along the western bank of Stone Bay and are oriented such that fired rounds pass through targets and come to rest in either a portion of the Bay, one of many creeks, or upland wooded areas north of the range. Along the banks of Stone Bay and the creeks are tidal mud flats interspersed with tall marsh grass. The elevations range from about 12 m NAVD88 for the upland locations to -3 m NAVD88 for the locations in the Bay. The tide range for this area is 1.2 m during spring tide with the mean range being 0.9 m.

The initial sampling at MCB Camp Lejeune took place in May 2008, around the perimeter of the Stone Bay Rifle Range complex. The heavy metal constituents of small arms munitions (i.e., spent bullets) deposited off-range in sediments were specifically of interest. The complete set of 23 locations sampled in 2008 is shown in Appendix A, Figure A-1. This included both upland locations and others within Stone Bay. In most cases, concentrations of the heavy metals of interest were below analytical detection limits, but at one upland site (L-2), copper was found at a concentration exceeding its ecological screening value (Sapp et al., 2010a).

The sampling effort detailed herein was conducted in April 2010 to provide data on sediment characteristics not previously examined, and to further investigate the one location at which an elevated copper level was found. Sediment cores were collected at seven of the original locations within the study area, all of which lie outside, but adjacent to, the firing range fan (Figure 2). Parameters quantified in these samples included bulk density, grain size distribution, total organic carbon (TOC), Acid Volatile Sulfide (AVS) and Simultaneously Extracted Metals (SEM). These parameters determine, in part, the bioavailability of heavy metals in sediment and are also of value in making predictions about the transport and fate of sediment contaminants. In the 2008 study, elevated levels of copper were found at one upland site, L-2. For this reason, an additional ten samples were collected around the previously sampled location and analyzed for lead, copper, zinc, antimony, manganese and iron (Figure 3).

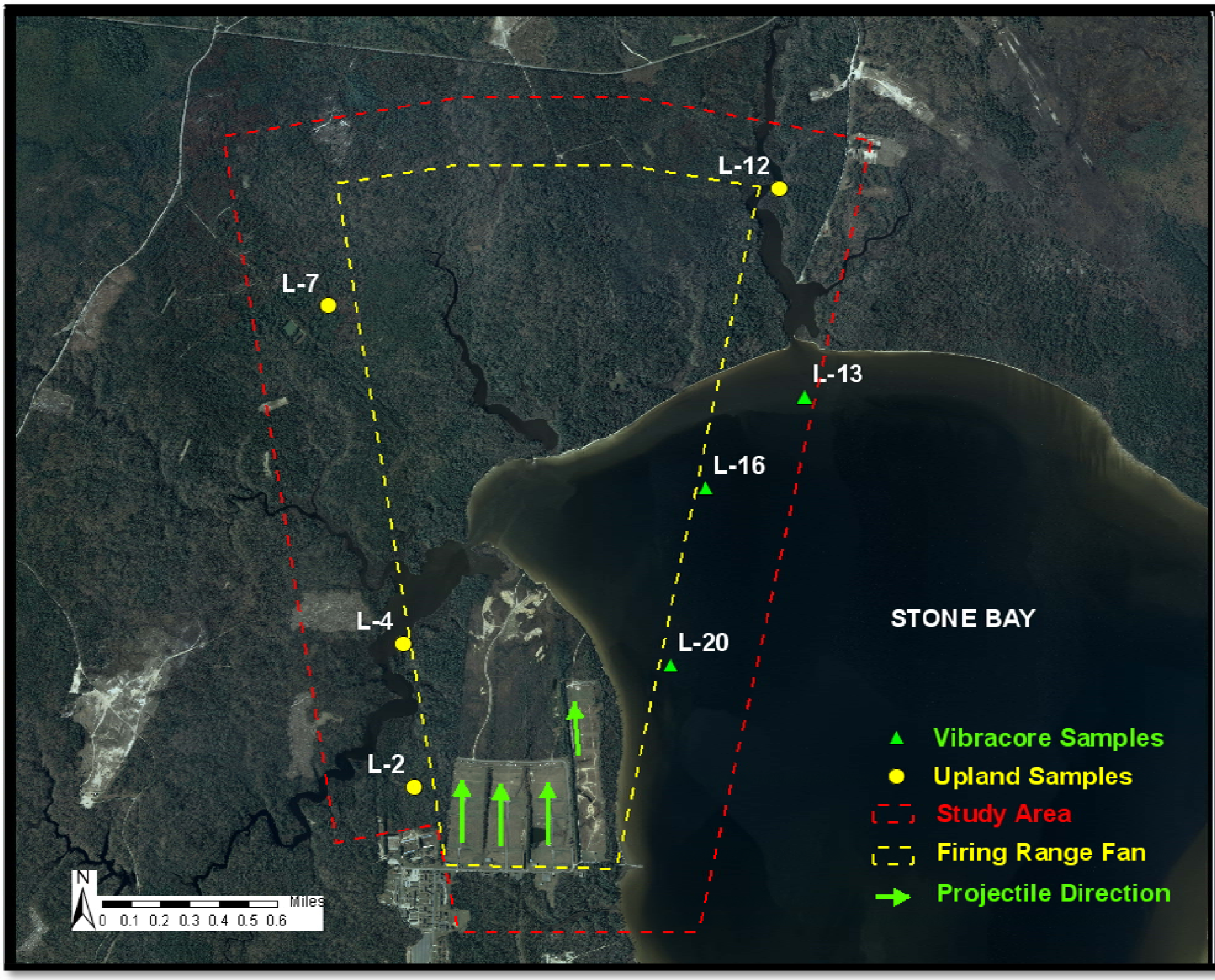

Figure 2. The Stone Bay Rifle Range at MCB Camp Lejeune, including projectile firing direction, firing range fan, study area, and locations at which sediment was collected with either a vibracore or push-core. Sampling locations around point L-2 are shown in Figure 3.

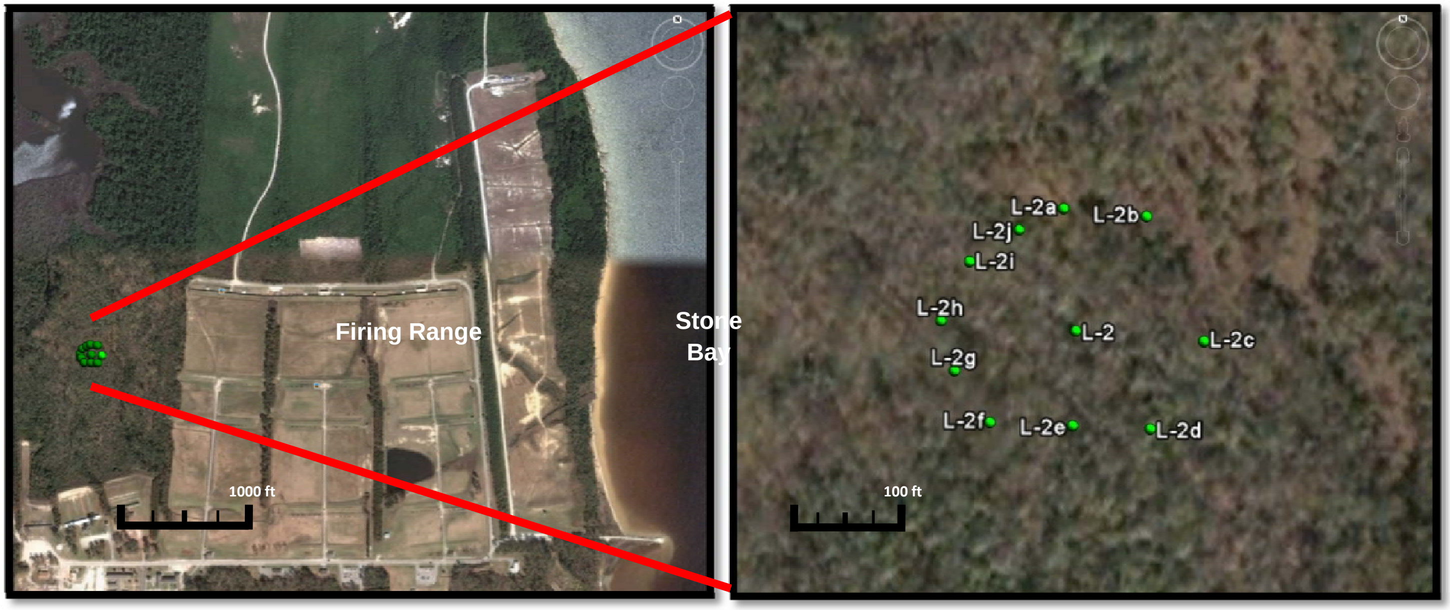

Figure 3. Additional sampling locations around point L-2, which was the one location that showed an elevated level of copper in the 2008 site assessment effort.

2. SAMPLE COLLECTION METHODOLOGY

The methods and tools used to collect sediment samples to be analyzed for heavy metals and the various chemico-physical parameters listed previously are detailed in the following subsections.

2.1 Global Positioning System (GPS)

Sampling locations for all field sites were determined using a survey-grade, Ashtech Z-12, dual-frequency GPS system. A GPS base station was set up near the survey area on the rifle range to provide data from a fixed point for post-processing of the GPS data acquired by the roving receiver. The rover GPS system was carried into the field or transported by boat to each sample location. All GPS data were post-processed with GraphNav processing software. Data defining the position and elevation of each sampling site and their corresponding estimated horizontal and vertical uncertainties can be found in Appendix A, Table A-1. The locations are given in UTM Zone 17 coordinate system and the uncertainties, which are directly related to the quality of the GPS signal, range from several centimeters for good signals, to a meter or more for points in the heavily forested areas.

2.2 Decontamination

Prior to the collection of sediment samples at the upland locations, all sampling equipment was washed with Liqui-Nox (liquid detergent) and triple-rinsed with distilled water to avoid cross-contamination of samples. Each piece of equipment was then individually wrapped in aluminum foil to prevent contamination while being transported to the sampling sites. A rinsate sample was collected during equipment decontamination and submitted for heavy metals analysis to verify the effectiveness of the decontamination procedures. The results of this test are shown in Table 1 below, and indicate the absence of any appreciable risk for cross-contamination.

Table 1. Heavy metal concentrations in sampling equipment rinsate. Values below the lower analytical detection limits are denoted by "LDL." All other results are in micrograms/Liter which equates to parts per billion.

	Sb (Antimony)	**Cu (Copper)**	**Fe (Iron)**	**Pb (Lead)**	**Mn (Manganese)**	**Zn (Zinc)**
Rinsate	0.28	0.45	LDL	0.22	1.1	9.0

2.3 Vibracore

Sediment samples from the bottom of Stone Bay at locations L-13, L-16 and L-20 were collected with an electric vibracore deployed from a modified pontoon boat on April 3, 2010 (Figure 4). A 4-inch diameter, 4-foot long, rigid, clear polycarbonate tube was attached to the vibracore head. The assembly was lowered to the seabed, vibrated into the sediment to a minimum depth of 4 feet, and then returned to the deck. The sediment sample was retained in the tube by a single-use, steel core-catcher installed in the nose of each tube. With the tube standing vertically on the deck, the vibracore head was lifted, releasing the tube which was then capped top and bottom with a flexible, rubber cap. A hose clamp secured the bottom cap to ensure sample retention during transport. Samples were placed vertically in a containment rack aboard the boat until ready for post-processing prior to shipment (Figure 5). The sample lengths obtained for each of the three sites are shown in Table 2. A full sample was obtained at each site except L-20; however, in the case of L-20, enough sediment was collected so that every horizon was represented in the analyses.

Figure 4. A pontoon boat retrofitted with a vibracore (left) was used to collect sediment samples in polycarbonate tubes (right).

Figure 5. Vertical stowage of sediment in capped sampling tubes, awaiting post-processing.

Each sediment core tube was processed by first cutting off the core catcher at the bottom of the tube (corresponding to the deepest six inches of the core). The remaining material was subdivided into three depth horizons by cutting the core tube with a hacksaw: the top horizon (0 to 6 inches below seabed), the middle horizon (6 to 12 inches below seabed) and the bottom horizon (12 to 24 inches below seabed elevation). Each resulting layer was capped while still in its short section of tube and placed in a small cooler filled with ice for shipment.

Table 2. Actual sample lengths retained in vibracore tubes. For each of the sites, the depth range indicates the sample depth from which sediment collection was attempted. Sample length is the actual length of sediment collected in the tube and is measured from the sediment water interface to the bottom of the tube.

Sample ID	Depth Range (in)	Sample Length (in)	Horizons Obtained from Sample
L-13	0 - 48	48	1, 2, 3
L-16	0 - 48	48	1, 2, 3
L-20	0 - 48	30	1, 2, 3

2.4 Push-coring

Sediment samples at locations L-2, L-4, L-7 and L-12 were collected using a manual push-core driven into the sediment with an attached slide hammer on April 3 and April 4, 2010. For each sample, a 2-inch diameter, 1-foot long plastic sleeve was inserted into the device and then driven into the top 12-inch layer of sediment. The push-core was then pulled out of the sample hole, and the plastic sleeve was extracted, retaining the sediment sample. This process was repeated in the same sample hole in order to extract another sediment core from approximately 12 to 24 inches into the soil column. When the sample collected did not fill the entire plastic sleeve, the empty section was cut off using a hacksaw and the ends were capped. Each sample was 2 inches in diameter and between 4 and 12 inches in total length. The actual sample lengths collected are shown in Table 3.

Samples collected by manual push-core were post-processed by first cutting the 0 to 12 inch sample in half with a hacksaw so that the two top horizons were separated (corresponding to the 0 to 6 and 6 to 12 inch layers). Caps were placed on each end of the sample tubes and secured with a hose clamp, after which they were wrapped with aluminum foil and placed in a cooler on ice to await shipment. The third horizon was obtained from the entirety of the second core corresponding to 12 to 24 inches.

Table 3. Actual sample lengths retained in push-core tubes. For each of the sites, the depth range indicates the sample depth from which sediment collection was attempted. Sample length is the actual length of sediment collected in the tube and is measured from the air sediment interface to the bottom of the tube.

Sample ID	Depth Range (in)	Sample Length (in)	Horizons Obtained from Sample
L-2	0 - 12	12	1, 2
L-2	12 - 24	4	3
L-4	0 - 12	8	1, 2
L-4	12 - 24	5	3
L-7	0 - 12	12	1, 2
L-7	12 - 24	6	3
L-12	0 - 12	8	1, 2
L-12	12 - 24	9	3

2.5 Manual coring

Sediment samples at L-2 and at each of the ten stations surrounding L-2 were collected by hand on April 4, 2010 for the purpose of heavy metals analysis. The first 6 inches of sediment were extracted with a decontaminated, stainless steel spoon and placed in a clean, plastic basin (Figure 6). The next two fractions, those from 6 to 12 and 12 to 24 inches, were extracted using decontaminated, steel hand augers and placed in clean, plastic basins. Each sample was then homogenized thoroughly on site, and a representative portion was placed in a small glass jar for laboratory analysis. The samples were labeled with horizon 1, 2 or 3 corresponding to the depth from which they were extracted and placed in a cooler on ice to await shipment. All samples, whether collected via vibracore, push-core or manual coring, were shipped the day following collection for overnight delivery to TestAmerica in Burlington, VT, where all analyses were conducted.

Figure 6. The top 6-inch layer of sediment was extracted with a decontaminated, stainless steel spoon and placed in a clean container (left); the remaining two layers, or 18 inches of sediment, were extracted using a decontaminated, steel hand auger and placed in clean containers.

3. HEAVY METAL AND SEDIMENT ANALYSES METHODS

The analysis of heavy metals (lead, copper, zinc, manganese, iron and antimony) was performed only on sediments collected from L-2 or sites surrounding L-2 (i.e., L-2a through L-2j). Metals analysis was conducted according to U.S. EPA SW-846 Methods 6020 and 6020B using Inductively Coupled Plasma - Mass Spectrometry (ICP-MS).

Chemico-physical properties of sediments were determined on samples L-2, L-4, L-7, L-12, L-13, L-16 and L-20 and included bulk density, grain size, TOC, AVS and SEM. Bulk density was determined in accordance with ASTM D2937. Bulk density results were corrected for percent moisture using a TestAmerica in-house method based on the following U.S. EPA Contract Laboratory Approval Program documents: Statement of Work for Organic Analyses, Multi-Media, Multi-Concentration (current version); Statement of Work for Inorganic Analyses, Multi-Media, Multi-Concentration (current version); and SW-846 Test Methods for the Evaluation of Solid Waste (Update III). Grain size was determined according to ASTM D422, which involves mechanical sieving for particles above 75 micrometers in size and hydrometer usage for smaller particles.

TOC analysis was conducted according to Kahn (1988), U.S. EPA Region II protocol. Each sample was analyzed in duplicate and results of the two determinations were averaged to yield the final result. In the event that the two TOC measurements differed by more than 40%, additional measurements were made and any outliers eliminated using the Dixon outlier analysis method. The 0-6 inch sample from site L-2 was not analyzed for TOC due to inadequate sample volume.

AVS and SEM were analyzed from the same sample portion in accordance with EPA SW-846 Method 6010B, using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES). The bivalent metals comprising SEM values were silver, cadmium, copper, nickel, lead and zinc. AVS and SEM were determined and corrected mathematically to dry mass values based on independent measurements for percent moisture content.

4. RESULTS OF HEAVY METALS ANALYSIS

The U.S. Marine Corps provided ecological toxicity screening values for the heavy metals of concern in marine sediments, with the exception of iron (Table 4). These screening values were used in the initial report on the Stone Bay Rifle Range, which included the finding of 479 ppm copper in the surficial sediment fraction collected at site L-2. Given that site L-2 is removed from Stone Bay and its tributaries by a considerable distance, it can be argued that toxicity screening values for marine sediments are not applicable. Nonetheless, they are again utilized in this follow-up report, as the Department of Defense’s Range and Munitions Use Subcommittee (RMUS) has not, to our knowledge, adopted toxicity screening values for soils. RMUS has adopted ecological toxicity screening values for freshwater sediments, however, and they are somewhat different than those featured in Table 4 (antimony, 2 vs. 12 mg/kg; copper, 18.7 vs. 34 mg/kg; lead, 30.2 vs. 47 mg/kg; and zinc, 124 vs. 150 mg/kg). The ecological toxicity screening value for manganese is 460 mg/kg, regardless of whether fresh or marine sediments are at issue.

Table 4. Ecological Toxicity Screening Values for Metals in Marine Sediments.

Metal	Screening Value (ppm)	Reference
Antimony	2	Long and Morgan, 1990
Copper	18.7	MacDonald et al., 2000
Lead	30.2	MacDonald et al., 2000
Manganese	460	Persaud, Jaagumagi, and Hayton, 1993
Zinc	124	MacDonald et al., 2000

Results from the follow-up investigation of site L-2 are presented in Figure 7. Only results where lead and/or copper concentrations exceed ecological toxicity screening values for marine sediments are shown. Surface-fraction lead concentrations exceeded the toxicity screening value at five locations around L-2 (ranging from 38.1 to 396 ppm), while only station L-2g showed a surficial copper concentration (71.2 ppm) in excess of the toxicity screening value. Appendix B, Table B-1 lists concentrations of each of the six metals in each horizon at the various sample locations (L-2 and L-2a-j). These concentrations are also presented as bar graphs and are normalized by their respective toxicity screening values in Figure B-1. Since no ecological toxicity screening value exists for iron, the concentration is graphed without normalization in Figure B-2.

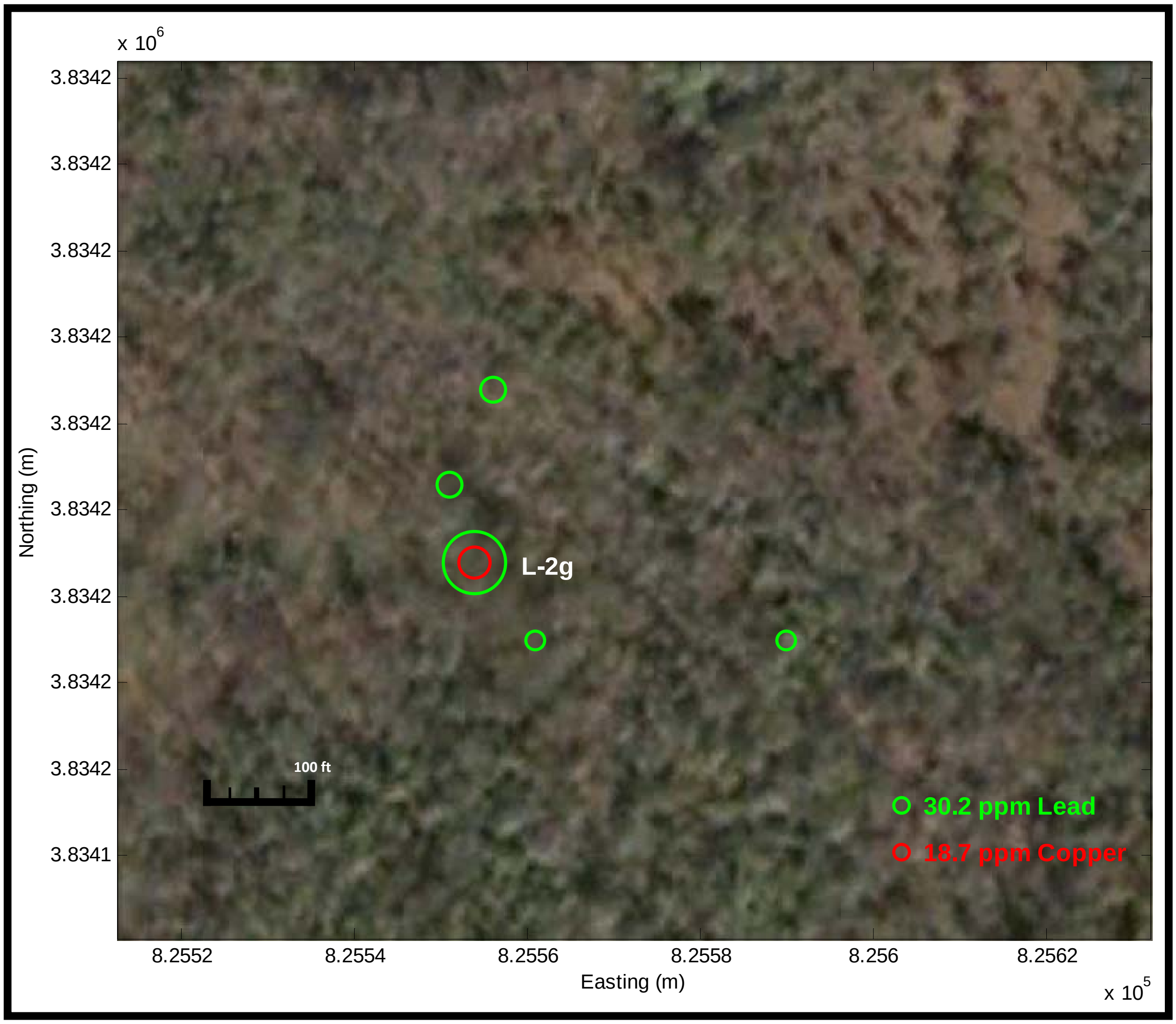

Figure 7. L-2 sampling locations where surface layer concentrations of lead and/or copper exceed toxicity screening values at MCB Camp Lejeune. Locations with concentrations of lead and copper below their respective screening values are not shown. The circles have been scaled by their respective toxicity screening values.

5. CHEMICO-PHYSICAL PROPERTIES OF SEDIMENTS

Results from laboratory tests for TOC, AVS, SEM, bulk density and median grain size (D50) are presented in Figure 8 and are tabulated in Appendix C. TOC values are low for all samples except L-4 and L-12. Of particular importance is the difference between AVS and SEM measurements for each sample. This quantity is calculated by subtracting the sum of SEM molar concentrations for the six bivalent metals (silver, cadmium, copper, nickel, lead and zinc) from the molar concentration of AVS present in the sediment. When the calculated value for AVS minus SEM (AVS-SEM) is positive (or if SEM minus AVS is negative), then the metals are considered fully bound to sediments, with essentially little or no bioavailability to benthic organisms or other ecological receptors (U.S. EPA, 2005). As is evident in Figure 8, AVS-SEM is positive for all samples, suggesting little or no bioavailability of the metals present at the sampled locations.

Similarly, the ratio of SEM to AVS (SEM/AVS) is also used as an indicator of metals bioavailability in sediments (DiToro et al., 1990, McGrath et al., 2002, U.S. EPA, 2005), with bioavailability assumed to occur when SEM/AVS > 1. It is clear from Figure 8 that this ratio does not exceed unity for any sample site. Another metals bioavailability metric involves normalizing the difference between AVS and SEM (AVS –SEM) based on the fraction of organic carbon (f_{OC}) present in the sediments (U.S. EPA, 2005). The organic carbon will affect the partitioning of metals in sediments, and normalization for f_{OC} will improve the prediction of toxicity due to metal partitioning (U.S. EPA, 2005). This is illustrated in Figure 8 for sampling location L-2 where f_{OC} is considerably higher in horizon 2 compared to horizon 3 (Appendix C, Table C-1). The AVS – SEM values in horizons 2 and 3 show the risk of metals bioavailability to be very similar at 0.19 and 0.21 µmole/g, respectively. However, when normalized by f_{OC}, the risk of metals bioavailability is nearly 6-fold less in horizon 2 than horizon 3.

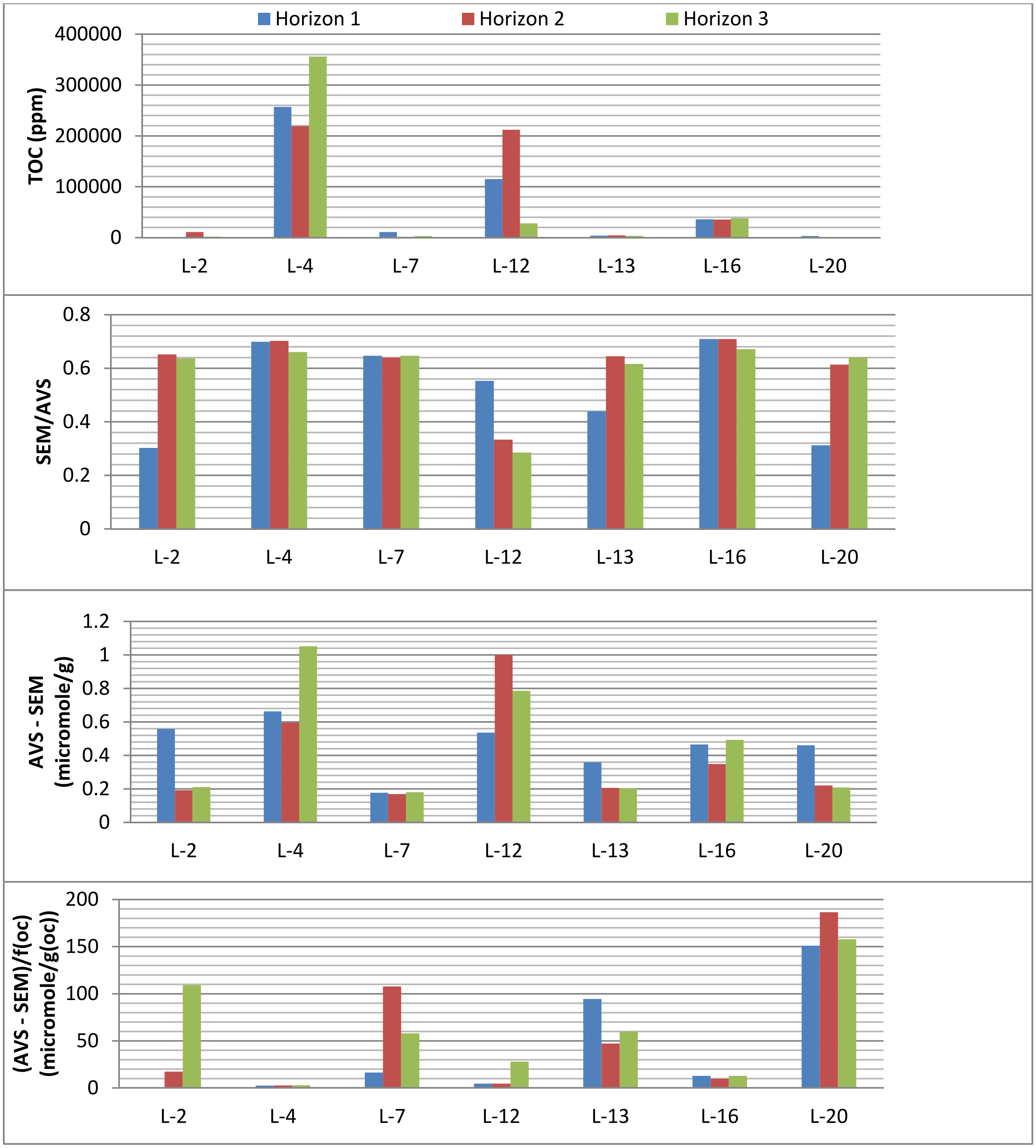

Figure 8. Total organic carbon (TOC), ratio of Simultaneously Extracted Metals and Acid Volatile Sulfide (SEM/AVS), AVS minus SEM (AVS-SEM), and AVS-SEM normalized for organic carbon at each location with respect to sample depth. Horizon 1 corresponds to 0 – 6" in depth, horizon 2 to 6 – 12" and horizon 3 to 12 – 24". Due to insufficient sample volume, L-2 does not include horizon 1 for TOC measurement. Since TOC measurements are used to calculate AVS – SEM/f(oc), there is no result from L-2, horizon 1 for this bioavailability metric.

Results for grain size and bulk density are shown in Figures 9 and 10. The median size (D50) for all samples except the three from site L-16 correspond to sand (greater than 75 microns but less than 4750 microns), with values at L-16 in the silt range (between 5 and 75 microns). This site is located the furthest into Stone Bay where sediment can be expected to be finer. L-7, located the furthest inland on the west side of the firing range, featured samples composed of about 90% fine sand in each horizon sampled. The largest values of D50 were for site L-20, which is located in Stone Bay on the eastern border of the firing range fan. Gravel is present in all horizons of L-4 and L-12 and in the first and third horizons of L-13 and L-20. Sites that contained mostly medium or fine sand with a narrow grain size distribution, (L-2, L-7, L-13 and L-20) have higher bulk densities than those sites with sediments comprised of finer particles or with broader distributions (L-4, L-12 and L-16). Grain size analysis results, along with the corresponding soil types and percent solids, can be found in Appendix C, Table C-2.

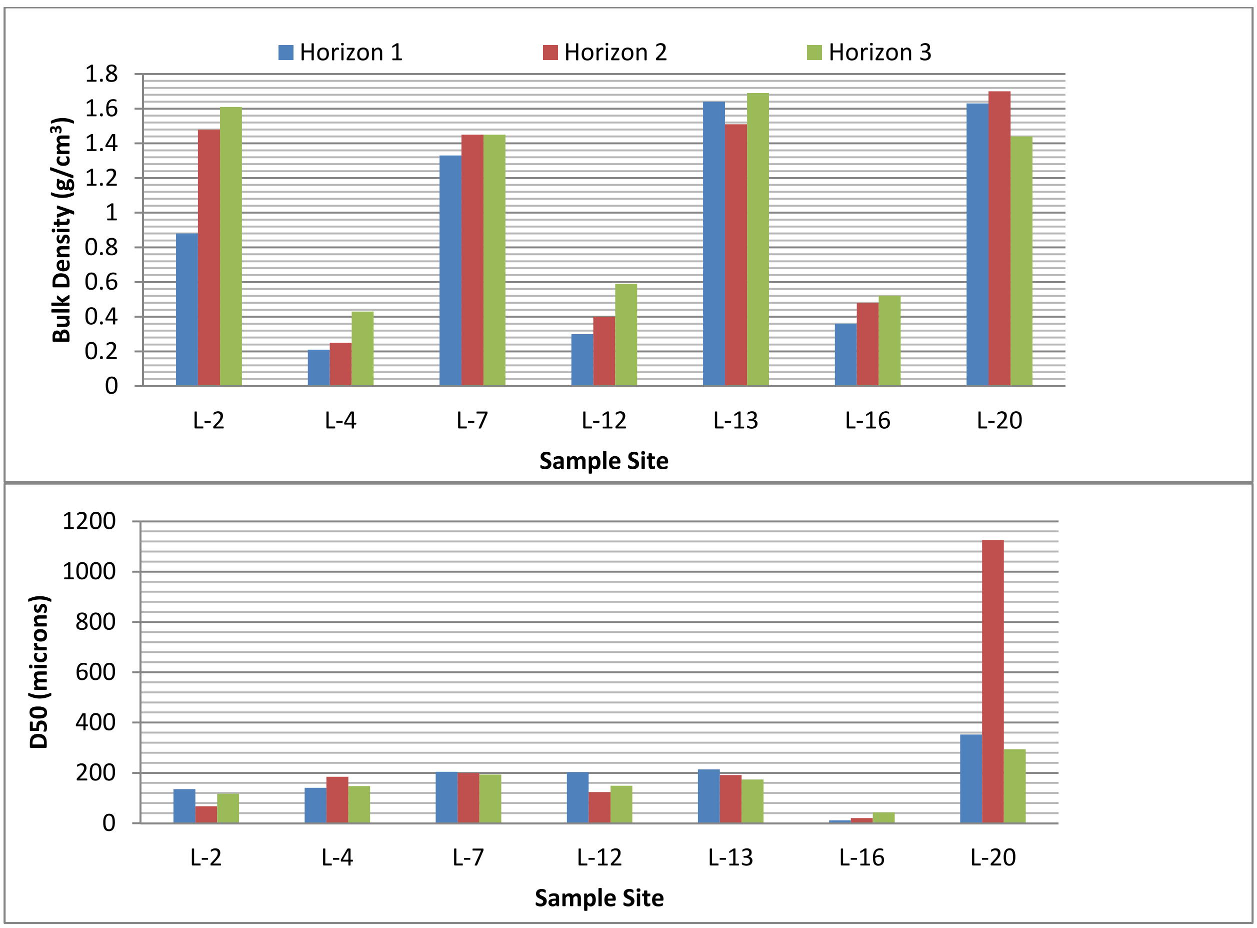

Figure 9. Bulk density and grain size distributions are given for each horizon at each sample site. Horizon 1 corresponds to sample depth 0 – 6", horizon 2 to 6 – 12" and horizon 3 to 12 – 24".

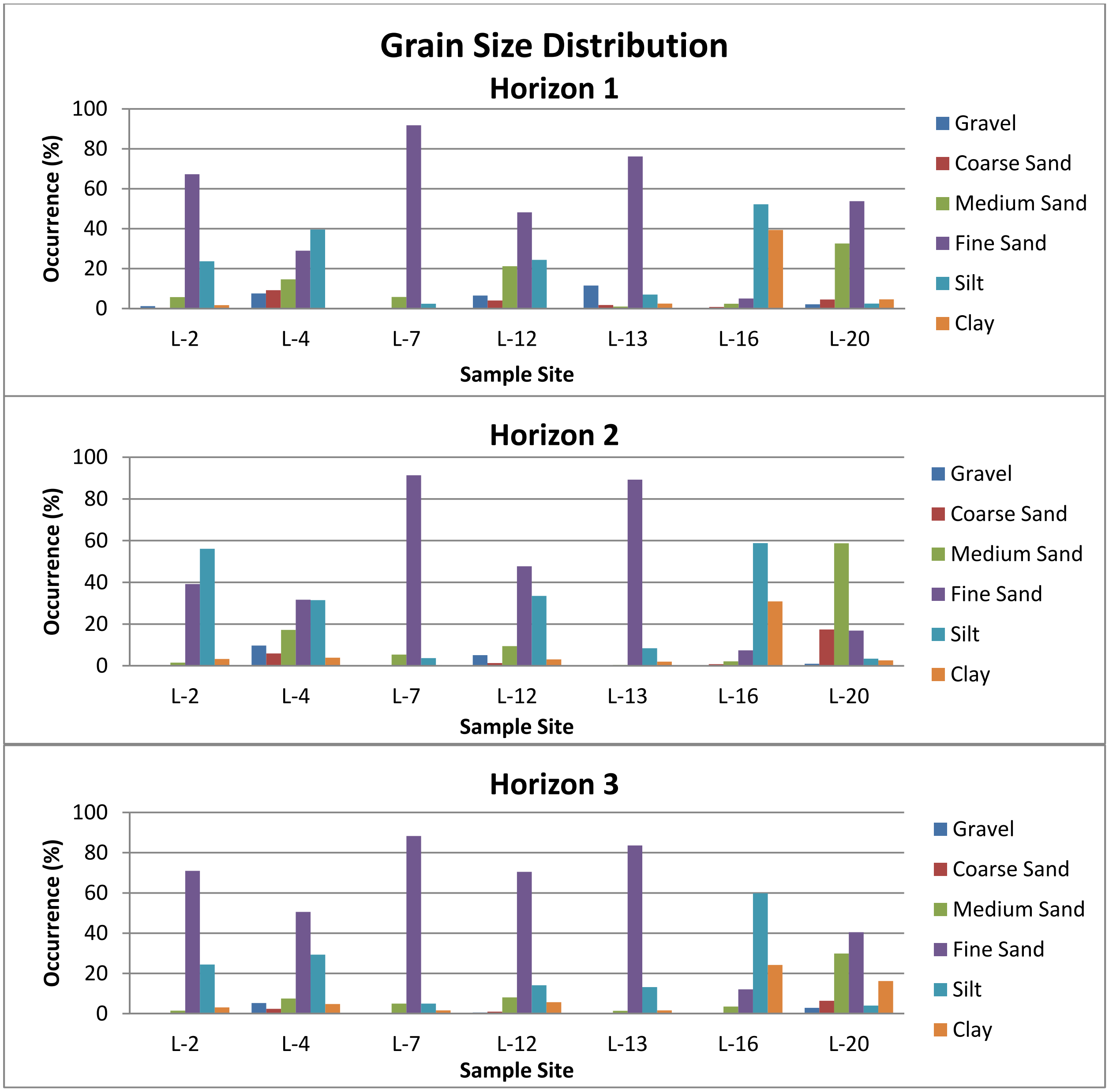

Figure 10. Grain size analysis results showing the percent of gravel, sand, silt and clay contained in each of the samples collected. Horizon 1 corresponds to sample depth 0 – 6”, horizon 2 to 6 – 12” and horizon 3 to 12 – 24”.

6. DISCUSSION

The Stone Bay Rifle Range complex receives small arms munitions (i.e., spent bullets) that could potentially lead to heavy metals being transported outside the theoretical range fan. In the previous study conducted in 2008, soil/sediment monitoring at 23 locations circumnavigating the range fan did not indicate metals had migrated from the operational range to off-range areas and accumulated to concentrations likely to be toxic to ecological receptors or even distinguishable from “background”. There was, however, one isolated sampling site (L-2) at which copper exceeded its ecological toxicity screening value by a considerable amount. The present study was designed to further investigate heavy metals at and around this sampling site and to characterize several chemico-physical sediment parameters that might influence metals bioavailability and determine, in part, their mobility in the environment.

The follow-up sampling at and around site L-2, at which 479 ppm copper was previously found in the surficial fraction, supports the original finding. Follow-up sampling indicated one location with elevated copper (71.2 ppm at L-2g) and five locations with elevated lead in horizon 1 (ranging from 38.1 to 396 ppm). Sample results indicate that the locations at and around site L-2 vary in terms of their metals concentrations, and elevations in concentration tend to be in the surficial fraction. Further, results suggest that site L-2 has been impacted by one or more sources of copper and lead, which is consistent with it lying within historical small arms firing range fans. Data do not support the current Stone Bay Rifle Range complex as the source.

The potential transport and bioavailability of heavy metals is dependent on a range of sediment characteristics that were not surveyed in the original study. Additional work was performed in 2010 to collect sediment cores at seven of the twenty-three stations sampled in 2008 to quantify 1) bulk (or in-place) density, 2) median grain size (D50), 3) total organic carbon (TOC), 4) acid volatile sulfide (AVS) and 5) simultaneously extracted metals (SEM). Based on the computed median grain sizes, all of the samples analyzed fall within the sand or silt size range. More significantly, each tested location had sufficient amounts of AVS and TOC in the sediment to sequester the amount of SEM present, suggesting a lack of metals bioavailability. The results presented in this report will also be useful for any subsequent efforts to model the potential transport and fate of heavy metals released from spent bullets to areas adjacent to the firing range complex. If metals continue to be deposited within the range via training activities, future monitoring efforts may be warranted to ensure range sustainability at MCB Camp Lejeune.

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Appendix A

U.S. MCB Camp Lejeune Sampling Locations

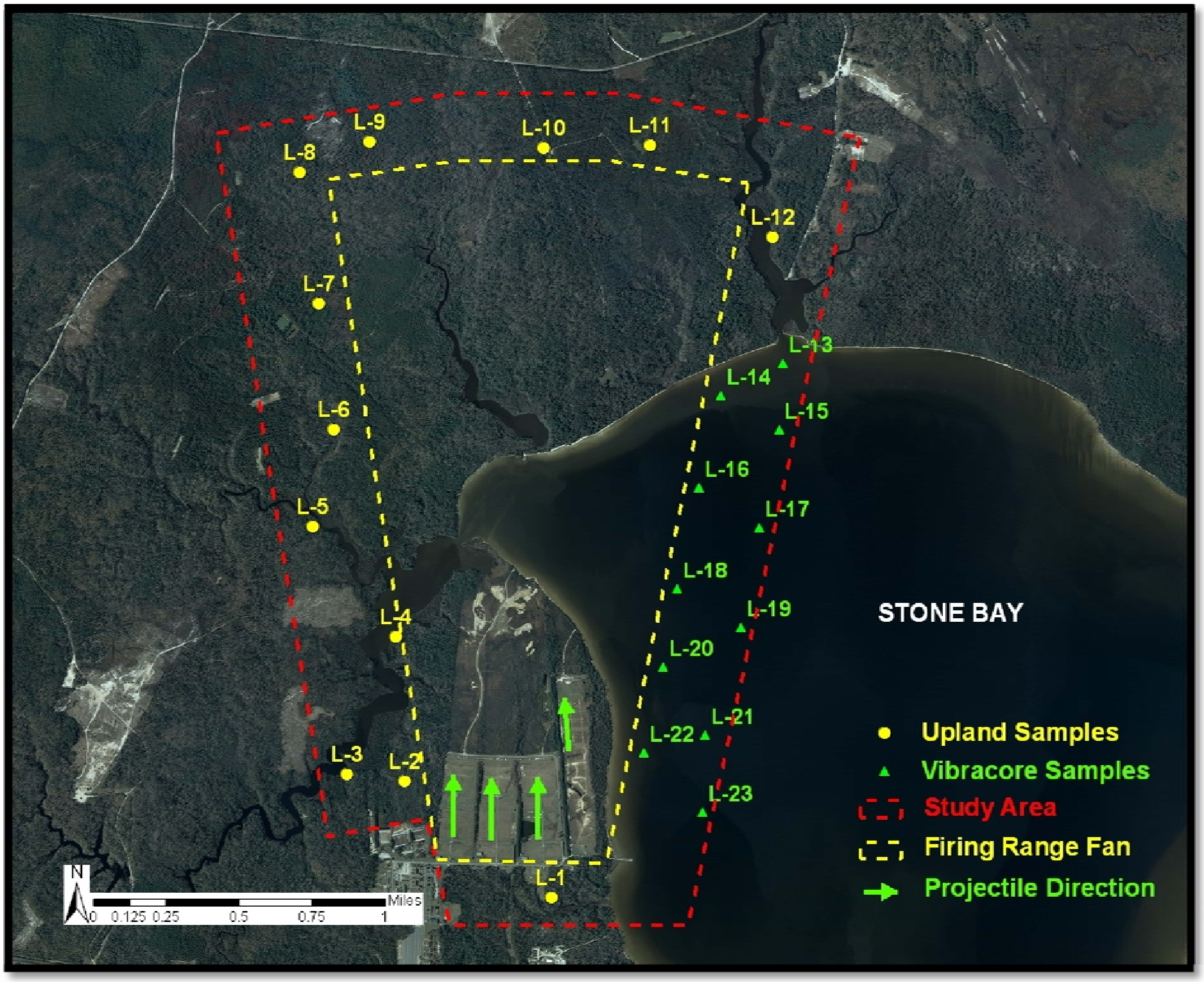

Figure A-1. The complete set of points that were sampled in the 2008 field effort at MCB Camp Lejeune (Sapp et al., 2008a).

Table A-1. MCB Camp Lejeune sampling dates, locations, elevations, accuracies and site descriptions. The location of point L-2a was estimated since no survey data were collected at the site (likewise, no elevation data were collected). The horizontal and vertical uncertainties are dependent on the quality of the GPS signal.

Sample ID	Date	UTM Coordinates Zone 17 (m)		Elevation NAVD88 (m)	GPS Horizontal Uncertainty (cm)	GPS Vertical Uncertainty (cm)	Location Type
		Easting	Northing				
L-2	4/4/2010	825576	3834182	5.68	< 2	< 5	Upland
L-2a	4/4/2010	825573	3834204		< 200		Upland
L-2b	4/4/2010	825588	3834203	6.07	< 2	< 5	Upland
L-2c	4/4/2010	825599	3834181	6.97	< 2	< 5	Upland
L-2d	4/4/2010	825590	3834165	5.90	< 50	< 100	Upland
L-2e	4/4/2010	825576	3834165	8.34	< 50	< 100	Upland
L-2f	4/4/2010	825561	3834165	8.80	< 50	< 100	Upland
L-2g	4/4/2010	825554	3834174	-0.93	< 50	< 100	Upland
L-2h	4/4/2010	825551	3834183	3.77	< 50	< 100	Upland
L-2i	4/4/2010	825556	3834194	4.89	< 50	< 100	Upland
L-2j	4/4/2010	825565	3834200	8.97	< 50	< 100	Upland
L-4	4/3/2010	825474	3834966	-2.93	< 50	< 100	Creek bank
L-7	4/3/2010	824952	3836796	11.65	< 50	< 100	Upland
L-12	4/3/2010	827381	3837587	2.20	< 50	< 100	Creek bank
L-13	4/3/2010	827586	3836449	2.20	< 2	< 5	Bay
L-16	4/3/2010	827076	3835918	-2.10	< 2	< 5	Bay
L-20	4/3/2010	826940	3834933	-1.55	< 2	< 5	Bay

Appendix B

U.S. MCB Camp Lejeune Heavy Metals Analyses

Table B-1. Heavy metals concentrations in sediment. Horizon 1 corresponds to a sample depth of 0 – 6” below surface, horizon 2 to 6 – 12” and horizon 3 to 12 – 24”. Values below the lower analytical detection limits are denoted by "LDL." All other results are in ppm.

Sample ID	Horizon	Sb (Antimony)	Cu (Copper)	Fe (Iron)	Pb (Lead)	Mn (Manganese)	Zn (Zinc)
L-2	1	0.12	3.4	1190	14.5	14.4	5.7
L-2	2	0.06	0.7	1320	9.4	15.0	3.9
L-2	3	0.06	0.6	3300	7.0	8.6	4.9
L-2a	1	0.09	4.3	9600	15.3	4.8	4.7
L-2a	2	0.07	3.4	16000	16.3	6.3	6.3
L-2a	3	0.06	3.0	19400	9.0	5.8	7.1
L-2b	1	0.07	2.1	8570	11.7	4.8	4.5
L-2b	2	0.07	2.9	16000	8.8	7.1	6.2
L-2b	3	0.06	3.0	10800	9.1	7.2	6.5
L-2c	1	0.10	1.7	795	27.5	25.1	3.9
L-2c	2	0.03	0.8	715	9.1	14.3	2.4
L-2c	3	LDL	0.5	1120	7.9	9.8	3.6
L-2d	1	0.13	4.6	2170	38.1	14.6	5.7
L-2d	2	0.03	1.3	1590	13.8	22.4	5.0
L-2d	3	0.03	1.7	6580	7.4	6.6	5.0
L-2e	1	0.07	2.4	1250	22.9	56.1	7.1
L-2e	2	0.04	1.1	1360	11.9	56.1	5.6
L-2e	3	LDL	0.5	1440	7.5	11.3	3.1
L-2f	1	0.11	9.0	8700	46.2	52.2	11.2
L-2f	2	0.07	2.9	3130	18.4	8.7	6.5
L-2f	3	0.05	1.6	9630	8.2	8.0	7.3
L-2g	1	0.26	71.2	7940	396.0	181.0	34.6
L-2g	2	0.10	6.8	6100	44.2	47.6	18.0
L-2g	3	0.07	2.8	4750	17.0	11.0	10.0
L-2h	1	0.13	8.5	3870	73.7	57.0	14.3
L-2h	2	0.07	2.1	3250	15.4	22.3	6.8
L-2h	3	0.06	1.1	4010	7.0	8.1	4.2
L-2i	1	0.10	7.1	2220	73.4	42.5	8.8
L-2i	2	0.05	5.8	2240	48.2	11.1	5.2
L-2i	3	0.03	4.5	9590	21.9	9.3	8.0
L-2j	1	0.10	7.2	7110	23.1	6.3	8.5
L-2j	2	0.05	13.1	6020	27.3	4.5	5.1
L-2j	3	0.03	5.0	11100	12.5	7.7	7.7

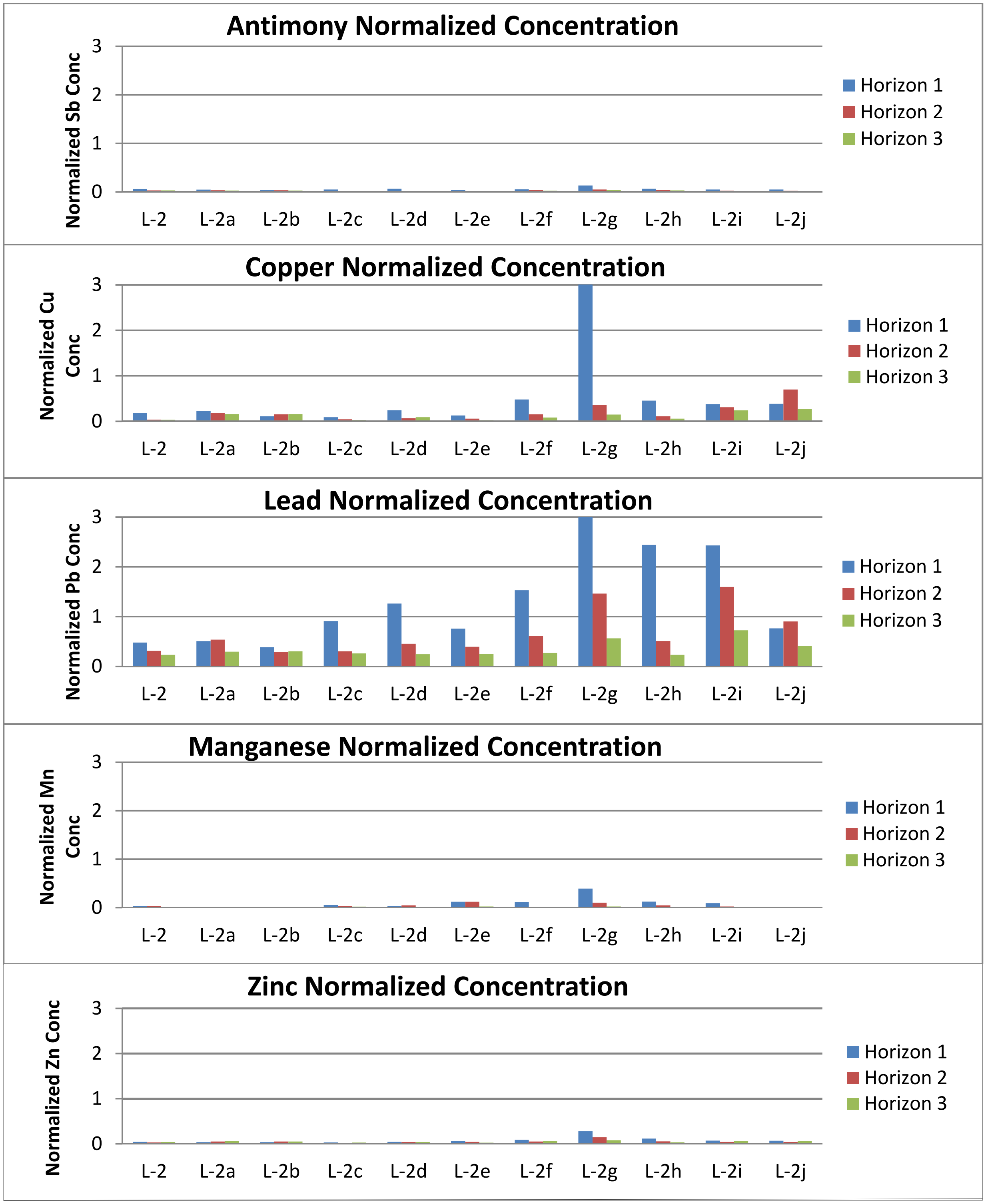

Figure B-1. Heavy metal concentrations in sediment samples at and around L-2, normalized by the respective toxicity screening values. Results below the lower analytical detection limit are not shown. Normalized values exceeding three were truncated and appear as normalized values of three for plotting purposes. Horizon 1 corresponds to a sample depth of 0 – 6”, horizon 2 to 6 – 12” and horizon 3 to 12 – 24”.

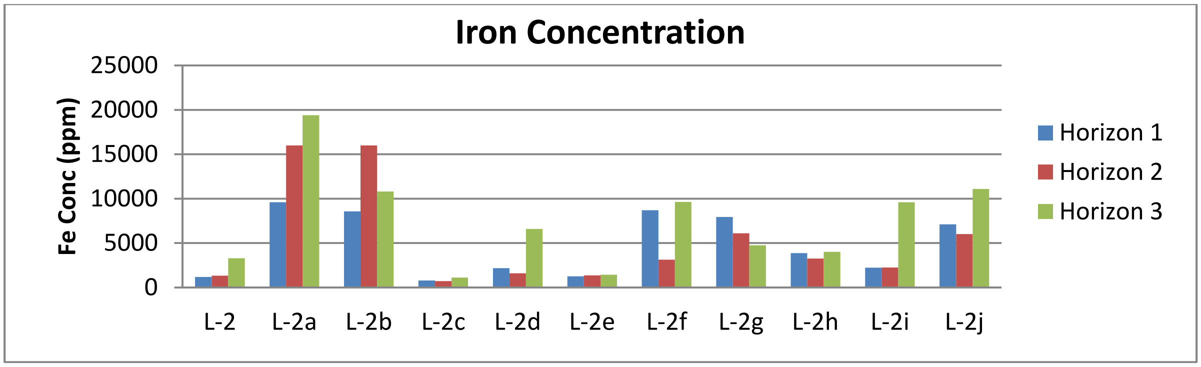

Figure B-2. Iron concentrations in sediment samples at and around L-2. An ecological toxicity screening value for iron in marine sediments does not exist; therefore, the data are not normalized. Horizon 1 corresponds to a sample depth of 0 – 6”, horizon 2 to 6 – 12” and horizon 3 to 12 – 24”.

Appendix C

U.S. MCB Camp Lejeune Sediment Characteristics and Bioavailability Metrics

Table C-1. AVS and SEM measurements, along with calculated values of various metals bioavailability metrics. Horizon 1 corresponds to a sample depth of 0 – 6", horizon 2 to 6 – 12" and horizon 3 to 12 – 24". AVS and SEM measurements are presented in micromoles/gram. Due to insufficient sample volume, TOC could not be determined for L-2, horizon 1.

Sample ID	Horizon	TOC (ppm)	AVS (µmole/g)	SEM (µmole/g)	AVS – SEM (µmole/g)	SEM/AVS	Fraction TOC f(oc) (g(oc)/g)	(AVS – SEM)/ f(oc) (µmole/g(oc))
L-2	1	-	0.8	0.2419	0.5581	0.3024	-	-
L-2	2	11000	0.55	0.3584	0.1916	0.6516	0.0110	17.42
L-2	3	1930	0.58	0.3693	0.2107	0.6367	0.0019	109.2
L-4	1	257000	2.2	1.537	0.6630	0.6986	0.2570	2.580
L-4	2	219000	2	1.405	0.5951	0.7025	0.2190	2.717
L-4	3	356000	3.1	2.048	1.052	0.6606	0.3560	2.955
L-7	1	10800	0.5	0.3233	0.1767	0.6466	0.0108	16.36
L-7	2	1570	0.47	0.3007	0.1693	0.6398	0.0016	107.8
L-7	3	3110	0.51	0.3298	0.1802	0.6467	0.0031	57.94
L-12	1	115000	1.2	0.6640	0.5360	0.5533	0.1150	4.661
L-12	2	212000	1.5	0.5000	1.000	0.3333	0.2120	4.717
L-12	3	28000	1.1	0.3138	0.7862	0.2853	0.0280	28.08
L-13	1	3800	0.64	0.2812	0.3588	0.4394	0.0038	94.42
L-13	2	4370	0.58	0.3740	0.2060	0.6448	0.0044	47.14
L-13	3	3390	0.53	0.3266	0.2034	0.6162	0.0034	60.00
L-16	1	36000	1.6	1.135	0.4650	0.7094	0.0360	12.92
L-16	2	35400	1.2	0.8510	0.3490	0.7092	0.0354	9.859
L-16	3	38000	1.5	1.007	0.4930	0.6713	0.0380	12.97
L-20	1	3050	0.67	0.2094	0.4606	0.6487	0.0031	151.0
L-20	2	1180	0.57	0.3499	0.2201	4.9388	0.0012	186.5
L-20	3	1320	0.58	0.3717	0.2083	0.3125	0.0013	157.8

Table C-2. Grain size analysis results showing the percent of gravel, sand, silt and clay contained in each of the samples collected. Soil type was determined using the percentages of sand, silt and clay on the Soil Texture Triangle.

Sample ID	Horizon	Gravel (%)	Course Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Bulk Density (g/cm^3)	D50 (microns)	Soil Type
L-2	1	1.2	0.4	5.7	67.3	23.7	1.7	0.88	135.2	Loamy sand
L-2	2	0	0	1.5	39.2	56.1	3.3	1.48	67.09	Silt loam
L-2	3	0	0	1.5	71	24.4	3.1	1.61	116.7	Sandy loam
L-4	1	7.6	9.2	14.6	29	39.6	0	0.21	140.5	Sandy loam
L-4	2	9.7	5.9	17.2	31.7	31.5	3.9	0.25	184.3	Loam
L-4	3	5.3	2.4	7.5	50.6	29.3	4.8	0.43	147.3	Sandy loam
L-7	1	0	0.1	5.8	91.8	2.4	0	1.33	204.2	Sand
L-7	2	0	0	5.4	91.3	3.7	0	1.45	199.3	Sand
L-7	3	0	0	5	88.3	5	1.6	1.45	193.5	Sand
L-12	1	6.5	4	21.2	48.2	24.4	0	0.30	202.4	Loamy sand
L-12	2	5.1	1.3	9.4	47.7	33.5	3.1	0.40	123.3	Sandy loam
L-12	3	0.6	1	8.1	70.5	14.1	5.7	0.59	148.5	Sandy loam
L-13	1	11.5	1.8	1	76.2	7	2.5	1.64	213.6	Sandy loam
L-13	2	0	0	0.4	89.2	8.4	2	1.51	191.4	Sand
L-13	3	0.1	0	1.4	83.6	13.2	1.6	1.69	173.4	Loamy sand
L-16	1	0.2	0.8	2.4	5	52.2	39.4	0.36	11.21	Silty clay loam
L-16	2	0	0.8	2.1	7.4	58.8	30.9	0.48	20.52	Silty clay loam
L-16	3	0	0.4	3.5	12.1	59.8	24.2	0.52	42.40	Silt loam
L-20	1	2.1	4.5	32.6	53.8	2.5	4.6	1.63	352.7	Sand
L-20	2	1	17.4	58.7	16.9	3.4	2.6	1.70	1126	Sand
L-20	3	2.9	6.4	29.9	40.5	4	16.2	1.44	293.8	Sandy loam