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FINAL

RANGE ENVIRONMENTAL VULNERABILITY ASSESSMENT

Marine Corps Base Quantico, Virginia

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Executive Summary

The United States Marine Corps Range Environmental Vulnerability Assessment (REVA) program meets the requirements of the current Department of Defense (DoD) Directive 4715.11 *Environmental and Explosives Safety Management on Operational Ranges within the United States* and DoD Instruction 4715.14 *Operational Range Assessments* (DoD, 2004; DoD, 2005).

The purpose of REVA is to identify whether there is a release or substantial threat of a release of munitions constituents (MC) from operational range or range complex areas to off-range areas. This is accomplished through a baseline assessment of operational range areas and, where applicable, the use of fate and transport modeling/analysis of the REVA indicator MC based upon site-specific environmental conditions at the operational ranges and training areas. In addition, environmental sampling is performed, where applicable, to determine whether an actual release of MC has occurred. Indicator MC selected for the REVA program include trinitrotoluene (TNT), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), hexahydro-trinitro-triazine(RDX), perchlorate, and lead.

At Marine Corps Base (MCB) Quantico, areas where the most significant portions of MC are believed to have been deposited from historical and current use of operational ranges (MC loading areas) were identified, conceptual and screening-level evaluations were carried out and surface water and groundwater sampling were conducted at locations where MC were predicted to be detectable. The field sampling results indicate that perchlorate and lead were detected more frequently than explosives at the surface water and groundwater locations sampled. However, all detected MC concentrations in surface water and groundwater were below the DoD Range and Munitions Use Subcommittee (RMUS) draft screening values for the identified receptors. Based on the assessment results, no immediate environmental concern of MC migration to off-range areas was identified.

This report presents the assessment results for the operational ranges and training areas at MCB Quantico, Virginia. This report is the first comprehensive report on MC associated with the operational ranges at MCB Quantico and serves as the baseline assessment of environmental conditions and potential vulnerabilities of the operational ranges. This report presents:

- details on the installation's operational ranges and use of military munitions,
- estimates of MC loading rates at each range or training area based on records of munitions use,
- prioritization of operational ranges and training areas for evaluation through the REVA process,

- description of the MCB Quantico conceptual site model, which forms the basis of most assumptions for potential surface water and groundwater pathways for off-range migration of MC,
- screening-level methods for analyses of surface water and groundwater pathways and results of those analyses,
- a separate, qualitative assessment of small arms ranges (SARs), and
- results of the REVA field sampling effort conducted in 2008 and 2009.

Subsequent vulnerability assessments will be conducted on operational ranges at MCB Quantico on a five-year cycle or when significant changes are made to existing ranges that potentially affect the determinations made during this baseline assessment, as described in the *REVA Reference Manual* (HQMC, 2009).

Military Munitions Training and Operations

MCB Quantico is located approximately 35 miles southwest of Washington, D.C. and 24 miles north of Fredericksburg, Virginia. The installation consists of approximately 60,000 acres in Prince William, Stafford, and Fauquier counties in Virginia. Approximately 90% of the installation area is considered operational range area, which includes impact areas, fixed ranges, training facilities, and maneuver areas. Family housing, billeting, and service support activities occupy the remainder of the property. The base is the home of the Marine Corps Combat Development Command, which develops the doctrine, tactics, techniques, equipment, training, and education employed by the Marine Corps in all war fighting areas. Tenants on the base include the Marine Corps University, Marine Corps War College, Marine Corps Command & Staff College, the Marine Corps Systems Command, other Marine Corps support offices, the Federal Bureau of Investigation (FBI) Academy and Laboratory, and the Drug Enforcement Administration Office of Training.

The operational range area of the base is managed as 44 range training areas (RTAs). However, not all 44 RTAs are or historically have been used for military munitions related training; some are used strictly for maneuvers that do not involve the use of military munitions. There are 19 RTAs that either currently are used or historically have been used for military related training. On these 19 RTAs, there are 11 fixed ranges (not including SARs), three gun positions, three demolition ranges, one fixed training facility, 10 historical use areas, and one landing zone (LZ) that are assumed to have MC deposited on them. There are three additional fixed training facilities and 28 other LZs located on the RTAs of MCB Quantico; however, a review of the military munitions expenditure data for these areas indicated that they contain little to no REVA indicator MC. As a result, no further assessment was conducted for these areas. Historical areas that do not overlap current operational range area are being addressed in the Military Munitions Response Program and, therefore, are not included in the REVA. Additionally, 26 SARs were identified for qualitative assessment of environmental vulnerability. SARs are assessed qualitatively due to the impracticality of modeling lead migration on a site-specific basis.

Munitions Constituents Loading Areas and Prioritization

The REVA fate and transport screening-level modeling analysis requires estimation of the amount of indicator MC deposited on operational ranges over time in order to predict whether there is a potential release or substantial threat of a release of MC. In REVA, the layout of the operational ranges (current and historical), expenditure data (current and historical munitions use), and discussions with range control personnel are used to identify and map areas suspected of containing MC. Then, following the MC loading estimating procedures outlined in the *REVA Reference Manual* (HQMC, 2009), the potential amounts of MC deposited on those identified areas are estimated on an average annual basis for each year the range was in use. Once the MC loading estimates are calculated, the individual MC loading areas are categorized as either primary or secondary. Primary MC loading areas are considered heavy use areas where relatively large amounts of high explosive military munitions are or have been utilized.

At MCB Quantico, 14 primary MC loading areas were identified based on range information obtained from expenditure data, documents reviewed, and interviews conducted with Training and Education Command and Range Control. Of the 14 primary MC loading areas, 8 currently are used for military munitions training and 6 are considered historical use areas. Based on MC loading and surface water and groundwater characteristics, these primary MC loading areas were prioritized to determine the most critical areas for fate and transport modeling. One of the 14 primary MC loading areas (Historical [HIS]-4 MC loading area) received a lower priority ranking than the other 13; therefore, HIS-4 was not modeled. As noted in Figure ES-1, the 13 primary MC loading areas modeled were:

- Impact Area 1 (located within RTA-9A),
- Impact Area 2 (located within RTA-9A),
- Impact Area 3 (located within RTA-9A),
- Charlie Demo (located within RTA-5A),
- Murphy Demo (located within RTA-8),
- LZ-Thrush (located within RTA-5C),
- Training Facility (TF)-Combat Town (located within RTA-16F),
- Range Training Area (RTA)-7B

N

Prince William

Fauquier

Cedar Run

619

234

95

1

HIS-1

Middle Chopawamsic Creek

North Chopawamsic Creek

Impact Aea 2

HIS-5

Impact Area 3

Impact Area 1

HIS-4

HIS-2

HIS-3

Stafford

Aquia Creek

South Chopawamsic Creek

Lunga Reservoir

Breckinridge Reservoir

Charlie Demo

Chopawamsic Creek

Quantico Creek

Smith Lake

Camp Barrett Demo

Murphy Demo

Potomac River

Note:
10% of RTA 7B is a primary MC Loading Area

REVA
FIGURE ES-1
PRIMARY MC LOADING AREAS AND WATERSHED BOUNDARIES

MCB QUANTICO
QUANTICO, VA

Legend

- INSTALLATION BOUNDARY
- RTA
- CURRENT MC LOADING AREA
- HISTORICAL MC LOADING AREA
- COUNTY BOUNDARY
- ROAD
- STREAM/RIVER PERMANENT
- STREAM/RIVER SEASONAL
- STREAM (OUTSIDE MCB QUANTICO)

WATERSHED BOUNDARY

- CEDAR RUN
- SOUTH FORK QUANTICO CREEK
- SMITH LAKE
- CHOPAWAMSIC CREEK

0 0.5 1 2 3
Miles

DATE: NOVEMBER 2010

SOURCE: MCB QUANTICO/NREA GIS Office 2006
ESRI GIS DATA, 2005

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- HIS-1 (historical use area, located within RTA-10C),
- HIS-2 (historical use area, located within RTA-10B),
- HIS-3 (historical use area, located within RTA-7B),
- HIS-5 (historical use area, located within RTA-9A), and
- Camp Barrett Demo (historical use area, located within RTA-5C).

Conceptual Site Model

MCB Quantico is located mostly in the Piedmont physiographic province, but approximately 17% of the installation east of the fall line lies within the Coastal Plain physiographic province. The terrain within the Piedmont physiographic province consists of low, gently rolling hills with well-rounded or flat tops. The long, narrow ridges trend mostly northeast and are split by deeply incised drainage channels. The Coastal Plain province east of the fall zone is typified by relatively flat, terraced terrain, with local relief provided by incised stream valleys. These small streams flow rapidly through the Piedmont into wide, slow-moving tidal estuaries and swamps on the Coastal Plain (MCB Quantico, 2001; Swain et al., 1991;TtNUS, 2000).About 95% of MCB Quantico is classified as unimproved grounds, and approximately 80% of this area is wooded (TtNUS,2000).

MCB Quantico has mild winters and humid summers. Its proximity to the Atlantic Ocean, Potomac River, and Chesapeake Bay adds moisture to the air and moderates the temperature. The average annual temperature is 56 degrees Fahrenheit, and the installation receives an average annual precipitation of 40 inches (MCB Quantico, 2001; NOAA, 2005). The precipitation is distributed fairly equally throughout the year, although frequent thunderstorms result in slightly more rain in the summer.

MCB Quantico is highly dissected by perennial and ephemeral streams. Most streams flow south and southeast toward the Potomac River. Some streams in the northwest part of the installation flow north and northeast to ultimately discharge into the Occoquan Creek. The drainage system at MCB Quantico is divided into six watersheds. The four watersheds that drain most of the installation are Cedar Run, Smith Lake, Chopawamsic Creek, and South Fork Quantico Creek. Two of the larger watersheds, Cedar Run and Smith Lake, also drain upgradient areas beyond the installation boundary. The Chopawamsic Creek and South Fork Quantico Creek watersheds occur almost entirely within the boundaries of MCB Quantico. The Chopawamsic Creek and Smith Lake watersheds contain drinking water reservoirs. Breckinridge Reservoir(within the Chopawamsic Creek watershed)and Lunga Reservoir and Smith Lake(both within the Smith Lake watershed) are drinking water sources located downgradient of identified primary MC loading areas.

Surface water runoff would be the major transport pathway of MC from primary MC loading areas to surface water bodies located within and around MCB Quantico. MC could enter surface runoff by direct dissolution or by erosion of soil-associated MC. MC transported in groundwater also could discharge into surface water. MC transported to surface water could reach human (drinking water reservoirs) and ecological (streams potentially supporting threatened and endangered species) receptor exposure points.

The groundwater system underlying MCB Quantico and the surrounding area is complex, with groundwater occurring in numerous bedrock and unconsolidated units. The majority of the installation area that is within the Piedmont physiographic province overlies fractured bedrock, which occurs beneath unconsolidated saprolite and other sediments that vary in thickness from a few feet to over 100 feet. Bedrock aquifers underlie almost the entire installation, with the exception of a small portion of the southeastern-most corner of MCB Quantico, which overlies the unconsolidated sediments of the Coastal Plain. The highest well yields in the Piedmont province occur where large, water-filled bedrock fractures are overlain by thick, saturated regolith. The regolith has a high primary porosity that serves as a reservoir for groundwater, and the fractured bedrock has a high secondary permeability, resulting in high velocity flow through fractures and allowing flow of groundwater to springs, streams, and wells (Brown, 1981; McFarland, 1996; Heath, 1984).

The geologic material of the Coastal Plain consists of sand, gravel, and clay layers that dip and thicken to the east. Groundwater within this region flows via primary permeability; many of the units that make up the Coastal Plain have very good to excellent water-bearing potential and are utilized throughout the region for water supply (Laczniac and Zenone, 1985; Nelms and Brockman, 1997).

The water table in the area is generally subparallel to the surface topography. As such, a large regional groundwater divide is expected to exist along the northwestern border of Stafford County and close to the southeastern boundary of the Cedar Run watershed. Similar to the surface water, the groundwater west and north of the groundwater divide generally flows northwest toward Cedar Run. Groundwater southeast of the divide generally flows southeast toward the Potomac River. However, factors such as fracture patterns, groundwater withdrawals, and impoundments can affect groundwater flow direction.

Groundwater from primary MC loading areas could flow southeastward and enter drinking water reservoirs on base by way of direct discharge. Conversely, the downstream segments of reservoirs that typically lose water to the subsurface could contribute MC to groundwater. The three groundwater supply wells located at Camp Upshur are upgradient of the general groundwater flow originating on the installation and generally are not expected to receive flow from impact areas at MCB Quantico. However, the wells could tap fractures in the bedrock and create cones of depression within the aquifer. In this case, the flow would be dependent on the fracture orientation in the bedrock, making it likely for the wells to receive some portion of

groundwater from within the installation. Groundwater flowing from primary MC loading areas could migrate to off-installation receptors, such as residential and agricultural users.

Surface Water Screening-Level Analysis

Fate and transport analysis of potential MC migration via surface water was conducted as part of the vulnerability assessment for MCB Quantico. The fate and transport analysis was conducted through screening-level transport analysis for the 13 primary MC loading areas that were identified to be high priority areas for modeling. This methodology was selected to provide conservative estimates of MC concentrations in surface water reaching the exposure endpoints for these primary MC loading areas (i.e., Smith Lake and downstream points of Cedar Run and South Fork Quantico Creek on the MCB Quantico installation boundary). MC transport to Lunga Reservoir and Breckinridge Reservoir was not modeled because there is negligible active MC loading upstream of these two water bodies; the only primary loading areas that drain to them are historical. MC loading from nonprimary MC loading areas located upstream from the 13 primary MC loading areas was factored into the screening-level analysis. Thus, the screening-level analysis was conducted for all MC loading areas draining within the Cedar Run, Smith Lake, and South Fork Quantico Creek watersheds. MC concentrations in surface water were estimated at the edge of the MC loading areas and at downgradient locations (i.e., Smith Lake and downstream points of Cedar Run and South Fork Quantico Creek on the MCB Quantico installation boundary), accounting for downstream mixing. These estimated concentrations were compared to established REVA trigger values for each MC (Table ES-1).

Table ES-1: REVA Trigger Values

MC	REVA Trigger Value (µg/L)[a]
RDX	0.16
TNT	0.08
HMX	0.08
Perchlorate	0.98

Note:µg/L – micrograms per liter

[a]HQMC, 2009

The screening-level analysis predicted the following results:

- The average annual concentrations of HMX would be below the REVA trigger value in runoff at the edge of all individual MC loading areas.
- RDX, TNT, and/or perchlorate could possibly be detectable in runoff at the edge of 16 individual MC loading areas.

- RDX could possibly be detectable in runoff at the edge of Impact Areas 1, 2, and 3, Charlie Demo, Murphy Demo, RTA-7B, and RTA-9C.
- TNT could possibly be detectable in runoff at the edge of Impact Areas 1, 2, and 3, LZ-Thrush, Charlie Demo, Murphy Demo, RTA-7B, and RTA-9C.
- Perchlorate could possibly be detectable in runoff at the edge of LZ-Thrush, TF-Combat,RTA-5A,RTA-5B, RTA-5C, RTA-7B, RTA-15A, RTA-15B, RTA-16A, and RTA-16C.

Postmixing concentrations of all MC were predicted to be below REVA trigger values in Cedar Run and South Fork Quantico Creek at the installation boundary. However, postmixing concentrations of RDX and TNT entering Smith Lake from all MC loading areas were predicted to possibly be detectable.

Based on the predicted MC concentrations in Smith Lake and the additional information obtained from the Headquarters Marine Corps (HQMC) REVA program manager and MCB Quantico installation personnel about range clearing activities, indicating higher potential MC loading at operational ranges within the Cedar Run watershed than was estimated as part of the screening-level modeling, surface water sampling was conducted down gradient of operational ranges in the Smith Lake and Cedar Run watersheds.

Groundwater Screening-Level Analysis

A screening-level fate and transport analysis of potential MC migration via groundwater was conducted as part of the vulnerability assessment for MCB Quantico. The analysis was conducted for 12 primary MC loading areas that were identified to be high priority areas for modeling. RTA-7B originally was not identified as a primary MC loading area; therefore, it was not included in the groundwater screening-level analysis. However, the potential impact of MC migration from this area was assessed as part of the groundwater sampling conducted at MCB Quantico which is discussed later in this summary. The screening-level analysis was accomplished in three main steps:

1. *Initial groundwater screening-level analysis.* The mass of MC estimated for each of the 12 MC loading area was divided by the volume of rainwater recharging to the groundwater to calculate the concentration of MC potentially in the infiltrating water.
2. *Vadose zone modeling:* A vadose zone model was created for those MC loading areas with MC concentrations above the REVA trigger values in the recharging water (step 1).
3. *Saturated zone modeling*: A saturated zone model was created for those MC loading areas that showed MC concentrations above the REVA trigger values at the water table (step 2). The saturated zone model was used to determine if the groundwater could travel to groundwater receptor exposure points (e.g., Camp Upshur drinking water wells, potential drinking water wells at the nearest installation boundary point, three drinking water

reservoirs on the installation—Lunga, Breckinridge, and Smith Lake) and arrive with a concentration above the REVA trigger values.

Due to the lack of various site-specific data, the screening-level analysis was conducted with multiple conservative and simplifying assumptions. For example, the flow paths from primary MC loading areas to Camp Upshur wells and to potential wells located near installation boundary points were expected to be through the fracture bedrock. Because of the lack of a detailed understanding of the fracture flow system at MCB Quantico at the time that the screening-level analysis was conducted, the transport mechanism from the primary loading areas to the drinking water wells (at Camp Upshur and assumed wells near the installation boundary) was assumed to be a single fracture in the bedrock.

Results from the initial groundwater screening-level analysis include the following:

- HMX concentrations in infiltrating water were estimated to be above the REVA trigger value at Impact Area 1, TF-Combat Town, and HIS-3. Therefore, HMX was retained as a parameter for further assessment at these loading areas.
- Perchlorate concentrations in infiltrating water were estimated to be above the REVA trigger value at Impact Areas 1, 2, and 3, Charlie Demo, LZ-Thrush, and TF-Combat Town. Thus, perchlorate was retained as a parameter for further assessment at these MC loading areas.
- TNT and RDX concentrations in infiltrating water at all primary MC loading areas were estimated to be above REVA trigger values. Therefore, TNT and RDX were retained as parameters for further assessment at all primary MC loading areas.

Results of the vadose zone modeling were as follows:

- HMX was predicted to reach the water table above the REVA trigger value at Impact Area 1 and HIS-3.
- Perchlorate was predicted to reach the water table above the REVA trigger value at Impact Areas 1, 2, and 3, Charlie Demo, LZ-Thrush, and TF-Combat Town.
- TNT was predicted to reach the water table above the REVA trigger value at 9 out of the 12 primary MC loading areas modeled (the three exceptions are LZ-Thrush, Murphy Demo, and TF-Combat Town).
- RDX was predicted to reach the water table at 10 out of the 12 primary MC loading areas modeled (the two exceptions are TF-Combat Town and LZ-Thrush).

The saturated zone modeling predicted the potential for perchlorate originating from Impact Areas 1, 2, and 3, Charlie Demo, LZ-Thrush, and TF-Combat Town MC loading areas to reach the following water supply sources at concentrations above the REVA trigger value:

- The drinking water supply wells located at Camp Upshur
- Potential drinking water wells located at the nearest installation boundary point

HMX, TNT, and RDX were not predicted to arrive at identified receptor points above the REVA trigger values from any of the MC loading areas. Based on results of the saturated zone modeling, further studies that involved fracture trace analysis and off-installation groundwater receptor survey were conducted. These studies were used to identify appropriate groundwater well locations for conducting groundwater sampling. Consequently, groundwater sampling was conducted at locations downgradient of operational ranges.

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 during a baseline assessment. Therefore, SARs are assessed qualitatively under the REVA program to identify factors that influence the potential for lead migration.

MCB Quantico has 26 SARs. Of these, 7 of the ranges are part of the FBI Academy and 10 are part of the Weapons Training Battalion ranges. Twenty-four SARs are located within the Chopawamsic Creek watershed; two are located within the Cedar Run watershed.

The analysis of the 26 SARs at the installation resulted in moderate environmental concern rankings for many of the ranges. The exceptions include two ranges that received minimal environmental concern rankings and two ranges that received minimal surface water environmental concern rankings but moderate groundwater environmental concern rankings. The rankings were based on the results of the qualitative assessment of the ranges using the protocol and professional judgment. No range received a high environmental concern ranking. The predominantly moderate scores for the ranges were due primarily to high precipitation rate, the relatively short distances between many of the SARs and drinking water sources, and the relatively shallow groundwater table near the SARs. These factors can increase lead migration. However, other factors, such as the presence of clay type soils, relatively flat topography, presence of vegetation, and higher pH of surface water and groundwater (pH range of 6.5 to 8.5) reduce lead migration and potential impacts. The considerations of all these factors led to the overall moderate environmental concern for many of the SARs.

Field Sampling Activities

Based on the initial assessment of the screening-level surface water and groundwater modeling, the REVA team initially recommended surface water sampling in Smith Lake, a hydrogeologic condition assessment, and an off-installation groundwater receptor survey. The HQMC REVA program manager and MCB Quantico installation personnel later provided additional information regarding operational ranges located within the Smith Lake and Cedar Run watersheds; this information indicates that MC loading was higher on these ranges than was estimated originally as part of the screening-level modeling. Therefore, the HQMC REVA program manager recommended additional sampling of surface water from streams in the Smith

Lake and Cedar Run watersheds. The REVA team recommended assessments of the hydrogeologic conditions to understand the fracture flow system and a groundwater receptor survey to identify appropriate groundwater monitoring well locations for further assessment of groundwater conditions at MCB Quantico through sampling.

The surface water field sampling effort was conducted in June 2008. After completion of the hydrogeologic fracture trace analysis and groundwater receptor study in June 2008, the groundwater investigation was carried out in three parts: well installation, borehole geophysical analysis, and groundwater sampling. Well installation and borehole geophysical analysis were conducted in December 2008 and February 2009. Groundwater sampling events were conducted in August and October 2009.

Surface Water Sampling

The surface water field sampling effort was conducted on June 23–24, 2008. This information was used to build upon previous REVA documentation and further evaluate the potential for off-range migration of MC at MCB Quantico.

Surface water samples were collected at 12 locations. Eight samples were collected in the Smith Lake watershed and included samples from the upper and lower water column at three locations in Smith Lake. Four samples were collected in the Cedar Run watershed. Of the 12 sampling locations, one was designated as a background location. All sampling locations were outside of operational range areas or along installation roadways, and all nonbackground locations were downstream of operational range areas. Surface water samples were analyzed for a full explosives suite, perchlorate, and lead.

The surface water analytical results were compared to established DoD RMUS draft surface water screening values (DoD, 2009). The DoD RMUS screening values were developed to promote consistency across the services' operational range assessment programs. This list of screening values is intended to be a general list of commonly found MC used in various range training activities. All DoD services compare their data to these screening values to determine if further assessment is warranted.

Surface water sampling results at MCB Quantico indicated the following:

- Explosives were not detected in surface water samples collected in either the Smith Lake or Cedar Run watershed.
- Total and dissolved lead samples collected from two locations in the lower water column of Smith Lake were detected above the laboratory reporting limits (RLs) of 1.5 and 1.0 µg/L, respectively. However, the concentrations were below the DoD RMUS draft drinking water value of 15 µg/L and the DoD RMUS draft surface water value of 2.5 µg/L. The dissolved lead concentrations were also below the Virginia ambient water quality standard for dissolved lead of 2.88 µg/L with hardness adjustment (Virginia Department of

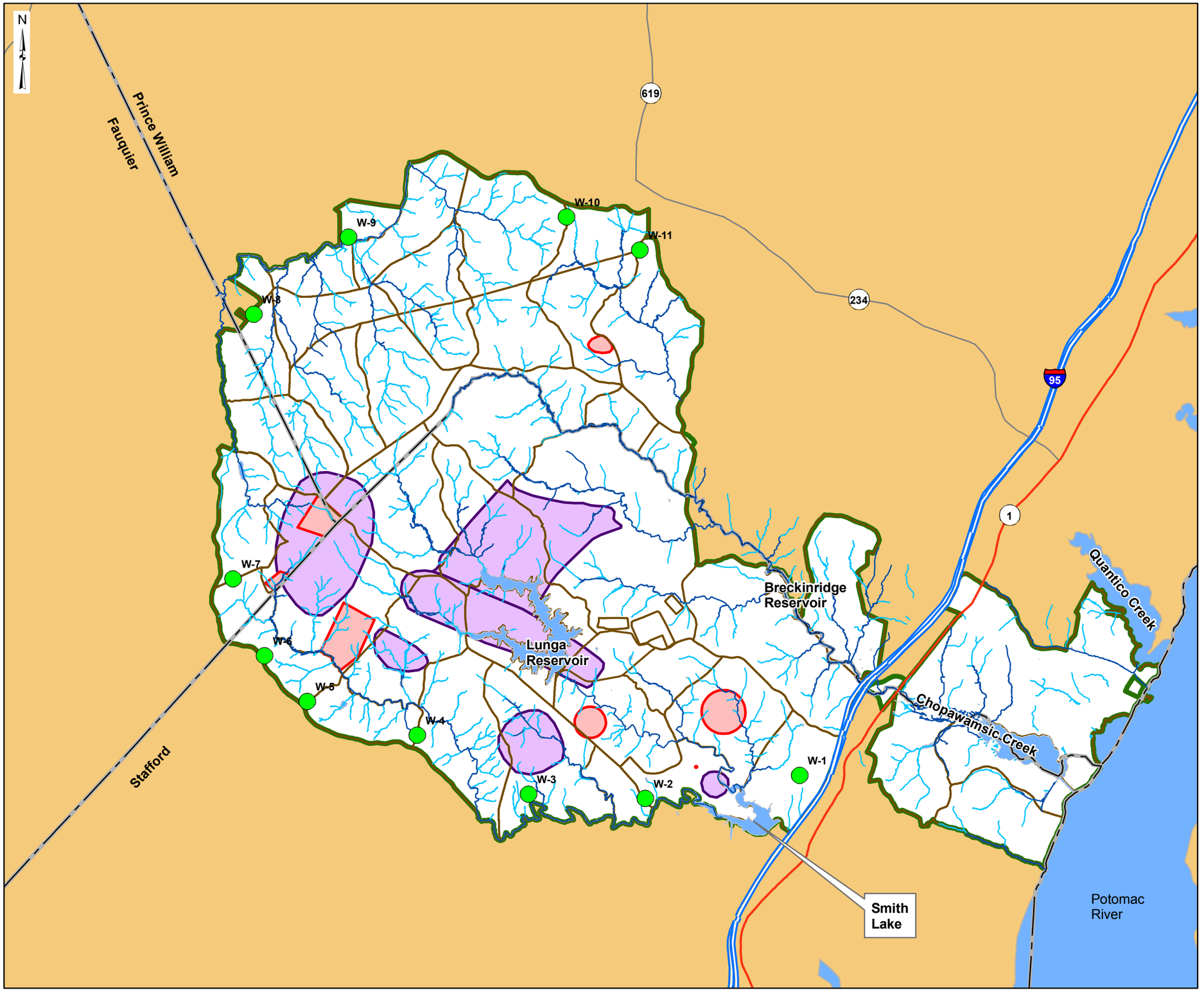
Environmental Quality, 2010). Total and dissolved lead were detected in all other samples collected in Smith Lake and Cedar Run watersheds, but the concentrations were below the laboratory RLs.

- Perchlorate concentrations were detected above the laboratory RL of 0.050 µg/L in samples collected from all locations in the Smith Lake watershed and two locations in the Cedar Run watershed. However, concentrations were below the DoD RMUS draft drinking water value of 15 µg/L and the DoD RMUS draft surface water value of 9,300 µg/L. Perchlorate was detected in all other samples collected in the Cedar Run watershed, but the concentrations were below the laboratory RL.

All detected MC concentrations in surface water in the Smith Lake and Cedar Run watersheds at MCB Quantico were below the DoD RMUS draft surface water and drinking water screening values, indicating no release or threat of a release of MC to off-range areas and no concern to human and ecological receptors potentially consuming water from these watersheds.

Groundwater Investigation

The groundwater investigation was carried out in three parts: well installation, borehole geophysical analysis, and groundwater sampling. Based on an initial groundwater assessment of fracture trace analysis and an off-installation receptor survey, suitable well locations were chosen for sampling groundwater. One polyvinyl chloride groundwater well (W-1) and 10 open borehole wells (W-2 through W-11) were installed around the perimeter of the installation between November 10 and December 17, 2008, based on proximity to identified potential source areas, identification of potential fracture systems that may connect source areas to off-installation receptors, and identified downgradient groundwater users (potential receptors) (Figure ES-2).



REVA
FIGURE ES-2
GROUNDWATER SAMPLE LOCATIONS

MCB QUANTICO
QUANTICO, VA

Legend

- INSTALLATION BOUNDARY
- RTA
- CURRENT MC LOADING AREA
- HISTORICAL MC LOADING AREA
- COUNTY BOUNDARY
- ROAD
- STREAM/RIVER PERMANENT
- STREAM/RIVER SEASONAL
- GROUNDWATER SAMPLE LOCATION

0 0.5 1 2 3
Miles

DATE: NOVEMBER 2010

SOURCE: MCB QUANTICO/NREA GIS Office 2006
ESRI GIS DATA, 2005

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Borehole geophysical analyses were conducted February 16–20, 2009. The analyses included measuring of borehole diameter using a three-arm caliper; fracture depth, angle and width using an acoustic televiewer; fluid temperature; fluid conductivity; natural gamma; fluid movement within the borehole using a heat pulse flowmeter; and video footage of the borehole. These results were used to identify water-producing fractures where groundwater samples could be collected by passive sampling in boreholes W-2 through W-11.

Groundwater samples were collected during two events: a passive sampling event in August 2009 and an active sampling event in October 2009. The first sampling event was designed to minimize the amount of investigation-derived waste generated and to collect representative samples of groundwater from the open bedrock interval at each location using Snap Samplers®. Ten wells (W-2 through W-11) were sampled during this event. The second sampling event was designed to collect groundwater samples under conditions similar to residential use of off-installation groundwater wells using traditional pump-and-sample techniques. All 11 wells were sampled during the second event. The groundwater samples from both events were analyzed for a full explosives suite, perchlorate, lead, and major cations and anions. In addition, alkalinity and hardness as calcium carbonate also were analyzed during the second sampling event.

Groundwater sampling at MCB Quantico showed the following:

- 2-Amino-4,6-dinitrotoluene was detected above the method detection limit (MDL) but below the laboratory RL at wells W-1 and W-7 with concentrations of 0.076 and 0.052µg/L, respectively. No other explosive was detected during either sampling event.
- With the exception of one sample (collected at well W-8), perchlorate was detected in all samples at concentrations above the MDL but below the laboratory RL during both sampling events. Perchlorate was detected in the sample collected from well W-8 above the laboratory RL during the passive and active sampling events. All concentrations are well below the RMUS screening drinking water value of 15µg/L.
    - August 2009 (passive) – Wells W-3, W-6, W-8, and W-9 showed concentrations of perchlorate at 0.014, 0.015, 0.15, and 0.07µg/L, respectively.
    - October 2009 (active) – Wells W-2, W-8, and W-9 showed concentrations of perchlorate at 0.018, 0.18, and 0.083µg/L, respectively.
- Total lead was detected above the RL at six wells during the passive sampling event and three wells during the active sampling event. An additional two wells during passive sampling and four wells during active sampling showed concentrations of total lead below the RL but above the MDL. All detections of total lead were below the RMUS screening drinking water value of 15µg/L.
- Dissolved lead was detected above the RL at one well (W-7) during the passive sampling event but not at any wells during the active sampling event. An additional well (W-11) during passive sampling and six wells during active sampling showed concentrations of

dissolved lead below the RL but above the MDL. All detections of dissolved lead were well below the RMUS screening drinking water value of 15µg/L.

Conclusions and Further Action

The REVA field sampling results for MCB Quantico indicate that perchlorate and lead were detected more frequently than explosives at the locations sampled. No detections of analytes exceeded DoD RMUS screening values for the identified receptors.

The field sampling effort was a continuation of the baseline assessment but was not intended to be a direct comparison to modeling results. Nevertheless, this REVA sampling provides a general confirmation of modeling results, which were based on conservative assumptions.

To ensure operational range sustainability at MCB Quantico, subsequent vulnerability assessments will be conducted on operational ranges at MCB Quantico on a five-year cycle or when significant changes are made to existing operational ranges that potentially affect the determinations made during this baseline assessment, as described in the *REVA Reference Manual* (HQMC, 2009).

Based on the assessment results presented in this report, no immediate environmental concern of MC migration to off-range areas was identified; however, further actions may be evaluated to continue to mitigate the possibility of MC migration from operational ranges at MCB Quantico to ensure future range sustainability.

To view the complete report, please go to
http://www.quantico.usmc.mil/activities/?Section=NREA