Human Health Risk Assessment
Open Burn/Open Detonation Units
Range C-52 North and Range C-62
Eglin Air Force Base, Florida
Operational Permit No. 006176-HO-007

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Prepared Under Contract to:
Air Force Civil Engineer Center
Contract Number: FA8903-15-F-0006

February 2019

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LRS Federal LLC (LRS), in conjunction with Arcadis, conducted this human health risk assessment (HHRA) for octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) detected in groundwater of the surficial aquifer at the Open Burn/Open Detonation (OB/OD) Units Range C-52 North (C-52N) and Range C-62 (location shown on **Figure 1**). The HHRA follows guidance outlined in the USEPA's Risk Assessment Guidance for Superfund (RAGS): Volume I, Human Health Evaluation Manual, Part A (USEPA, 1989), which is consistent with USACE guidance EM-200-1-15 (USACE, 2015), EM 200-1-4: Risk Assessment Handbook - Volume I: Human Health Evaluation (USACE, 1999), and other relevant USEPA guidance cited throughout the assessment. Accordingly, the HHRA is presented in a series of tables in RAGS Part D format (USEPA, 2001) and consists of the following four components:

1) Hazard Identification
2) Exposure Assessment
3) Toxicity Assessment, and
4) Risk Characterization.

In the Hazard Identification, relevant data are compiled and chemicals of potential concern (COPCs) are identified based on a comparison of maximum detected concentrations to human health risk-based screening levels. In the Exposure Assessment, actual or potential chemical release and transport mechanisms are identified; potentially exposed human populations and possible exposure pathways and routes are described; COPC concentrations at points of potential human contact are determined; and human exposures to the COPCs are estimated. In the Toxicity Assessment, quantitative and qualitative toxicity data used to characterize the potential for adverse health effects are identified. In the Risk Characterization, the likelihood and magnitude of adverse health effects are estimated for each applicable exposure scenario. Sources of uncertainty in the HHRA are then noted and discussed. Lastly, alternate concentration limits are derived to be protective of offsite receptors.

Supporting documentation for this HHRA are included in **Attachment 1**.

1.0 HAZARD IDENTIFICATION

This section identifies the COPCs in sampled environmental media based on a comparison of maximum detected concentrations to human health risk-based screening levels. The selected screening levels are protective of adverse health effects; therefore, chemicals present at concentrations below the corresponding screening levels are not anticipated to pose human health risks.

1.1 Available Data

Range C-52N and Range C-62 are currently used as active test and training ranges. Refer to **Figure 2** and **Figure 3** for the range features, including monitoring well locations, surface water drainage locations, the target areas (historically referred to as the ‘Cat’s Eye’), open burn units (OBU), and open detonation units (ODU).

As described in previous site investigation reports (LRS 2018), three groundwater monitoring wells, including one upgradient background well (MW-94-52-01) and two point of compliance (POC) wells (MW-94-52-01 and MW-94-52-03) were installed at Range C-52N, and five monitoring wells, including one upgradient background well (MW-94-62-01) and four POC wells (MW-94-62-02 through MW-94-62-05 were installed at Range C-62. During quarterly, biannual, and annual sampling events between 1994 and 2018, groundwater data representing the area around the ‘Cat’s Eye’ (the target area) open burn (OB) unit from the three monitoring wells at Range C-52N were collected. During the same time period, groundwater data representing the area surrounding the OB/OD units from the five monitoring wells at Range C-62 were also collected. Depending on timeframe, groundwater samples from both areas were analyzed for explosives, nitrate and nitrite, metals, and semi-volatile organic compounds (SVOCs). Samples at Range C-62 were also analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX). In addition to HMX and RDX, other explosive compounds detected at Ranges C-52N and/or C-62 include 2-amino-4, 6-Dinitrotoluene, and 4-amino-2, 6-Dinitrotoluene.

Currently, annual groundwater sampling for the OB/OD facilities is required in accordance with Part IV, Subpart A of Permit 006176-HO-007 issued by Florida Department of Environmental Protection (FDEP) on March 29, 2016. The Groundwater Cleanup Target Levels (GCTLs) are included in the updated 2016 Permit and the previous permit. In particular, the selected screening levels for HMX and RDX in groundwater are the FDEP GCTLs: 350 µg/L and 0.3 µg/L, respectively (FDEP, 2005). The GCTLs used are based on a target cancer risk of $1{\times}10^{-6}$ (i.e., one-in-a-million excess lifetime cancer risk) or a non-cancer hazard quotient (HQ) of 1.

During the 2018 sampling event, BTEX compounds, nitrite, and nitrate were either not detected or did not exceed the GCTLs at Range C-52N or C-62. However, HMX and/or RDX was detected at both ranges. **Table 1** summarizes the available groundwater data from monitoring wells from Range C-52N and Range C-62. At Range C-52N, HMX was not detected in any of the 5 samples in the data set, with detection limits ranging from 0.078 µg/L to 0.13 µg/L. At the same range, RDX was detected in 4 of 5 samples in the data set from 0.72 µg/L to 1.5 µg/L. At Range C-62, both HMX and RDX were detected in all 10 samples included in the data set, ranging from 22.6 µg/L to 59 µg/L for HMX and 13.2 µg/L to 72 µg/L for RDX.

1.2 Selection of Chemicals of Potential Concern

As shown in **Table 1**, RDX is the only constituent detected at concentrations greater than the screening level and is selected as a COPC for both Range C-52N and Range C-62. HMX was also selected as a COPC for this HHRA. For the purposes of this HHRA, only the most recent RDX and HMX data from the sampling rounds from 2014 to 2018 were selected to provide the most representative data sets for evaluation.

1.3 Exposure Point Concentrations

Consistent with USEPA guidance on calculating exposure point concentrations (EPCs) for groundwater (USEPA, 2014a), monitoring wells representative of being within the 'core of the plume' were used to estimate EPCs for RDX in groundwater. The data for Range C-52N were limited to results from MW-94-52-01 because, as shown in Attachment 2, Table 1, RDX was not detected in the other two monitoring wells at Range C-52N (i.e., MW-94-52-02 and -03). The data for Range C-62 were limited to results from MW-94-62-04 and MW-94-62-05 because, as shown in Attachment 2, Table 1, RDX was detected in the other monitoring wells at Range C-62 (i.e., MW-94-62-01, MW-94-62-02, and MW-94-62-03) at concentrations approximately one order of magnitude or more lower than in MW-94-62-04 and MW-94-62-05. The following lists the monitoring wells and sample dates in the two data sets used for EPC calculations. The monitoring well locations are shown on **Figure 2** and **Figure 3**.

Range C-52 North	Range C-62
MW-94-52-01 (6/12/14)	MW-94-62-04 (5/23/14)
MW-94-52-01 (6/19/15)	MW-94-62-05 (5/23/14)
MW-94-52-01 (6/6/16)	MW-94-62-04 (5/19/15)
MW-94-52-01 (5/11/17)	MW-94-62-05 (5/19/15)
MW-94-52-01 (5/12/18)	MW-94-62-04 (6/6/16)
	MW-94-62-05 (6/6/16)
	MW-94-62-04 (5/11/17)
	MW-94-62-05 (5/11/17)
	MW-94-62-04 (5/12/18)
	MW-94-62-05 (5/12/18)

1.4 Fate and Transport Modeling

In order to estimate concentrations of COPCs in groundwater at the point of contact with downgradient surface water bodies, a BIOSCREEN-AT assessment was conducted using groundwater data collected at Range C-52N OB, Range C-62 OB, and Range C-62 OD. The BIOSCREEN-AT assessment is described in detail in the memorandum 'BIOSCREEN-AT Evaluation and Alternate Concentration Limits Ranges C-52N and C-62 Eglin Air Force Base, Florida', provided in **Attachment 2.**

2.0 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of human exposure to COPCs in groundwater within Range C-52N and Range C-62, as well as in offsite surface water bodies. This is accomplished by establishing assumptions about the potential for human exposure (e.g., exposed populations, exposure frequency) to groundwater within the two areas. For COPCs, representative EPCs are calculated and used to model potential human exposure in the form of daily chemical intakes and dermally absorbed doses (DAD). Since RDX is not volatile, inhalation is not a relevant route of exposure. These exposure estimates are combined in the Risk Characterization with chemical-specific toxicity values to calculate incremental lifetime cancer risks and non-cancer hazards.

Consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (USEPA, 1990) and USEPA guidance (1989; 1995), estimates of COPC intake and exposure were developed to portray reasonable maximum exposure (RME) scenarios. The RME scenario considers the highest exposure that might reasonably be expected to occur, one that is well above the average case of exposure but within the range of possibility. Use of the RME individual to model human health risks is a conservative approach, in that it yields upper-bound cancer risk and non-cancer hazard estimates (USEPA, 1989).

2.1 Human Health Conceptual Site Model

Table 2 presents the human health conceptual site model (CSM) for the site. The human health CSM illustrates the current understanding of the potential for human exposure to the COPCs at the site. The CSM includes the exposure media of concern, potential human receptor populations, and the pathways through which human exposure may occur. In accordance with USEPA (1989) guidance, a complete exposure pathway includes: [1] a chemical source and release mechanism, [2] a transport or retention medium, [3] an exposure point where human contact with the contaminated medium may occur, and [4] an exposure route (i.e., ingestion, dermal absorption, or inhalation) at the contact point. If any one of these elements is missing, the pathway is considered incomplete.

2.1.1 Groundwater

The OB/OD units are located on both Range C-52N and C-62 (i.e., OD on C-52N and OB/OD on C-62), and site conditions on both ranges enable site-related munitions constituents to enter the groundwater system. However, groundwater in the surficial aquifer is currently not used as a potable water supply at Eglin AFB. Therefore, potentially complete exposure pathways at the site include hypothetical future onsite worker exposure to groundwater via future potable wells and hypothetical future onsite resident exposure to groundwater via future potable wells. Exposure to RDX in tap water includes ingestion and dermal contact.

2.1.2 Groundwater Discharge to Surface Water

Bay Head Branch Creek is located downgradient of the OB unit on Range C-52N, and Blount Mill Creek is located downgradient of the OB/OD unit plumes on Range C-62. Based on BIOSCREEN-AT modeling (refer to **Attachment 2**), RDX in surficial groundwater beneath the site has the potential for migration into downgradient surface water bodies. Therefore, additional exposure pathways associated with the site include future recreator exposure to groundwater discharged to downgradient surface water bodies and, although it is highly unlikely, offsite residential exposure to downgradient surface water used as a potable supply. These hypothetical exposure pathways are more conservative than base personnel occasional exposure during work or training. Exposure to RDX in both tap water and surface water includes ingestion and dermal contact.

2.2 Exposure Point Concentrations

2.2.1 Onsite Groundwater

EPCs used to model human exposure to onsite groundwater were calculated using the data sets as described above and are summarized in **Table 3.1** for Range C-52N and in **Table 3.2** for Range C-62. The USEPA (1992, 1989) recommends that the arithmetic average concentration of the data be used for evaluating long-term exposure and, because of the uncertainty associated with estimating the true average concentration at a site, the 95% upper confidence limit (UCL) on the arithmetic average be used as the EPC. The 95% UCL concentration provides reasonable confidence that the true average will not be under-estimated. The USEPA also indicates that where there is a question about the distribution of the data, a statistical test should be used to identify the best distributional assumption for the data set (USEPA, 1992). The USEPA (2014a) also recommends that in estimating EPCs for groundwater, recent data from the core of the plume are preferred.

Consistent with USEPA guidance on calculating EPCs for groundwater (USEPA, 2014a), monitoring wells identified within the 'core of the plume' were used to estimate EPCs for RDX in the two ranges. Groundwater samples collected from MW-94-52-01 were used in determining EPCs for Range C-52N, and MW-94-62-04 and MW-94-62-05 were used in determining EPCs for Range C-62.

The ProUCL® 5.1 (ProUCL) program developed by the USEPA's Technology Support Center for Monitoring and Site Characterization was used to calculate 95% UCL concentrations for the data sets for each range. When entering data into ProUCL, if RDX was not detected in a sample, the sample reporting limit was entered as a proxy concentration and the sample result was coded as non-detect. ProUCL contains rigorous parametric and nonparametric statistical methods that can be used on full or uncensored data sets and on data sets with below detection limit observations (also called left-censored data sets). Depending on the distribution and 95% UCL estimation method, ProUCL will use only detected data or will incorporate detection limits (USEPA, 2015).

2.2.2 Groundwater Discharge to Surface Water

EPCs used to estimate human exposure to surface water conservatively assume that receptors will be exposed to the modeled concentrations expected in groundwater at the confluence with the surface water bodies downgradient of Range C-52N and Range C-62. The most conservative (i.e. highest) modeled RDX concentrations expected at the point of discharge was selected as the surface water EPC for each respective range.

The inputs, methods, and assumptions for the BIOSCREEN evaluation are described in detail in the memorandum 'BIOSCREEN-AT Evaluation and Alternate Concentration Limits Ranges C-52N and C-62 Eglin Air Force Base, Florida', provided in **Attachment 2**.

The EPCs for RDX in groundwater and surface water at Range C-52N and Range C-62 are presented in **Tables 3.1** and **3.2**, respectively. The ProUCL output sheet is provided **in Attachment 1**.

2.3 Exposure Equations and Parameter Values

The exposure equations and receptor-specific parameter values used to estimate COPC intakes and DADs are presented in **Table 4** for ingestion and dermal contact exposure. The exposure parameters used to estimate COPC intakes and DADs under the RME scenarios evaluated in this HHRA are based on USEPA (2014b, 2011, 2004, and 1989) guidance.

For future site workers, residents, and recreators, application of the exposure equations results in chronic daily intake for ingestion exposure or DAD for dermal contact exposure, expressed in milligrams per kilogram of body weight per day (mg/kg-day). The estimated daily intake is the amount of chemical at the exchange boundary (i.e., stomach for ingestion and skin for dermal absorption). A fundamental assumption in the estimate of the DAD is that absorption continues long after the exposure has ended (USEPA, 2004). As such, the final absorbed dose is estimated to be the total dose dissolved in the skin at the end of the exposure. Application of these equations requires a COPC concentration, or the average concentration contacted over the exposure period (e.g., mg/L water). These equations also require a contact rate (i.e., the amount of COPC contacted per unit time or event), body weight (i.e., the average body weight over the exposure period), and averaging time (i.e., the time over which exposure is averaged).

The averaging time depends on the type of toxic effect being assessed. When evaluating exposures for potential non-cancer health effects, intakes are calculated by averaging over the period of exposure. This is equivalent to the receptor-specific exposure duration multiplied by 365 days/year. When evaluating potential cancer risks, intakes are calculated by prorating the total cumulative intake over a lifetime (i.e., lifetime average daily intake). For calculation purposes, this is equal to 70 years multiplied by 365 days/year (i.e., 25,550 days). This distinction is consistent with the hypothesis that the mechanism of action for each of these health effects endpoints is different. The approach for carcinogens assumes that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

3.0 TOXICITY ASSESSMENT

The toxicity assessment, also termed the dose-response assessment, characterizes the relationship between the magnitude of exposure and the potential that an adverse health effect will occur. Toxicity assessment involves determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated, and the relationship between the dose of chemical received and the incidence of adverse health effects in the exposed population is evaluated.

3.1 Sources of Toxicity Values

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals, and their guidance was used in this HHRA. Toxicity values include reference doses (RfDs) and reference concentrations for the evaluation of non-cancer health effects from chronic and sub-chronic exposure to chemicals, and cancer slope factors and inhalation unit risks for evaluating incremental cancer risk from exposure to chemicals prorated over a lifetime (i.e., excess lifetime cancer risks).

Sources of toxicological information and toxicity values, in order of preference consistent with USEPA (2003) guidance, include:

- Tier 1 - Integrated Risk Information System (IRIS) (USEPA, 2018b). IRIS is an USEPA administered internet database that has received internal and external scientific review and contains current information on human health effects that may result from exposure to chemicals in the environment.
- Tier 2 - Provisional Peer-Reviewed Toxicity Values (PPRTV) (USEPA, 2018c). PPRTVs were developed by the USEPA Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center, as presented in a series of chemical-specific issue papers.
- Tier 3 - Additional USEPA and non-USEPA sources of toxicity information, including but not limited to the California Environmental Protection Agency Office of Environmental Health Hazard Assessment's chronic reference exposure levels and cancer potency values, the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (ATSDR, 2018), and toxicity values published in the Health Effects Assessment Summary Tables (USEPA, 2018d).

3.1.1 Adverse, Non-cancer Health Effects

The NCP (USEPA, 1990) indicates that acceptable exposure levels for chemicals with non-cancer health effects should represent concentration levels to which the human population, including sensitive subpopulations (e.g., the elderly, young children), may be exposed without adverse health effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety. The potential for non-cancer health effects associated with oral and dermal exposures is evaluated by comparing an estimated chemical intake or DAD over a specified time period with an RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Therefore, the ratio of the intake or DAD to the RfD, termed the HQ, assumes there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. For child receptors, where exposure is assumed to occur over the six-year exposure duration, the subchronic RfD for RDX was used

Table 5 presents the non-cancer toxicity data for RDX, including the RfD, primary target organ(s), and uncertainty/modifying factors. Generally, order-of-magnitude uncertainty factors reflect the various types of toxicological data (e.g., a laboratory animal study extrapolated to the human condition) used to estimate the RfDs. Modifying factors, which can range from greater than zero to 10, reflect qualitative professional judgment regarding scientific uncertainties (e.g., the completeness of the overall database) not covered by the uncertainty factors. Application of the uncertainty and modifying factors is intended to result in RfDs that are protective of human health.

RfDs are not available to evaluate dermal exposure. In their absence, oral RfDs were used and adjusted following USEPA (2004) guidance to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses.

3.1.2 Carcinogenic Effects

Regardless of the mechanism of effect, risk evaluation methods employed by the USEPA generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Based on this hypothesis, USEPA has derived estimates of incremental cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and fitting dose-response data to a low-dose extrapolation model. The slope factor, which describes the dose-response relationship at low doses, is expressed as a function of intake [i.e., $(mg/kg\text{-}day)^{-1}$].

Excess lifetime cancer risks were estimated by multiplying an estimated daily intake or DAD prorated over 70 years by the slope factor. The resulting risk estimate is expressed as a unitless probability (e.g., 2×10^{-5} or 2 in 100,000) of an individual developing cancer. The unitless probability represents the incremental (or increased) lifetime cancer risk associated with the estimated exposure above the background risk of developing cancer. This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). According to the USEPA (1989), this approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown and may be as low as zero.

Table 6 presents the cancer toxicity data for RDX, including: the slope factor and weight-of-evidence classifications under USEPA's 2005 guidelines for carcinogen risk assessment (USEPA, 2005). As with RfDs, USEPA has not derived slope factors to evaluate dermal exposure. In their absence, slope factors for oral exposure were used and adjusted per USEPA guidance to reflect absorbed dose. This allows for risk estimation based on exposures estimated as absorbed doses and slope factors expressed as absorbed doses.

4.0 RISK CHARACTERIZATION

Risk characterization involves combining exposure estimates with toxicity information to assess the potential for adverse health effects from exposure to groundwater by the receptor groups evaluated in the HHRA. In this section, the non-cancer hazards and cancer risks for each exposure scenario are presented and discussed.

As described in the Toxicity Assessment section, the potential for non-cancer health effects is evaluated by calculating the ratio of an estimated intake or DAD over a specified time period with a chemical-specific RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. The non-cancer HQ therefore assumes there is a level of exposure below which it is unlikely for even sensitive subpopulations to experience adverse health effects. The total individual HQs are summed for each route of exposure and exposure medium to yield hazard indices (HIs) representative of the potential for adverse, non-cancer health effects from cumulative exposure. For the non-cancer assessment, exposure scenarios with an HI greater than 1 are of potential concern.

Individual cancer risks are expressed as unitless probabilities of a person developing cancer. The cancer risks were summed for each exposure route to arrive at an estimate of the total receptor cancer risk. For known or suspected carcinogens, like RDX, the NCP established that acceptable exposure levels are generally concentration levels that represent an incremental upper-bound lifetime cancer risk in the range from 1×10^{-4} (i.e., 1 in 10,000) to 1×10^{-6} (i.e., 1 in 1,000,000) or less (USEPA, 1990). The cancer risks estimated for each exposure scenario are therefore compared to this risk range established by the NCP.

4.1 Future Onsite Site Worker Non-Cancer Hazards and Cancer Risks

Table 7.1.1 presents the cancer risk estimates and non-cancer HIs for the future onsite site worker at Range C-52N. As shown, the estimated cancer risk for future onsite site worker exposure to tap water via ingestion and dermal contact ($9x10^{-7}$) does not exceed the USEPA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$. Additionally, the HI (0.008) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

Table 7.1.2 presents the cancer risk estimates and non-cancer HIs for the future onsite site worker at Range C-62. As shown, the estimated cancer risk for future onsite site worker exposure to tap water via ingestion and dermal contact ($2x10^{-5}$) is within the USEPA acceptable cancer risk range of 1×10^{-4} to 1×10^{-6}. Additionally, the HI (0.2) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

4.2 Future Hypothetical Onsite Resident Non-Cancer Hazards and Cancer Risks

Table 7.2.1 presents the cancer risk estimates and non-cancer HIs for the future hypothetical onsite resident at Range C-52N. As shown, the estimated cancer risk for future hypothetical onsite resident child and adult exposure to tap water via ingestion and dermal contact ($1x10^{-6}$) does not exceed the USEPA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$. Additionally, the HI (child exposure only of 0.0007) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

Table 7.2.2 presents the cancer risk estimates and non-cancer HIs for the future hypothetical onsite resident at Range C-62. As shown, the estimated cancer risk for future hypothetical onsite resident child and adult exposure to tap water via ingestion and dermal contact ($4x10^{-5}$) is within the USEPA acceptable cancer risk range of 1×10^{-4} to 1×10^{-6}. Additionally, the HI (child exposure only of 0.02) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

4.3 Offsite Recreator Non-Cancer Hazards and Cancer Risks

Table 7.3.1 presents the cancer risk estimates and non-cancer HIs for the future offsite recreator downgradient of Range C-52N. As shown, the estimated cancer risk for future child and adult offsite recreator exposure to surface water via ingestion and dermal contact ($9x10^{-9}$) is less than the USEPA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$. Additionally, the HI (child exposure only of 0.00001) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

Table 7.3.2 presents the cancer risk estimates and non-cancer HIs for the future offsite recreator downgradient of Range C-62. As shown, the estimated cancer risk for future child and adult recreator exposure to surface water via ingestion and dermal contact ($1x10^{-5}$) is within the USEPA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$. Additionally, the HI (child exposure only of 0.001) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

4.4 Offsite Resident Non-Cancer Hazards and Cancer Risks

Table 7.4.1 presents the cancer risk estimates and non-cancer HIs for the future hypothetical offsite resident at Range C-52N. As shown, the estimated cancer risk for future hypothetical offsite resident child and adult exposure to tap water via ingestion and dermal contact ($2x10^{-7}$) does not exceed the USEPA acceptable cancer risk range of $1x10^{-4}$ to $1x10^{-6}$. Additionally, the HI (child exposure only of 0.00008) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

Table 7.4.2 presents the cancer risk estimates and non-cancer HIs for the future hypothetical offsite resident at Range C-62. As shown, the estimated cancer risk for future hypothetical offsite resident child and adult exposure to tap water via ingestion and dermal contact ($2x10^{-5}$) is within the USEPA acceptable cancer risk range of 1×10^{-4} to 1×10^{-6}. Additionally, the HI (child exposure only of 0.008) is less than the USEPA acceptable noncancer HQ of 1. These results indicate adverse health effects are unlikely.

5.0 UNCERTAINTIES

Risk assessment entails the integration of complex analyses of chemical concentrations in the environment, the fate and transport of chemicals in the environment, the potential for and extent of human exposure, and the chemical's toxicity. Some degree of uncertainty is associated with each component of the risk assessment process. Uncertainty can be quantitatively addressed by identifying specific sources of uncertainty and characterizing whether the potential for risk may be over-stated or under-stated. The intent of most risk assessments, including this HHRA, is to err on the side of conservatism, so the potential for risk is over-stated rather than under-stated. However, for this HHRA, major assumptions made and the potential impact on risk estimates are qualitatively discussed.

5.1 Environmental Sampling and Analysis

This HHRA is based on groundwater data for a limited number of monitoring wells at both Range C-52N and Range C-62. Data for soil at these sites were not reviewed for this HHRA. Based on the understanding that the areas around these sites are used for active testing missions, it may be that these activities also contribute as sources of explosives like RDX. RDX is consistently detected in the hydraulically upgradient well (MW-94-52-01) at Range C-52N at higher concentrations than at the two downgradient wells (MW-94-52-02 and MW-94-52-03). The RDX detections are likely due to the proximity of MW-94-52-01 to the 'Cat's Eye' target area and the presence of substantial debris/exploded ordinances in the vicinity of MW-94-52-01. However, as the HHRA assumed exposure was to concentrations in or migrating from that upgradient well it is not likely that EPCs for C-52N were underestimated. As indicated in the BIOSCREEN evaluation provided in **Attachment 2**, concentrations of RDX in groundwater of the surficial aquifer at C-52N are decreasing, while at C-62 increasing trends are observed in groundwater at monitoring wells MW-94-62-04 and MW-94-62-05. Therefore, if concentrations at C-62 continue to increase, EPCs were underestimated. Yet, the assumption that concentrations in surface water would be equal to those modeled at the point of groundwater discharge is highly conservative as mixing with surface water and photodegradation of RDX would occur. Therefore, EPCs were likely overestimated overall.

5.2 Exposure Assessment

The exposure assessment relies on a series of assumptions regarding the potential for human exposure, outlined in the CSM and approximated in the daily intake calculation by parameters such as the groundwater EPC and receptor-specific exposure duration, frequency, and time. This HHRA attempted to address some of the uncertainty in these assumptions by conservatively evaluating the potential for cancer risk and non-cancer hazard to individuals under RME conditions in the hypothetical future exposure scenarios. The surficial aquifer in the Citronelle Formation, referred to as the 'Sand and Gravel Aquifer,' the 'Miocene-Pliocene Aquifer,' or the 'Citronelle Aquifer', is the primary source of water for the population of Santa Rosa and Escambia Counties in the Florida Panhandle (United States Geologic Survey [USGS], 2016). However, groundwater in the surficial aquifer is not currently used as a potable water supply at Eglin AFB, and no potable wells within the surficial aquifer will be allowed in the future at Eglin AFB. Both ranges are located well within the Eglin AFB boundary, with the closest off-base boundary being approximately 6 miles downgradient for C-52 and approximately 4 miles downgradient for C-62 (refer to **Figure 1**). In addition, surface water in the area is not used as a potable source. As described in **Attachment 2**, RDX in groundwater of the surficial aquifer is likely to degrade significantly within 1 mile downgradient of the units. Therefore, potable water scenarios are highly unlikely.

Eglin AFB is an active military facility engaged in testing and training activities and the primary mission in this portion of the Eglin Test and Training Complex (ETTC) or "Range" is expected to remain the same into the foreseeable future. In addition, wildlife and forest conservation activities are also conducted in this area of the Range. However, as the OB/OD units are within training ranges, the areas are closed to hunting, fishing and recreation, and all public access. Although base personnel may access these areas, the recreation user scenario with child exposure is highly unlikely. Therefore, this HHRA likely overestimates the potential for risk overall.

The HHRA primarily relied on the USEPA's standard default exposure assumptions which are used at Superfund sites across the country with appropriate modifications to reflect site-specific conditions. The intention is to over-estimate the potential for risk and hazards, so that actual risks are less than those predicted in this HHRA.

Uncertainties associated with the fate and transport modeling are discussed in **Attachment 2**. The HHRA did not include evaluation of RDX degradation products such as the nitroso derivatives including MNX, DNX, and TNX, as they were not analyzed for in groundwater samples and which form more readily under aerobic conditions and which undergo mineralization to hydrazines and methanol under anaerobic conditions. These compounds are not commonly analyzed constituents. Toxicity values (reference doses and cancer slope factors) are not available for MNX, DNX, and TNX. The cancer slope factor for hydrazine indicates it is 27 times more potent a carcinogen than RDX. However, based on groundwater sampling logs (from May 2018) aquifer conditions are likely aerobic. Therefore, while risks may be underestimated due to the lack of information on RDX degradation products, human exposure in this HHRA is probably still overestimated, overall.

5.3 Toxicity Assessment

The derivation of the toxicity values that form the basis of the risk characterization can result in over- or under-estimates of the potential for adverse health effects. As in most cases, the toxicity values for RDX are derived from extrapolation from laboratory animal data to humans. As indicated in **Table 4**, the oral RfD for RDX contains uncertainty factors totaling to 300.

Following USEPA guidance, the RfD and cancer slope factor for oral exposure were adjusted and used to assess risks from dermal absorption of RDX in water. However, the oral absorption was assumed to be 100 percent which may under-estimate dermal contact exposure for some chemicals. Consideration was not given to the absorption efficiency of the exposure vehicle used in the studies on which the factors are based. This may over-estimate or under-estimate dermal contact risks.

6.0 ALTERNATE CONCENTRATION LIMITS

Alternate concentration limits (ACLs) were developed for both HMX and RDX in groundwater that are protective of hypothetical future potable use of groundwater as it discharges to nearby streams. While hypothetical and highly unlikely, this scenario is conservative. The ACLs were derived considering migration from the source to the receptor (i.e., point of groundwater discharge for hypothetical future potable water users) as provided in **Attachment 2**. The ACLs derived are shown in the table below; for further details see the memorandum in **Attachment 2**.

Area	Chemical	Distance to Receptor (feet)	Alternate Concentration Limit (ug/L)	Notes
Range C-52 N				
Cat's Eye	RDX	310	0.32	distance from well MW-94-C52-02 to creek
Cat's Eye	HMX	310	580	distance from well MW-94-C52-02 to creek
Range C-62 OBU				
OBU	RDX	150	0.31	distance from well MW-94-C62-03 to creek
OBU	HMX	150	430	distance from well MW-94-C62-03 to creek
Range C-62 ODU				
ODU	RDX	380	0.87	distance from well MW-94-C62-04 to creek
ODU	HMX	380	21,000	distance from well MW-94-C62-04 to creek

Notes:
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
OBU = Open Burn Unit
ODU = Open Detonation Unit
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
ug/L = micrograms per liter

6.1 Comparison of Site Data to ACLs

The ACLs were derived to be protective of potable use of groundwater in the surficial aquifer as it discharges to surface water downstream of C-52N and C-62. As shown in **Table 8**, the maximum detected concentrations and 95% UCLs of RDX at both C-52N and C-62, and the modeled RDX concentration at the point of surface water discharge for C-62 exceed the ACLs developed for protection of potable use. The modeled RDX concentration at the point of discharge to surface water for C-52N is below the ACL for protection of potable use.

The results of the BIOSCREEN-AT modeling suggest that:

- The groundwater RDX concentration at C-52N would drop below the FDEP GCTL by 1,800 feet downgradient from MW-94-52-01.

- The groundwater RDX concentration at C-62 is likely to attenuate significantly within one mile downgradient of the OB and OD Units, and is not expected to contribute to offsite groundwater exceedances of the FDEP GCTL for RDX further downgradient.
- It is likely that groundwater that daylights in the headwaters of Blount Mill Creek downgradient of C-62 would not pose a threat to potential receptors.

The recreator exposure scenario is also unlikely. Although instream concentrations were not modeled for this HHRA, comparing data to the FDEP Freshwater Surface Water Cleanup Target Levels (SWCTLs) (FDEP, 2005) can provide some perspective for protection of recreator exposure to surface water. As shown in **Table 8**, the maximum detected concentrations and 95% UCLs of both HMX and RDX, and the modeled concentrations of RDX at the point of discharge for both C-52N and C-62 are all less than the FDEP SWCTLs.

7.0 SUMMARY

The HHRA evaluated conservative hypothetical exposure scenarios to err on the side of conservatism and to over-state rather than under-state the potential for risk. Estimated cancer risks and noncancer HIs for all receptors were below or within the USEPA acceptable risk levels. RDX will not migrate offsite above the GCTL, with the possible exception of groundwater that daylights into the headwaters of Blount Mill Creek downgradient of the OD Unit at C-62. However, mixing with surface water and photodegradation of RDX are anticipated to limit any potential impacts to surface water from this source area. Additionally, since exposure to RDX in the surficial aquifer via a potable use scenario is highly unlikely, comparing modeled concentrations at the point of groundwater discharge (into the downgradient streams) to the FDEP SWCTLs (i.e., 180 µg/L for RDX and 1,300 µg/L for HMX (FDEP, 2005) provides useful information. Although exposure to surface water is also less likely than assumed in this HHRA, maximum detected concentrations of both RDX and HMX are less than the SWCTLs. Based on these considerations and the results of this HHRA, RDX and HMX in the surficial aquifer at C-52N and C-62 are unlikely to pose unacceptable risk to human receptors.

8.0 REFERENCES

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FIGURES

From Figure 1 in LRS (2018)

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE 1

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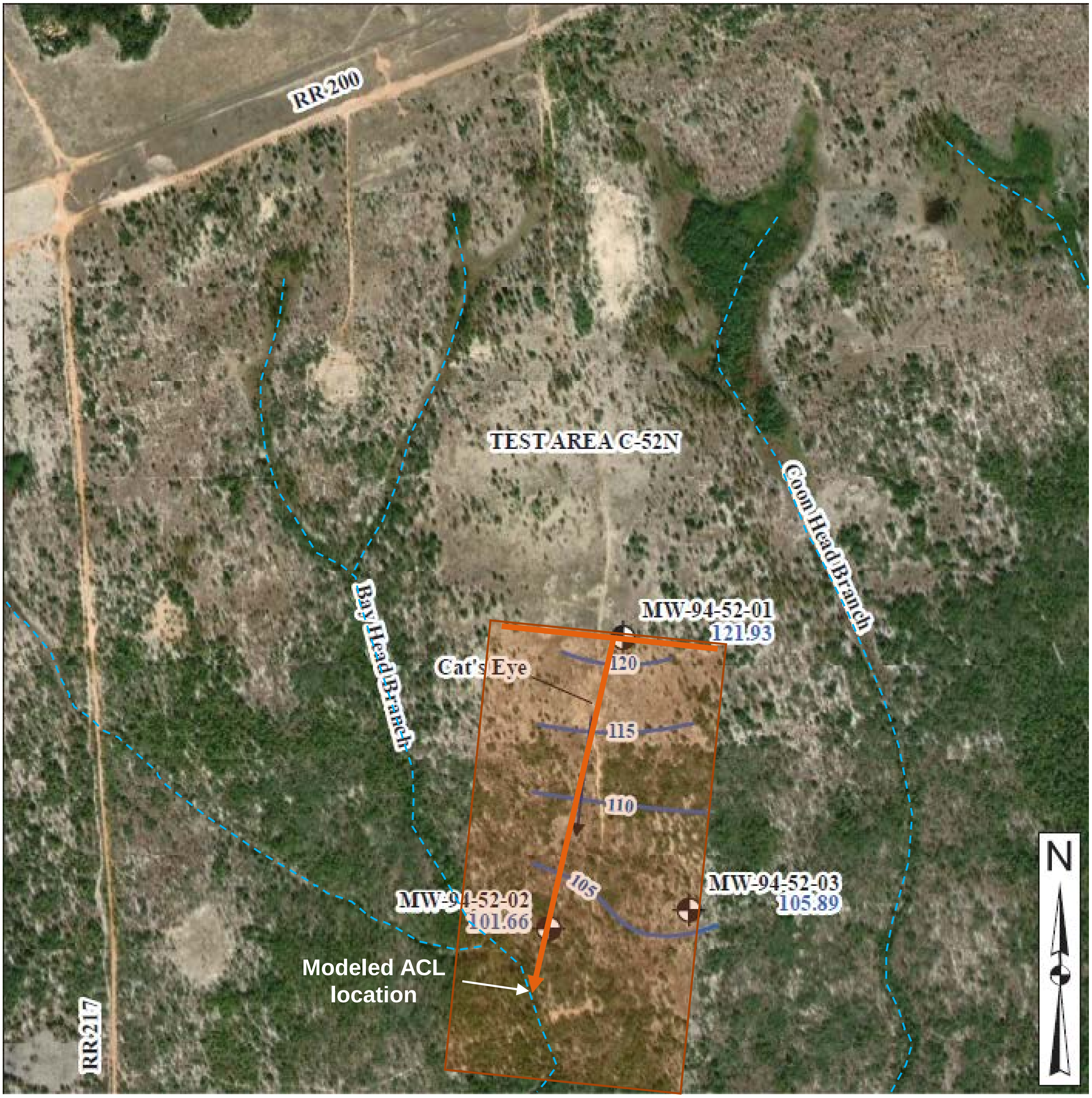

From Figure 8 in LRS (2018)

0 250 500 1,000 Feet

Monitoring Well

Estimated Groundwater Flow Direction

120 Groundwater Elevation Contour (ft NGVD)

Modeled Plume Length

Modeled Domain Area

Modeled Source Width

Surface Water Drainage

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

RANGE C-52N
POTENTIOMETRIC CONTOUR MAP
MAY 2018

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2

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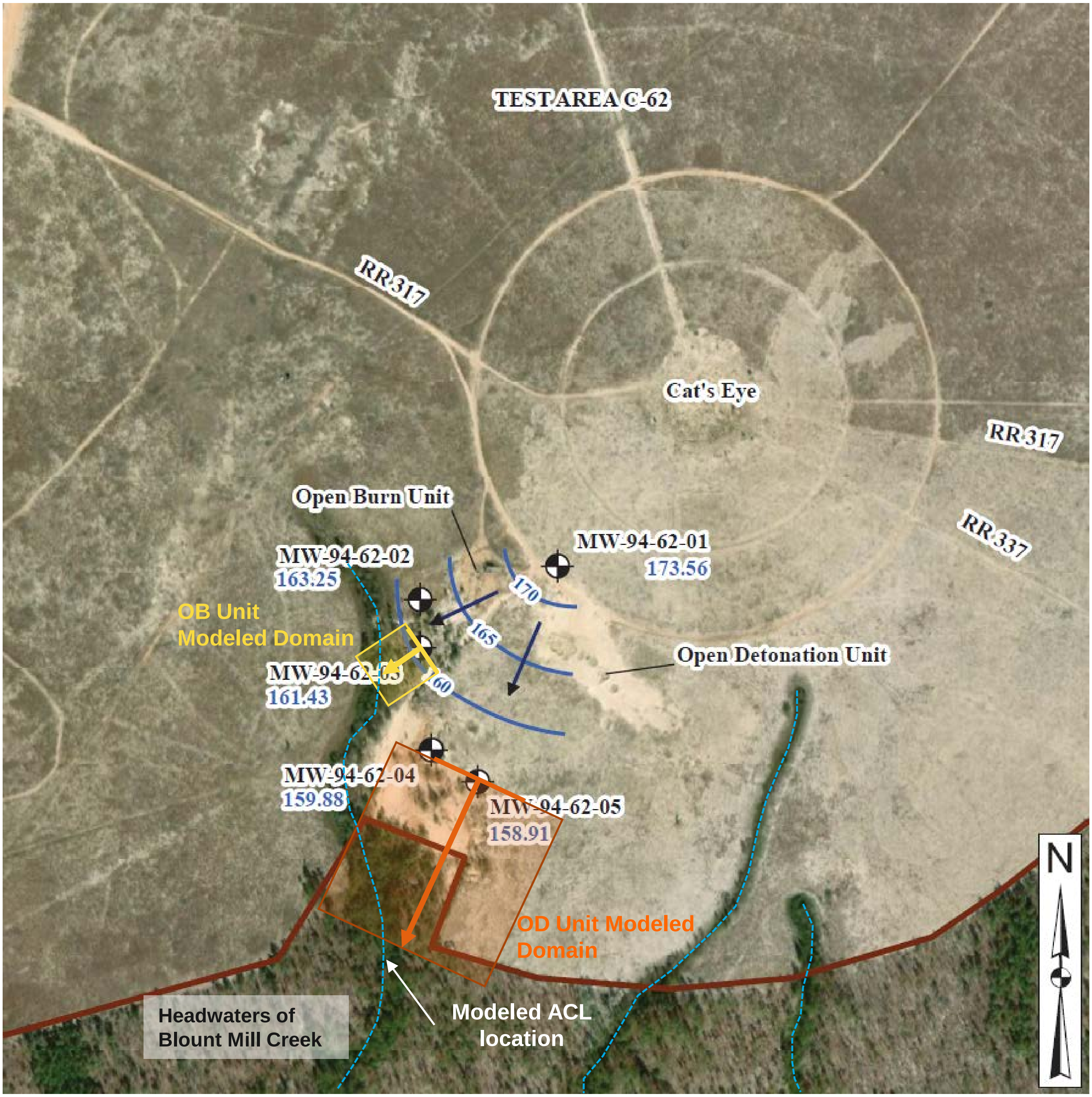

From Figure 9 in LRS (2018)

0 250 500 1,000 Feet

Legend:

- Monitoring Well
- 170 Groundwater Elevation Contour (ft NGVD)
- Estimated Groundwater Flow Direction
- Surface Water Drainage
- Modeled OB Unit Plume
- Modeled OD Unit Plume
- OB Unit Modeled Domain
- OD Unit Modeled Domain
- Modeled OB Unit Source Width
- Modeled OD Unit Source Width

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

RANGE C-62
POTENTIOMETRIC CONTOUR MAP
MAY 2018

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FIGURE
3

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TABLES

Table 1
RAGS Part D Table 2
Occurrence, Distribution, and Selection of Chemicals of Potential Concern in the OB/OD Units
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Current/Future
Medium:	Groundwater
Exposure Medium:	Groundwater and Surface Water

Exposure Point	CASRN	Chemical	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value	Screening Toxicity Value (2)		Screening Toxicity Value (3)	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
C-52 North	2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	ND	ND	µg/L	ND	0/5	0.078 - 0.13	ND	NA	350	nc	FDEP	N	BSC
	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.72	1.5	µg/L	MW-94-52-01(6/19/2015)	4/5	0.17 - 0.17	1.5	NA	0.3	c	FDEP	Y	ASC
C-62	2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	22.6	59	µg/L	MW-94-62-05(5/12/2018)	10/10	NA	59	NA	350	nc	FDEP	N	BSC
	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	13.2	72	µg/L	MW-94-62-05(5/12/2018)	10/10	NA	72	NA	0.3	c	FDEP	Y	ASC

Notes:

(1) Maximum concentration.

(2) The screening toxicity value is the lower of the United States Environmental Protection Agency (USEPA) Regional Screening Level (RSL) for Tapwater (USEPA, November 2018a) or the Florida DEP Groundwater Cleanup Target Level (2005)

(3) Codes used for Screening Toxicity Value Source
FDEP - Florida Department of Environmental Protection

(4) Codes used for the "Rationale for Selection or Deletion":
ASC - Above Screening Criterion
BSC - Below Screening Criterion

CASRN = Chemical Abstract Services Registry Number.
µg/L = microgram(s) per liter.
NA = not available.
N/A = not applicable.
ND = not detected.

Table 2
RAGS Part D Planning Table 1
Selection of Exposure Pathways
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Human Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future	Groundwater	Tapwater	Range C-52N	Site Worker	Adult	Incidental Ingestion	Quantitative	Site worker exposure to tap water from future potable wells is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
			Range C-62	Site Worker	Adult	Incidental Ingestion	Quantitative	Site worker exposure to tap water from future potable wells is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
			Range C-52N	Resident	Adult	Incidental Ingestion	Quantitative	Residential exposure to tap water from future private potable wells is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	
			Range C-62	Resident	Adult	Incidental Ingestion	Quantitative	Residential exposure to tap water from future private potable wells is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	
	Surface Water	Surface Water	Points of C-52N Groundwater Discharge	Recreational Users	Adult	Incidental Ingestion	Quantitative	Recreator exposure to surface water is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	
			Points of C-62 Groundwater Discharge	Recreational Users	Adult	Incidental Ingestion	Quantitative	Recreator exposure to surface water is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	
		Tapwater	Points of C-52N Groundwater Discharge	Resident	Adult	Incidental Ingestion	Quantitative	Residential exposure to surface water as potable water is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	
			Points of C-62 Groundwater Discharge	Resident	Adult	Incidental Ingestion	Quantitative	Residential exposure to surface water as potable water is a potentially complete exposure pathway.
						Dermal contact	Quantitative	
					Child (0-6 years old)	Incidental Ingestion	Quantitative	
						Dermal contact	Quantitative	

Table 3.1
RAGS Part D Table 3
Exposure Point Concentration Summary: Groundwater at C-52N
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Current/Future
Medium:	Groundwater
Exposure Medium:	

Exposure Point	Receptor	Exposure Medium	CAS RN	Chemical of Potential Concern	Units	Arithmetic Mean [1]	95% UCL Concentration [2] (Distribution)		Maximum Concentration	Exposure Point Concentration			
										Value	Units	Statistic	Rationale
C-52 North	Worker	Tapwater	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	0.000891	0.001447	KM (t) UCL	0.0015	0.001447	mg/L	95% UCL	ProUCL v5.1
	Resident	Tapwater	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	0.000891	0.001447	KM (t) UCL	0.0015	0.001447	mg/L	95% UCL	ProUCL v5.1
	Recreator	Surface Water	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	--	--	--	0.00015	0.00015	mg/L	Modeled	BIOSCREEN
	Offsite Resident	Surface Water	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	--	--	--	0.00015	0.00015	mg/L	Modeled	BIOSCREEN

Notes
[1] For the arithmetic mean, where constituents were not detected half the detection limit was included in the calculation.
[2] The 95% Upper Confidence Level (UCL) on the arithmetic average concentration (*i.e.,* the 95% UCL concentration) was calculated using ProUCL version 5.1.

mg/L = milligram(s) per liter.

Data Distribution Codes:
G = Gamma
LN = Lognormal
N = Normal
NP = Nonparametric

Table 3.2
RAGS Part D Table 3
Exposure Point Concentration Summary: Groundwater at C-62
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Current/Future
Medium:	Groundwater
Exposure Medium:	

Exposure Point	Receptor	Exposure Medium	CAS RN	Chemical of Potential Concern	Units	Arithmetic Mean [1]	95% UCL Concentration [2] (Distribution)		Maximum Concentration	Exposure Point Concentration			
										Value	Units	Statistic	Rationale
C-62	Worker	Tapwater	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	0.0279	0.04069	Adjusted G UCL	0.072	0.04069	mg/L	95% UCL	ProUCL v5.1
	Resident	Tapwater	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	0.0279	0.04069	Adjusted G UCL	0.072	0.04069	mg/L	95% UCL	ProUCL v5.1
	Recreator	Surface Water	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	--	--	--	0.015	0.015	mg/L	Modeled	BIOSCREEN
	Offsite Resident	Surface Water	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	mg/L	--	--	--	0.015	0.015	mg/L	Modeled	BIOSCREEN

Notes
[1] For the arithmetic mean, where constituents were not detected half the detection limit was included in the calculation.
[2] The 95% Upper Confidence Level (UCL) on the arithmetic average concentration (*i.e.,* the 95% UCL concentration) was calculated using ProUCL version 5.1.

mg/L = milligram(s) per liter.

Data Distribution Codes:
G = Gamma
LN = Lognormal
N = Normal
NP = Nonparametric

Table 4
RAGS Part D Table 4
Values Used for Daily Exposure Calculations (Ingestion and Dermal Contact) - Reasonable Maximum Exposure
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:
Medium: Groundwater
Exposure Medium:

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Notes	Intake Equation/ Model Name
Ingestion	Worker	Adult	Tapwater	C_W	RDX Concentration in Groundwater	--	mg/L	--	See Tables 3.1 and 3.2	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-W	Ingestion Rate	2.5	liters/day	USEPA, 2014		CW × IR-W × EF × ED × 1/BW × 1/AT
				EF	Exposure Frequency	250	days/year	USEPA, 2014		
				ED	Exposure Duration	25	years	USEPA, 2014		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	9,125	days	USEPA, 1989		
Dermal	Worker	Adult	Tapwater	Cw	RDX Concentration in Groundwater	--	mg/L	--	See Tables 3.1 and 3.2	Dermally Absorbed Dose (DAD) (mg/kg-day) =
				DA_{event}	Absorbed dose per event	calculated	mg/cm^2-event	USEPA, 2004	See Table 4.1	DA_{event} × EV × ED × EF × SA × 1/BW × 1/AT
				FA	Fraction Absorbed Water	1.0	unitless	USEPA, 2004		
				Kp	Permeability Coefficient	3.4E-04	cm/hour	USEPA, 2004		where for organic chemicals:
				SA	Skin Surface Area Available for Contact	3,527	cm^2	USEPA, 2014		Absorbed Dose per Event (DAevent) (mg/cm2-event) =
				t-event	Event Duration	0.0083	hours/event	Professional judgment		If t-event < t*, then: DAevent = 2FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				tau-event	Lag time per event	1.8	hours/event	USEPA, 2004		
				t*	Time to reach steady-state = 2.4 x tau-event	4.4	hours	USEPA, 2004		
				B	Ratio of permeability coefficient of a chemical thr	0.0019	unitless	USEPA, 2004		or
				EV	Event Frequency	4	events/day	USEPA, 2011; Professional judgment		If t-event > t*, then: DAevent = FA x Kp x CW x CF x {(t-event/(1 + B)) + 2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 +
				EF	Exposure Frequency	250	days/year	USEPA, 2014		
				ED	Exposure Duration	25	years	USEPA, 2014		
				CF	Volumetric Conversion Factor for Water	1E-03	L/cm^3	--		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	9,125	days	USEPA, 1989		

Table 4
RAGS Part D Table 4
Values Used for Daily Exposure Calculations (Ingestion and Dermal Contact) - Reasonable Maximum Exposure
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:
Medium: Groundwater
Exposure Medium:

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Notes	Intake Equation/ Model Name
Ingestion	Resident	Adult	Tapwater	C_W	RDX Concentration in Groundwater	--	mg/L	--	See Tables 3.1 and 3.2	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-W	Ingestion Rate	2.5	liters/day	USEPA, 2014		CW × IR-W × EF × ED × 1/BW × 1/AT
				EF	Exposure Frequency	350	days/year	USEPA, 2014		
				ED	Exposure Duration	20	years	USEPA, 2014		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	7,300	days	USEPA, 1989		
		Child (0-6 years old)	Tapwater	C_W	RDX Concentration in Groundwater		mg/L	--	See Tables 3.1 and 3.2	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-W	Ingestion Rate	0.78	liters/day	USEPA, 2014		CW × IR-W × EF × ED × 1/BW × 1/AT
				EF	Exposure Frequency	350	days/year	USEPA, 2014		
				ED	Exposure Duration	6	years	USEPA, 2014		
				BW	Body Weight	15	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	2,190	days	USEPA, 1989		
Dermal	Resident	Adult	Tapwater	Cw	RDX Concentration in Groundwater		mg/L	--	See Tables 3.1 and 3.2	Dermally Absorbed Dose (DAD) (mg/kg-day) =
				DA_{event}	Absorbed dose per event	calculated	mg/cm^2-event	USEPA, 2004	See Table 4.1	DA_{event} × EV × ED × EF × SA × 1/BW × 1/AT
				FA	Fraction Absorbed Water	1.0	unitless	USEPA, 2004		
				Kp	Permeability Coefficient	3.4E-04	cm/hour	USEPA, 2004		where for organic chemicals:
				SA	Skin Surface Area Available for Contact	20,900	cm^2	USEPA, 2014		Absorbed Dose per Event (DAevent) (mg/cm2-event) =
				t-event	Event Duration	0.71	hours/event	USEPA, 2014		If t-event < t*, then: DAevent = 2FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				tau-event	Lag time per event	1.8	hours/event	USEPA, 2004		
				t*	Time to reach steady-state = 2.4 x tau-event	4.4	hours	USEPA, 2004		
				B	Ratio of permeability coefficient of a chemical thr	0.0019	unitless	USEPA, 2004		or
				EV	Event Frequency	1	events/day	Professional judgment		If t-event > t*, then: DAevent = FA x Kp x CW x CF x {(t-event/(1 + B)) + 2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
				EF	Exposure Frequency	350	days/year	USEPA, 2014		
				ED	Exposure Duration	20	years	USEPA, 2014		
				CF	Volumetric Conversion Factor for Water	1E-03	L/cm^3	--		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	7,300	days	USEPA, 1989		
		Child (0-6 years old)	Tapwater	Cw	RDX Concentration in Groundwater		mg/L	--	See Tables 3.1 and 3.2	Dermally Absorbed Dose (DAD) (mg/kg-day) =
				DA_{event}	Absorbed dose per event	calculated	mg/cm^2-event	USEPA, 2004	See Table 4.1	DA_{event} × EV × ED × EF × SA × 1/BW × 1/AT
				FA	Fraction Absorbed Water	1.0	unitless	USEPA, 2004		
				Kp	Permeability Coefficient	3.4E-04	cm/hour	USEPA, 2004		where for organic chemicals:
				SA	Skin Surface Area Available for Contact	6,378	cm^2	USEPA, 2014		Absorbed Dose per Event (DAevent) (mg/cm2-event) =
				t-event	Event Duration	0.54	hours/event	USEPA, 2014		If t-event < t*, then: DAevent = 2FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				tau-event	Lag time per event	1.8	hours/event	USEPA, 2004		
				t*	Time to reach steady-state = 2.4 x tau-event	4.4	hours	USEPA, 2004		
				B	Ratio of permeability coefficient of a chemical thr	0.0019	unitless	USEPA, 2004		or
				EV	Event Frequency	1	events/day	Professional judgment		If t-event > t*, then: DAevent = FA x Kp x CW x CF x {(t-event/(1 + B)) + 2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
				EF	Exposure Frequency	350	days/year	USUSEPA, 2014		
				ED	Exposure Duration	6	years	USEPA, 2014		
				CF	Volumetric Conversion Factor for Water	1E-03	L/cm^3	--		
				BW	Body Weight	15	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	2,190	days	USEPA, 1989		

Table 4
RAGS Part D Table 4
Values Used for Daily Exposure Calculations (Ingestion and Dermal Contact) - Reasonable Maximum Exposure
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:
Medium: Groundwater
Exposure Medium:

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Notes	Intake Equation/ Model Name
Ingestion	Recreator	Adult	Surface Water	C_W	RDX Concentration in Surface Water		mg/L	--	See Tables 3.1 and 3.2	Chronic Daily Intake (CDI) (mg/kg-day) = CW × IR-W × EF × ED × 1/BW × 1/AT
				IR-W	Ingestion Rate	0.43	liters/day	USEPA, 2014		
				EF	Exposure Frequency	50	days/year	Professional judgment		
				ED	Exposure Duration	20	years	USEPA, 2014		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	7,300	days	USEPA, 1989		
		Child	Surface Water	C_W	RDX Concentration in Surface Water		mg/L	--	See Tables 3.1 and 3.2	
				IR-W	Ingestion Rate	0.72	liters/day	USEPA, 2014		
				EF	Exposure Frequency	50	days/year	Professional judgment		
				ED	Exposure Duration	6	years	USEPA, 2014		
				BW	Body Weight	15	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	2,190	days	USEPA, 1989		
Dermal	Recreator	Adult	Surface Water	Cw	RDX Concentration in Surface Water		mg/L	--	See Tables 3.1 and 3.2	Dermally Absorbed Dose (DAD) (mg/kg-day) = DA_{event} × EV × ED × EF × SA × 1/BW × 1/AT where for organic chemicals: Absorbed Dose per Event (DAevent) (mg/cm2-event) = If t-event < t*, then: DAevent = 2FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi} or If t-event > t*, then: DAevent = FA x Kp x CW x CF x {(t-event/(1 + B)) + 2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
				DA_{event}	Absorbed dose per event	calculated	mg/cm^2-event	USEPA, 2004	See Table 4.1	
				FA	Fraction Absorbed Water	1.0	unitless	USEPA, 2004		
				Kp	Permeability Coefficient	3.4E-04	cm/hour	USEPA, 2004		
				SA	Skin Surface Area Available for Contact	5,419	cm^2	Professional judgment		
				t-event	Event Duration	6	hours/event	Professional judgment		
				tau-event	Lag time per event	1.8	hours/event	USEPA, 2004		
				t*	Time to reach steady-state = 2.4 x tau-event	4.4	hours	USEPA, 2004		
				B	Ratio of permeability coefficient of a chemical thr	0.0019	unitless	USEPA, 2004		
				EV	Event Frequency	1	events/day	Professional judgment		
				EF	Exposure Frequency	50	days/year	Professional judgment		
				ED	Exposure Duration	20	years	USEPA 2014		
				CF	Volumetric Conversion Factor for Water	1E-03	L/cm^3	--		
				BW	Body Weight	80	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	7,300	days	USEPA, 1989		
		Child	Surface Water	Cw	RDX Concentration in Surface Water		mg/L	--	See Tables 3.1 and 3.2	
				DAevent	Absorbed dose per event	calculated	mg/cm2-event	USEPA, 2004	See Table 4.1	
				FA	Fraction Absorbed Water	1.0	unitless	USEPA, 2004		
				Kp	Permeability Coefficient	3.4E-04	cm/hour	USEPA, 2004		
				SA	Skin Surface Area Available for Contact	2,058	cm2	Professional judgment		
				t-event	Event Duration	6	hours/event	Professional judgment		
				tau-event	Lag time per event	1.8	hours/event	USEPA, 2004		
				t*	Time to reach steady-state = 2.4 x tau-event	4.4	hours	USEPA, 2004		
				B	Ratio of permeability coefficient of a chemical thr	0.0019	unitless	USEPA, 2004		
				EV	Event Frequency	1	events/day	Professional judgment		
				EF	Exposure Frequency	50	days/year	Professional judgment		
				ED	Exposure Duration	6	years	USEPA, 2014		
				CF	Volumetric Conversion Factor for Water	1E-03	L/cm3	--		
				BW	Body Weight	15	kg	USEPA, 2014		
				AT-C	Averaging Time (Cancer)	25,550	days	USEPA, 1989		
				AT-N	Averaging Time (Non-Cancer)	2,190	days	USEPA, 1989		

References:
USEPA. 2014. HumanHealth Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. February.
USEPA. 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part A). Interim Final. USEPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, DC. December.
USEPA. 2004. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. USEPA/540/R/99/005. Office of Superfund Remediation and Technology Innovation, Washington, DC. July.

Table 4.1
RAGS Part D Table 4.1
Values Used for Dermal Absorbed Dose (DAevent) Calculations
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

If t-event < t*

Chemical of Potential Concern	CAS RN	t*	FA	Kp	CF	tau-event
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	4.43	1	3.36E-04	0.001	1.84

Scenario	Event Duration	DAevent
Worker	0.00833	1.15E-07
Adult Resident	0.71	1.06E-06
Child Resident	0.54	9.27E-07

If t-event > t*

Chemical of Potential Concern	CAS RN	t*	FA	Kp	CF	B	tau-event
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	4.43	1	3.36E-04	0.001	1.93E-03	1.84

Scenario	Event Duration	DAevent
Recreator	6	3.25E-06

Note:
DAevent values shown here are multiplied by the EPC (Cw) for final DAD calculations.

Table 5
RAGS Part D Table 5.1
Non-Cancer Toxicity Data - Oral/Dermal
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Chemical of Potential Concern	CASRN	Chronic/ Subchronic	Oral Reference Dose (RfD)		Oral Absorption Efficiency for Dermal	Absorbed RfD for Dermal		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfD	
			Value	Units		Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	Chronic	4E-03	mg/kg-day	1	4E-03	mg/kg-day	Nervous System	300	IRIS	8/30/2018
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	Subchronic	1E-01	mg/kg-day	1	1E-01	mg/kg-day	Nervous System	30	ATSDR	1/1/2012

Notes:
NA = not available.

Hierarchy of Sources:
IRIS = Integrated Risk Information System (https://cfpub.epa.gov/ncea/iris2/atoz.cfm).
NCEA = National Center for Environmental Assessment, Provisional Peer-Reviewed Toxicity Value (http://hhpprtv.ornl.gov/).
CalEPA = California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (https://oehha.ca.gov/chemicalsp).
ATSDR = Agency for Toxic Substances and Disease Registry, Minimal Risk Level (https://www.atsdr.cdc.gov/mrls/index.asp).
HEAST = Health Effects Assessment Summary Tables (https://epa-heast.ornl.gov/).

Table 6
RAGS Part D Table 6.1
Cancer Toxicity Data - Oral/Dermal
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Chemical of Potential Concern	CASRN	Oral Cancer Slope Factor (CSF)		Oral Absorption Efficiency for Dermal	Absorbed CSF for Dermal		USEPA Weight of Evidence Classification / Cancer Guideline Description	Oral CSF	
		Value	Units		Value	Units		Source(s)	Date(s) (MM/DD/YYYY)
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4	8E-02	(mg/kg-day)-1	1	8.0E-02	$(mg/kg\text{-}day)^{-1}$	Suggestive Evidence of Carcinogenic Potential	IRIS	8/30/2018

Notes:
NA = not available.

Hierarchy of Sources:
IRIS = Integrated Risk Information System (https://cfpub.epa.gov/ncea/iris2/atoz.cfm).
NCEA = National Center for Environmental Assessment, Provisional Peer-Reviewed Toxicity Value (http://hhpprtv.ornl.gov/).
CalEPA = California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (https://oehha.ca.gov/chemicalsp).
ATSDR = Agency for Toxic Substances and Disease Registry, Minimal Risk Level (https://www.atsdr.cdc.gov/mrls/index.asp).
HEAST = Health Effects Assessment Summary Tables (https://epa-heast.ornl.gov/).

Table 7.1.1
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Current/Future Adult Onsite Worker Exposure to Groundwater at C-52N
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Current/Future
Receptor Population:	Onsite Worker
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Tapwater	C-52N	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.4E-03	mg/L	1.1E-05	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	9E-07	3.1E-05	mg/kg-day	4.0E-03	mg/kg-day	8E-03
			Exp. Route Total								9E-07					8E-03
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.4E-03	mg/L	7.2E-09	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	6E-10	2.0E-08	mg/kg-day	4.0E-03	mg/kg-day	5E-06
			Exp. Route Total								6E-10					5E-06
							Total of Receptor Risks Across All Media				9E-07	Total of Receptor Hazards Across All Media				8E-03

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.1.2
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Current/Future Adult Onsite Worker Exposure to Groundwater at C-62
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Current/Future
Receptor Population:	Onsite Worker
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Tapwater	C-62	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	4.1E-02	mg/L	3.1E-04	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	2E-05	8.7E-04	mg/kg-day	4.0E-03	mg/kg-day	2E-01
			Exp. Route Total								2E-05					2E-01
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	4.1E-02	mg/L	2.0E-07	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	2E-08	5.7E-07	mg/kg-day	4.0E-03	mg/kg-day	1E-04
			Exp. Route Total								2E-08					1E-04
							Total of Receptor Risks Across All Media				2E-05	Total of Receptor Hazards Across All Media				2E-01

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.2.1
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Hypothetical Onsite Resident Exposure to Groundwater C-52N
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Hypothetical Onsite Resident
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Tapwater	C-52N	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.4E-03	mg/L	1.9E-05	mg/kg-day	8.0E-02	(mg/kg-day)$^{-1}$	1E-06	7.2E-05	mg/kg-day	1.0E-01	mg/kg-day	7E-04
			Exp. Route Total								1E-06					7E-04
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.4E-03	mg/L	1.6E-07	mg/kg-day	8.0E-02	(mg/kg-day)$^{-1}$	1E-08	5.5E-07	mg/kg-day	1.0E-01	mg/kg-day	5E-06
			Exp. Route Total								1E-08					5E-06
							Total of Receptor Risks Across All Media				1E-06	Total of Receptor Hazards Across All Media				7E-04

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
(mg/kg-day)$^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.2.2
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Hypothetical Onsite Resident Exposure to Groundwater at C-62
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Hypothetical Onsite Resident
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Tapwater	C-62	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	4.1E-02	mg/L	5.2E-04	mg/kg-day	8.0E-02	(mg/kg-day)⁻¹	4E-05	2.0E-03	mg/kg-day	1.0E-01	mg/kg-day	2E-02
			Exp. Route Total								4E-05					2E-02
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	4.1E-02	mg/L	4.4E-06	mg/kg-day	8.0E-02	(mg/kg-day)⁻¹	4E-07	1.5E-05	mg/kg-day	1.0E-01	mg/kg-day	2E-04
			Exp. Route Total								4E-07					2E-04
							Total of Receptor Risks Across All Media				4E-05	Total of Receptor Hazards Across All Media				2E-02

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.3.1
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Offsite Recreator Exposure to Groundwater at C-52N
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Offsite Recreator
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Surface Water	C-52N	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-04	mg/L	1.2E-07	mg/kg-day	8.0E-02	(mg/kg-day)⁻¹	9E-09	9.9E-07	mg/kg-day	1.0E-01	mg/kg-day	1E-05
			Exp. Route Total								9E-09					1E-05
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-04	mg/L	2.1E-09	mg/kg-day	8.0E-02	(mg/kg-day)⁻¹	2E-10	9.2E-09	mg/kg-day	1.0E-01	mg/kg-day	9E-08
			Exp. Route Total								2E-10					9E-08
							Total of Receptor Risks Across All Media				9E-09	Total of Receptor Hazards Across All Media				1E-05

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.3.2
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Offsite Recreator Exposure to Groundwater at C-62
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Offsite Recreator
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Surface Water	C-62	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-02	mg/L	1.2E-05	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	9E-07	9.9E-05	mg/kg-day	1.0E-01	mg/kg-day	1E-03
			Exp. Route Total								9E-07					1E-03
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-02	mg/L	2.1E-07	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	2E-08	9.2E-07	mg/kg-day	1.0E-01	mg/kg-day	9E-06
			Exp. Route Total								2E-08					9E-06
							Total of Receptor Risks Across All Media				9E-07	Total of Receptor Hazards Across All Media				1E-03

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.4.1
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Hypothetical Offsite Resident Exposure to Surface Water at C-52N
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Hypothetical Offsite Resident
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Surface Water	Tapwater	C-52N	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-04	mg/L	1.9E-06	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	2E-07	7.5E-06	mg/kg-day	1.0E-01	mg/kg-day	7E-05
			Exp. Route Total								2E-07					7E-05
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-04	mg/L	1.6E-08	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	1E-09	5.7E-08	mg/kg-day	1.0E-01	mg/kg-day	6E-07
			Exp. Route Total								1E-09					6E-07
							Total of Receptor Risks Across All Media				2E-07	Total of Receptor Hazards Across All Media				8E-05

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 7.4.2
RAGS Part D Table 7
Calculation of Chemical Cancer Risks and Non-Cancer Hazards for a Future Adult+Child (Cancer Risk), Child (Non-Cancer Hazard) Hypothetical Offsite Resident Exposure to Surface Water at C-62
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Scenario Timeframe:	Future
Receptor Population:	Hypothetical Offsite Resident
Receptor Age:	Adult+Child (Cancer Risk), Child (Non-Cancer Hazard)

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake / Exposure Concentration		Cancer Slope Factor / Unit Risk		Cancer Risk	Intake / Exposure Concentration		Reference Dose / Reference Concentration		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Surface Water	Tapwater	C-62	Ingestion	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-02	mg/L	1.9E-04	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	2E-05	7.5E-04	mg/kg-day	1.0E-01	mg/kg-day	7E-03
			Exp. Route Total								2E-05					7E-03
			Dermal	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	1.5E-02	mg/L	1.6E-06	mg/kg-day	8.0E-02	$(mg/kg\text{-}day)^{-1}$	1E-07	5.7E-06	mg/kg-day	1.0E-01	mg/kg-day	6E-05
			Exp. Route Total								1E-07					6E-05
							Total of Receptor Risks Across All Media				2E-05	Total of Receptor Hazards Across All Media				8E-03

Notes:
-- = not applicable.
EPC = exposure point concentration.
mg/L = milligrams per liter.
mg/kg-day = milligrams per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = inverse milligrams per kilogram per day.
NA = not available.

Table 8
Summary of Groundwater Data and Modeled Concentrations at Points of Discharge
Human Health Risk Assessment Memo - Open Burn/Open Detonation Units at Range C-52 North and Range C-62
Eglin Air Force Base
Florida

Exposure Point	CASRN	Chemical	Units	Maximum Concentration	95 Upper Confidence Limit	Modeled Concentration at Point of Discharge into Surface Water (1)	Alternate Concentration Limit (2)	Surface Water Cleanup Target Level (3)
C-52 North	2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	μg/L	ND	NA	NA	580	1300
	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	μg/L	1.5	1.45	0.15	0.32	180
C-62	2691-41-0	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	μg/L	59	41.6	NA	430	1300
	121-82-4	Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	μg/L	72	40.7	15	0.31	180

Notes:
(1) Most conservative modeled concentration at point of discharge location
C-52N: Bay Head Branch Creek
C-62: Blount Mill Creek
(2) Most conservative (lowest) ACL calculated for each range
(3) Surface Water Cleanup Target Level (SWCTL) from Florida DEP

CASRN = Chemical Abstract Services Registry Number.
μg/L = microgram(s) per liter.
NA = not available.
ND = not detected.

ATTACHMENTS

Attachment 1

ProUCL Output

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	Distribution for UCL Selection	Total Sample Size	% ND	FOD%	SDp of ln Detected - Skewness (p)	Gamma K star (bias corrected)	Selected UCL Method
HMX	µg/L	insufficient data	5	--	0%	NA	NA	insufficient data
RDX	µg/L	Nonparametric	5	20%	80%	0.340347984	2.399	95% KM (t) UCL

Notes:
When the RPD is <5% of multiple suggested/potential UCLs provided by ProUCL, the maximum value is shown in Column J
When the RPD is >5% of multiple suggested/potential UCLs provided by ProUCL, review of those UCLs is recommended.
FOD - frequency of detection
ND - non-detect
mg/kg - miligrams per kilogram
µg/kg - micrograms per kilogram
RPD = Relative Percent Difference = (MaxUCL - MinUCL) / ((MaxUCL + MinUCL) * 0.5)
UCL - upper confidence limit

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	Sel UCL Value	# Detects	# NDs	Num Distinct Observations	Num Distinct Detects	Minimum Detected	Maximum Detected
HMX	µg/L	**NA**	0	5	5	0	--	--
RDX	µg/L	**1.447**	4	1	5	4	0.72	1.5

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	Mean Detected	SD of ln Detected - Skewness	KM Mean	KM SD	Minimum ND	Maximum ND	GOF Test Result
HMX	µg/L	--	NA	NA	NA	NA	NA	NA
RDX	µg/L	1.093	0.393	0.908	0.489	0.17	0.17	Detected Data appear Normal Distributed at 5% Significance Level

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	# Pot. UCLs	Potential UCL(s) to Use	Pot UCL Val	UCL Flags - See Notes
HMX	µg/L	NA	NA	NA	NA
RDX	µg/L	1	95% KM (t) UCL	1.447	

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	Warning
HMX	µg/L	Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
RDX	µg/L	

Attachment 1
Table 1
ProUCL Output for MW-94-52-01
Eglin Air Force Base
Florida

Constituent	UCL Units	Selected 95% UCL to Use	Selected 95% UCL Method	Min Suggested UCL	Min Suggested UCL Method	Version
HMX	µg/L					ProUCL version 5.1
RDX	µg/L	1.447	95% KM (t) UCL	1.447	95% KM (t) UCL	ProUCL version 5.1

Attachment 1
Table 2
ProUCL Output for MW-94-62-04 and MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Distribution for UCL Selection	Total Sample Size	% ND	FOD%	SDp of ln Detected - Skewness (p)	Gamma K star (bias corrected)	Selected UCL Method
HMX	µg/L	Normal	10	0%	100%	0.292194456	8.089	95% Student's-t UCL
RDX	µg/L	Gamma	10	0%	100%	0.458214033	3.129	95% Adjusted Gamma UCL

Notes:
When the RPD is <5% of multiple suggested/potential UCLs provided by ProUCL, the maximum value is shown in Column J
When the RPD is >5% of multiple suggested/potential UCLs provided by ProUCL, review of those UCLs is recommended.
FOD - frequency of detection
ND - non-detect
mg/kg - miligrams per kilogram
µg/kg - micrograms per kilogram
RPD = Relative Percent Difference = (MaxUCL - MinUCL) / ((MaxUCL + MinUCL) * 0.5)
UCL - upper confidence limit

Attachment 1
Table 2
ProUCL Output for MW-94-62-04 and MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Sel UCL Value	# Detects	# NDs	Num Distinct Observations	Num Distinct Detects	Minimum Detected	Maximum Detected
HMX	µg/L	**41.56**	10	0	10	10	22.6	59
RDX	µg/L	**40.69**	10	0	9	9	13.2	72

Attachment 1
Table 2
ProUCL Output for MW-94-62-04 and MW-94-62-05
Eglin Air Force Base
Florida

ARCADIS Design & Consultancy for natural and built assets

Constituent	UCL Units	Mean Detected	SD of ln Detected - Skewness	KM Mean	KM SD	Minimum ND	Maximum ND	GOF Test Result
HMX	µg/L	34.94	0.308	NA	NA	NA	NA	Data appear to follow a Discernible Distribution at 5% Significance Level
RDX	µg/L	27.86	0.483	NA	NA	NA	NA	Data appear to follow a Discernible Distribution at 5% Significance Level

Attachment 1
Table 2
ProUCL Output for MW-94-62-04 and MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	# Pot. UCLs	Potential UCL(s) to Use	Pot UCL Val	UCL Flags - See Notes	Warning
HMX	µg/L	1	95% Student's-t UCL	41.56		
RDX	µg/L	1	95% Adjusted Gamma UCL	40.69		

Attachment 1
Table 2
ProUCL Output for MW-94-62-04 and MW-94-62-05
Eglin Air Force Base
Florida

ARCADIS Design & Consultancy for natural and built assets

Constituent	UCL Units	Selected 95% UCL to Use	Selected 95% UCL Method	Min Suggested UCL	Min Suggested UCL Method	Version
HMX	µg/L	41.56	95% Student's-t UCL	41.56	95% Student's-t UCL	ProUCL version 5.1
RDX	µg/L	40.69	95% Adjusted Gamma UCL	40.69	95% Adjusted Gamma UCL	ProUCL version 5.1

Attachment 1
Table 3
ProUCL Output for MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Distribution for UCL Selection	Total Sample Size	% ND	FOD%	SDp of ln Detected - Skewness (p)	Gamma K star (bias corrected)	Selected UCL Method
HMX	µg/L	Normal	5	0%	100%	0.341671187	3.726	95% Student's-t UCL
RDX	µg/L	Normal	5	0%	100%	0.626099034	1.129	95% Student's-t UCL

Notes:
When the RPD is <5% of multiple suggested/potential UCLs provided by ProUCL, the maximum value is shown in Column J
When the RPD is >5% of multiple suggested/potential UCLs provided by ProUCL, review of those UCLs is recommended.
FOD - frequency of detection
ND - non-detect
mg/kg - miligrams per kilogram
µg/kg - micrograms per kilogram
RPD = Relative Percent Difference = (MaxUCL - MinUCL) / ((MaxUCL + MinUCL) * 0.5)
UCL - upper confidence limit

Attachment 1
Table 3
ProUCL Output for MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Sel UCL Value	# Detects	# NDs	Num Distinct Observations	Num Distinct Detects	Minimum Detected	Maximum Detected
HMX	µg/L	**53.12**	5	0	5	5	23	59
RDX	µg/L	**53.95**	5	0	5	5	13.2	72

Attachment 1
Table 3
ProUCL Output for MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Mean Detected	SD of ln Detected - Skewness	KM Mean	KM SD	Minimum ND	Maximum ND	GOF Test Result
HMX	µg/L	39.36	0.382	NA	NA	NA	NA	Data appear to follow a Discernible Distribution at 5% Significance Level
RDX	µg/L	30.66	0.7	NA	NA	NA	NA	Data appear to follow a Discernible Distribution at 5% Significance Level

Attachment 1
Table 3
ProUCL Output for MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	# Pot. UCLs	Potential UCL(s) to Use	Pot UCL Val	UCL Flags - See Notes	Warning
HMX	µg/L	1	95% Student's-t UCL	53.12		
RDX	µg/L	1	95% Student's-t UCL	53.95		

Attachment 1
Table 3
ProUCL Output for MW-94-62-05
Eglin Air Force Base
Florida

Constituent	UCL Units	Selected 95% UCL to Use	Selected 95% UCL Method	Min Suggested UCL	Min Suggested UCL Method	Version
HMX	µg/L	53.12	95% Student's-t UCL	53.12	95% Student's-t UCL	ProUCL version 5.1
RDX	µg/L	53.95	95% Student's-t UCL	53.95	95% Student's-t UCL	ProUCL version 5.1

Attachment 2

BIOSCREEN-AT Evaluation and Alternate Concentration Limits Ranges C-52N and C-62 Eglin Air Force Base, Florida

Attachment 2 – BIOSCREEN-AT Evaluation and Alternate Concentration Limits

Open Burn/Open Detonation Units
Range C-52 North and Range C-62
Eglin Air Force Base, Florida
Operational Permit No. 006176-HO-007

Prepared For:
Eglin Air Force Base
96 CEG/CEIEC
700 Range Road, Building 592
Eglin Air Force Base, Florida 32542

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Prepared Under Contract to:
Air Force Civil Engineer Center
Contract Number: FA8903-15-F-0006

February 2019

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FIGURES

TABLES

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LRS Federal LLC (LRS) conducted this Draft BIOSCREEN-AT evaluation of the hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) concentrations and alternate concentration limit (ACL) calculations for RDX and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) in groundwater at the C-52 North (C-52N) and C-62 ranges on the Eglin Air Force Base (AFB) in Florida (the Site). This memorandum summarizes Arcadis' review of the previous BIOSCREEN modeling conducted by CH2M Hill (CH2M Hill 2000, 2002a, and 2002b), summarizes an updated modeling scenario, and provides ACLs for RDX and HMX in groundwater.

1.0 SITE BACKGROUND

1.1 Release and Monitoring History

The Site is located in the northwest portion of the Florida Panhandle (Figure 1), occupying a large portion of Santa Rosa, Okaloosa, and Walton counties (LRS 2018). The Site is comprised of cantonments, ranges/live-fire areas, and undeveloped landscape. Bombing ranges at the Site have been operated since 1950. Ranges C-52N and C-62 are primarily used for testing and training of air-to-land bombing, gunnery, and rocketry training exercises. Range C-52N is located on an active mission target range, whereas Range C-62 is located on a practice mission target range. C-52N is located approximately 6 miles north of Niceville, Florida and 2.5 miles east of the Okaloosa-Walton County line. Range C-62 is situated approximately 6 miles southwest of Defuniak Springs, Florida in Walton County. The C-62 range is also secondarily used as open burn/open detonation (OB/OD) units for treatment of unserviceable and/or excess serviceable munitions, items, and/or waste explosives, as permitted by the Florida Department of Environmental Protection (FDEP; Permit No. HO46-286388). Range C-52N contains a 100-foot by 200-foot area known as the Cat's Eye target, which is also used for OD activities. The southern end of Range C-62 (a 100-yard by 200-yard area) contains an OD unit and two 20-foot by 9-foot covered burn kettles for OB operations. There are no current plans to change the land use at either of these ranges (CH2M Hill 2000, 2002a, and 2002b, LRS 2018).

Two constituents of potential concern from site operations include the explosive compounds RDX and HMX. In November 1994, three groundwater monitoring wells were installed at C-52N (MW-94-52-01 through MW-94-52-03), and five wells were installed at C-62 (MW-94-62-01 through MW-94-62-05). Three rounds of quarterly baseline sampling, including soil sampling, were conducted in November and December 1994 and March and May 1995. At Range C-52N, no explosive compounds were reported above detection limits for any of the six surface or subsurface soil samples. At Range C-62, explosive compounds were not detected at 19 of 20 surface soil samples, with only a trace amount of 1,3-dinitrobenzene (0.42 milligrams per kilogram [mg/kg]) was detected at concentrations below the United States Environmental Protection Agency Region III risk-based concentration of 0.78 mg/kg in one sample. In the subsurface soil samples collected from Range C-62, only nitrobenzene was detected at 0.26 mg/kg, below the United States Environmental Protection Agency Region III risk-based concentration of 3.9 mg/kg.

Twenty-two rounds of quarterly groundwater monitoring events were performed between September 1996 and January 2002 to establish baseline groundwater conditions at the site. Groundwater samples were analyzed for explosives (including RDX and HMX), nitrate, and nitrite. In addition to these parameters, groundwater samples collected from Range C-62 were analyzed for benzene, toluene, ethylbenzene, and total xylenes. Since 2002, groundwater monitoring at Range C-52N has consisted of one upgradient background well (MW-94-52-01) and two point of compliance (POC) wells (MW-94-52-01 and MW-94-52-03). Monitoring at Range C-62 has consisted of sampling one upgradient background well (MW-94-62-01) and four POC wells (MW-94-62-02 through MW-94-62-05; LRS 2018).

1.2 Site Setting

Topography at Range C-52N varies from elevations of near 170 feet above mean sea level (ft amsl) in the north to nearly 70 ft amsl at the southern end of the Range. Range Road 200 tracks a ridge dissecting the northern portion of the site with a bearing roughly southwest/northeast. Two drainages lie on the either side of the Cat's Eye (the target area): Bay Head Branch to the west and Coon Head Branch to the east. These drainages eventually flow south into the Basin Bayou via Basin Creek. Two downgradient monitoring wells at C-52N are located south of the Cat's Eye, at elevations of approximately 100 to 120 ft amsl (Figure 2)

A large open flatland dominates the central portion of the C-62 range. Drainages in the northern and southern extremes of the range drop off in elevation from near 200 ft amsl to 100 ft amsl. Downgradient monitoring wells at C-62 are located southwest of the Cat's Eye, upgradient of the headwaters of Blount Mill Creek (Figure 3). Both bombing ranges are deforested.

1.3 Geology and Hydrogeology

The Site is situated in the Gulf Coastal Plain and is underlain by deltaic deposits of the Plioceneage Citronelle Formation (Florida Geological Survey [FGS] 2001). This formation is characterized by very fine to very coarse, poorly sorted, clean to clayey sands. Clay, silt, and gravel frequently occur as variable and discontinuous lenses. The Citronelle Formation is 20 to 50 feet thick on the eastern half of the Site where the two ranges are located (FGS 2001). The surficial aquifer in the Citronelle Formation is referred to as the 'Sand and Gravel Aquifer,' the 'Miocene-Pliocene Aquifer', or the 'Citronelle Aquifer'. Specifically, this aquifer is approximately 60 feet thick at Range C-52N and 100 feet thick at Range C-62 (FDEP 2001). The Sand and Gravel Aquifer is comprised of fine to coarse sand, clay, silt, and gravel. While the aquifer is typically unconfined above with permeable material exposed at ground surface, lenses of less permeable material including fine sand, clay, and silt create discontinuous confined zones that result in localized 'leaky confined' conditions. Groundwater flow in the Sand and Gravel Aquifer is typically controlled by topography, with flow generally trending south towards the Gulf of Mexico. Flow patterns are locally influenced by streams and rivers which dissect the aquifer and serve as potential discharge boundaries (LRS 2018).

Underlying the Citronelle Formation on the eastern side of the base is the Miocene-age Alum Bluff Group. These sediments are characterized by clays, sands, and shell beds, with variable grain size (from very fine to very coarse). The Alum Bluff Group is approximately 180 feet thick below the eastern half of the Site (FGS 2001). The Pensacola Clay, which forms part of the Alum Bluff group, has low permeability and functions as a confining unit that separates the surficial Sand and Gravel Aquifer in the Citronelle Formation from the underlying Floridian aquifer (LRS 2018).

1.3.1 Range C-52N

Three monitoring wells were installed at Range C-52N (EA Engineering 1995). The monitoring wells were triangulated around the Cat's Eye and installed in the surficial aquifer of the Citronelle Formation. MW-94-52-01 was intended to be the upgradient "background" well, and monitoring wells MW-94-52-02 and MW-94-52-03 were intended to be downgradient POC wells (installed downgradient to the south). The lithology at C-52N consists of fine- to coarse-grained moderate- to well-sorted sands with minor amounts of silt. The sands appear to be continuous across the range, with occasional discontinuous peat lenses present near the top of the water table (EA Engineering 1995). Locally at Range C-52N, the groundwater flow direction appears to flow to the south away from the Cat's Eye (Figure 2).

1.3.2 Range C-62

Five monitoring wells were installed in the surficial aquifer of the Citronelle Formation at Range C-62 (EA Engineering 1995). The monitoring wells were set to surround the OB and OD units. MW-94-62-01 was intended to be the upgradient "background" well for both the OB and OD units. Monitoring wells MW-94-62-02 and MW-94-62-03 were installed downgradient of the OB unit (to the west-southwest) and upgradient of the headwaters of Blount Mill Creek. Monitoring wells MW-94-62-04 and MW-94-62-05 were installed downgradient of the OD Unit (to the south-southwest) and upgradient of the headwaters of Blount Mill Creek. The lithology of Range C-62 consists of continuous fine- to coarse-grained moderate- to well-sorted sands with minor amounts of silt. Locally at Range C-62, the groundwater flow direction appears to flow to the west-southwest from the OB Unit, while flowing more toward the southwest from the OD Unit toward the headwater of Blount Mill Creek (Figure 3).

1.4 RDX and HMX in Groundwater

Available historical sampling results (from May 2003 through May 2018; LRS 2018b) are presented in Table 1. The results from the last four years of monitoring data (May 2014 through May 2018) are summarized below.

Range C-52N

At Range C-52N, HMX has not been detected in the groundwater samples and are below the 350 µg/L FDEP Groundwater Cleanup Target Levels (GWCTL). RDX concentrations at Range C-52N in the last four years ranged from nondetect to a maximum detected concentration of 1.5 µg/L in June 2015 at MW-94-52-01, which exceeds the FDEP GWCTL (0.3 µg/L). Concentrations of RDX in downgradient monitoring wells MW-94-52-02 and MW-94-52-03 have been nondetect below the FDEP GWCTL since May 2005, with the exception of one sampling qualified due to blank contamination (June 2016 at MW-94-52-03). The calculated 95 percent UCL (95 UCL) for RDX is 1.45 µg/L, with the arithmetic mean at 0.891 µg/L. The 95 UCL was not calculated for HMX, but the arithmetic mean was 0.0474 µg/L. Concentrations of HMX and RDX in groundwater appear to have stable to decreasing trends.

Range C-62

At Range C-62, in the past four years of monitoring data, concentrations of HMX have ranged from not detected (at MW-94-62-01) to a maximum detected HMX concentration at MW-94-62-05 of 59 µg/L in May 2018. RDX concentrations have ranged 0.19 µg/L (at MW-94-62-01 in May 2017) to a maximum detected concentration of 72 µg/L in May 2018 at MW-94-62-05. RDX concentrations have exceeded the FDEP GWCTL at MW-94-62-04 and MW-94-62-05 during each sampling event in the past four years. The calculated 95 UCL for RDX (at monitoring wells MW-94-62-02 through MW-94-62-05) is 32.3 µg/L, with the arithmetic mean at 15.6 µg/L. At MW-94-62-05 alone, the calculated 95 UCL was 0.054 µg/L. For HMX, The 95 UCL was not calculated for HMX, the calculated 95 UCL at monitoring wells MW-94-62-02 through MW-94-62-05 is 61.1 µg/L, with the arithmetic mean at 17.5 µg/L. Concentrations of HMX and RDX in groundwater appear to have potentially increasing trends at monitoring wells MW-94-62-04 and MW-94-62-05.

2.0 FATE AND TRANSPORT OF RDX

RDX is commonly deposited as discrete particles with strongly heterogeneous distributions, and soil concentrations can vary by more than an order of magnitude for samples collected less than a meter apart (USEPA 2014a; USACE 2002). Dissolution from explosives particles is often the controlling factor for fate and transport of RDX as it has a low water solubility (Furey et al. 2008; United States Environmental Protection Agency [USEPA] 2014a). Following dissolution, RDX is not strongly retained by soil and migrates in groundwater, with a low to moderate organic carbon sorption coefficient (Koc ranging from 42 to 167 liters per kilogram). Soils rich in organic carbon, clay, or iron increase sorption to soil and decrease mobility in groundwater (Furey et al. 2008; Sharma et al. 2013).

Photolysis of RDX by ultraviolet light is the primary mechanism that degrades aqueous RDX, and consequently, RDX does not persist in surface waters and sediments (USEPA 2014a). In soil and groundwater, however, photolysis is not significant. Nitroso derivatives, nitrate, nitrite, nitrogen-monoxide, ammonium, formaldehyde, formamide, and N-nitroso-methylenediamine have been identified as products of RDX photodegradation in surface water (Gorontzy et al. 1994).

Microbial biodegradation (i.e., mineralization) and transformation to organic derivatives are the primary attenuation processes for RDX in groundwater under typical subsurface conditions (Nishino et al. 2000). In laboratory experiments, RDX generally biodegrades most effectively under anaerobic conditions and mineralization is favored, yielding several nitroso and nitramine intermediates and, ultimately, hydrazines and methanol (Pennington et al. 1999; Hawari 2000). Under aerobic conditions, RDX undergoes biotransformation to mono-, di-, and tri-nitroso derivatives (hexahydro-1-nitroso-3,5- dinitro-1,3,5-triazine [MNX], hexahydro1,3-dinitroso-5-nitro-1,3,5-triazine [DNX], and hexahydro1,3,5-trinitroso-1,3,5-triazine [TNX]) (Pennington et al. 1999).

3.0 REVIEW OF PREVIOUS BIOSCREEN MODEL

In 2000 and 2002, CH2M Hill (2000, 2002a, and 2002b) used BIOSCREEN Natural Attenuation Decision Support System Version 1.4 (USEPA 1997) to estimate the potential risk posed to potential downgradient receptors from RDX in groundwater at Ranges C-52N and C-62 at the site. The input parameters for the updated BIOSCREEN-AT model is presented in Table 2A, and the previous BIOSCREEN model inputs (CH2M Hill 2002b) are summarized in Table 2b. CH2M Hill concluded that RDX would not migrate in groundwater more than 1,600 feet at Range C-52N and 2,500 feet at Range C-62 at concentrations greater than the 0.1 µg/L. (CH2M Hill 2000 and 2002a). However, as described above, recent groundwater monitoring data indicates that RDX concentrations at Ranges C-52N and C-62 have exceeded the current FDEP GWCTL and that concentrations appear to be increasing through time at Range C-62 downgradient from the OD Unit. Therefore, an updated, revised BIOSCREEN model is warranted. Arcadis, on behalf of LRS, reviewed the CH2M Hill BIOSCREEN model input parameters, assumptions and output and offers the following observations:

- BIOSCREEN Version 1.4 was updated in 2006 (BIOSCREEN Natural Attenuation Decision Support System AT Version 1.45 [BIOSCREEN-AT]) and offers a more exact solution (S.S. Papadopoulos, Inc. 2006). CH2M Hill's use of an earlier version of BIOSCREEN is expected to include a slightly higher degree of numerical error, but, may not be significant.
- CH2M Hill prepared three, independent, BIOSCREEN models to simulate the RDX concentrations: one for Range C-52N and two for Range C-62 (modeling the OB and OD unit plumes). The results from the two BIOSCREEN models at Range C-62 were then superimposed on each other.
- It is unclear how source area input parameters were derived. Available soil data (EA Engineering 1995) did not find RDX or HMX concentrations above the method detection limits, and cross-gradient groundwater data (to help delineate plume dimensions) are limited. CH2M Hill used the maximum detected concentration at the groundwater monitoring wells (through the 16th quarterly monitoring event) to estimate a source concentrations and estimated source widths from isopleth maps (which could not be independently verified). RDX concentrations have increased downgradient from the Range C-62 OD Unit. Since these models were constructed using lower HMX and RDX concentrations and concentrations appear to be increasing at Range C-62 and decreasing at range C-52N, a revised BIOSCREEN model is advisable.

4.0 UPDATED BIOSCREEN-AT MODEL

The most recent groundwater data that were available (from 2003 through 2018) at Ranges C-52N and C-62 were evaluated for an updated BIOSCREEN model using the BIOSCREEN-AT tool, Version 1.45 (S.S. Papadopoulos, Inc. 2014). RDX was the only constituent selected for a BIOSCREEN model, since HMX concentrations have not exceeded the FDEP GWCTL.

BIOSCREEN-AT assumes RDX concentrations in all wells (targets) downgradient from the source area are zero at time zero. Typically, historical and/or current analytical data from soil borings or groundwater monitoring wells in the center of the source area would be used to define the source area. However, at Ranges C-52N an C-62, RDX was not detected in the historical soil samples (EA Engineering 1995), and the existing monitoring wells with the highest RDX concentrations are installed either upgradient or downgradient of the source areas. Thus, the potential source area concentrations could not be defined for the ranges. Thus, the typical modeling approach of entering source area data and calibrating the model using downgradient monitoring well data could not be used. Instead, the updated BIOSCREEN-AT model established source concentrations as follows:

- Range C-52N – the source concentration was established at upgradient monitoring well MW-94-52-01, where the maximum RDX concentration was detected. The plume was then modeled downgradient to MW-94-52-02 to the potential confluence of the groundwater flow path with surface water in Bay Head Branch.
- Range C-62 – Given the two source areas at Range C-62 (i.e., the OB and OD units) have slightly different groundwater flow directions, two BIOSCREEN-AT models were developed for Range C-62: one for the OB unit and one for the OD unit. The source concentrations were established at the downgradient monitoring wells for the OB unit (at MW-94-62-03) and the OD Unit (at MW-94-62-05), where the maximum RDX concentrations were detected for each source area. The plume was then modeled downgradient from those monitoring wells to two potential receptors: the intersection of the groundwater flow path from OB or OD units with the headwaters of Blount Mill Creek (to assess potential impacts to surface water receptors) and approximately 5,000 feet downgradient from the OD Unit (to assess potential impacts to groundwater receptors).

This approach will provide a reasonable and conservative assessment of the likelihood of RDX to migrate to potential receptors under current conditions at the Site. However, using this approach, the BIOSCREEN-AT model will need to be periodically re-evaluated through time as new site data become available, particularly if RDX or HMX concentrations continue to display increasing trends. The input parameters for these BIOSCREEN-AT models are presented in Table 2A and described below. The previous input parameters for the 2002 BIOSCREEN evaluation (CH2M Hill 2002b) are included in Table 2B.

4.1 Input Parameters

4.1.1 Hydrogeology

The seepage velocity (v_x) was calculated by the BIOSCREEN-AT model using the horizontal hydraulic conductivity, (K), the hydraulic gradient (i), and the effective porosity (n_e) using the following equation in consistent units:

$$v_x = \frac{K \cdot i}{n_e}$$

Hydraulic Conductivity

For the updated BIOSCREEN-AT model, Arcadis calculated the average hydraulic conductivity values based on the slug test data collected in August 2001 (CH2M Hill 2002b). The average hydraulic conductivity for each range was calculated using the results from both the Bouwer and Rice and Hvorselv analytical solutions for the slug tests. At Range C-52N, the average hydraulic conductivity was $1.4X10^{-2}$ cm/sec (approximately 33 feet per day [ft/day]). This is slightly higher than that previously used by the BIOSCREEN model ($8.1X10^{-3}$ cm/sec; CH2M Hill 2002b). At Range C-62, hydraulic conductivities were calculated for both the OD Unit (MW-94-62-04 and MW-94-62-05) and the OB Unit (MW-94-62-02 and MW-94-62-03) The average hydraulic conductivity at the OD Unit was $6.32X10^{-04}$ cm/sec (1.8 ft/day), and at the OB Unit the average hydraulic conductivity was $7.68X10^{-03}$ cm/sec (22 ft/day). These hydraulic conductivities are higher (i.e., more conservative) than that previously used by the BIOSCREEN model ($5.3X10^{-4}$ cm/sec; CH2M Hill 2002b).

Hydraulic Gradient

Hydraulic gradients were calculated using the May 2018 potentiometric contour maps (LRS 2018a). For Range C-52N, the calculated hydraulic gradient between MW-94-52-01 and MW-94-52-02 was 0.01 ft/ft. For Range C-62, the calculated hydraulic gradients were 0.018 ft/ft for the OB Unit and 0.017 ft/ft for the OD Unit, based on the May 2018 groundwater water elevations between MW-94-62-01 and MW-94-62-03 (for the OB Unit) and between MW-94-62-01 and MW-94-62-05 (for the OD Unit; Figure 3; LRS 2018a). These values are comparable to the hydraulic gradients used in the previous BIOSCREEN models (approximately 0.017 ft/ft).

Effective Porosity

The previous BIOSCREEN model used an n_e of 30 percent as a default value. For the updated BIOSCREEN-AT model, the n_e was estimated at 20 percent based on the correlation between soil types (poorly graded sands at the Site) and n_e according to USEPA guidance (USEPA 1989). This results in a higher v_x.

Seepage Velocity

Based on these parameters, a v_x of 538 feet per year was used for Range C-52N, and a v_x of 55.6 feet per year (OD unit) and 715 feet per year was calculated and used for Range C-62. These v_x estimate are higher than those used in the previous BIOSCREEN model (279 ft/year and 23 ft/year, for Ranges C-52N and C-62, respectively; CH2M Hill 2002b) and thus is considered slightly more conservative (protective).

4.1.2 Dispersion

The longitudinal and transverse dispersivity values are calculated by BIOSCREEN-AT following the Xu and Eckstein (1995) and the Gelhar et al. (1992) relationships (USEPA 1996a), respectively, based on an approximated plume length. For Range C-52N, Arcadis estimated the plume length to be 2,650 feet, based on the distance from MW-94-52-01 to Bay Head Branch along the groundwater flow path. This results in longitudinal and transverse dispersivities of 35.8 feet and 3.58 feet, respectively. At Range C-62, Arcadis modeled the plume lengths for the OB and OD Units as the distances between the downgradient monitoring wells (MW-94-62-03 and MW-94-62-05, respectively) and the headwaters of the Blount Mill Creek (Figure 3). For the OD unit, the estimated plume length was approximately 500 feet, resulting in longitudinal and transverse dispersivities of 17.9 and 1.9 feet, respectively. For the OB Unit, the estimated plume length was 170 feet, resulting in longitudinal and transverse dispersivities of 10.0 and 1.0 feet, respectively.

Vertical dispersivities were estimated using the relationship in American Society of Testing and Materials (ASTM; 1995), where the vertical dispersivity is equal to 5 percent of the longitudinal dispersivity. This results in a vertical dispersivity of 1.79 feet for Range C-52N, and 0.90 ft and 0.50 feet for the OD and OB Units, respectively, at Range C-62.

4.1.3 Adsorption and Chemical Retardation

The BIOSCREEN-AT model uses the soil bulk density (ρ_b), total porosity (n), partitioning coefficient (K_{oc}), and fraction of organic carbon (f_{oc}) to determine the retardation factor (r_f):

$$r_f = 1 + \frac{\rho_b K_{oc} f_{oc}}{n}$$

The ρ_b was estimated to be 1.5 kg/L and the f_{oc} was estimated to be 0.002 grams per gram based on USEPA's Soil Screening Guidance default values for potential migration to groundwater assessments (USEPA 1996b). Total porosity was estimated at 35 percent based on literature values for sand (Freeze and Cherry 1979). The K_{oc} was determined using the USEPA chemical-specific parameters table for regional screening level assessments (USEPA 2018). For RDX, the K_{oc} is estimated to be 89.07 L/kg. Using the same n_e as before, this results in an estimated r_f value of 1.76 for the BIOSCREEN-AT models at both ranges. The retardation factor used is potentially biased low based on more recent studies that indicate the soil-water partitioning coefficient

(K_d=K_{oc}·f_{oc}) used is on the lower range of observed values. Recent literature values indicate the K_d is 0.37 and 1.5 (Yammamoto et al. 2004) for sorption and desorption processes, which would result in an r_f between 2.0 to 5.3.

4.1.4 Biodegradation and Natural Attenuation Half-Life *($t_{1/2}$)*

BIOSCREEN-AT calculates a first order decay coefficient based on a user-supplied solute half-life. The half-lives of RDX in groundwater is a highly uncertain input, but the value is expected to be relatively high. RDX does not readily degrade in aerobic systems (Speitel et al. 2001 and Hawari 2000), and groundwater monitoring data from the Site indicate that the shallow aquifer system is aerobic (LRS 2018a). Half-lives of RDX on the order of years to over a hundred years have been reported in the literature for aerobic systems (Speitel et al. 2001 and Ronen et al. 2008). However, some *in-situ* studies have shown that the half-life of RDX can range between four and 13 years under aerobic conditions in shallow (less than 15 meters) portions of the aquifer (Bernstein et al. 2010).

The previous BIOSCREEN model estimated the first order decay coefficient during model calibration at 60 to 75 years (CH2M Hill 2000, 2002a, 2002b). However, site-specific estimates of constituent half-lives are preferable to estimates made through model calibration. To estimate the half-life of RDX using site-specific data, linear regression was performed on the analytical data from monitoring wells at the C-52N Site where source area concentrations appear to be more stable and/or declining. Monitoring wells at Range C-62 could not be utilized for this evaluation because they display increasing RDX concentrations through time. However, monitoring well MW-94-52-01 at Range C-52N display decreasing RDX concentrations through time. Monitoring wells MW-94-52-02 and MW-994-52-03 were not selected for linear regression analysis because of the high percentage of nondects. Linear regression was performed using the RDX concentrations observed from May 2003 to May 2018 at monitoring well MW-94-52-01 at Range C-52N to estimate the attenuation half-life ($t_{1/2}$) in years for RDX on a 1st order decay rate. The linear regression analysis is provided as Attachment 1. The calculated half-life was 8 years, which corresponds to a first order decay coefficient (k) of 0.087 year^{-1} based on the following relationship:

$$k = \frac{ln(2)}{t_{\frac{1}{2}}}$$

This half-life was used in the BIOSCREEN-AT models for both range and within reasonable, expected ranges.

4.1.5 General (Modeled Domain)

Modeled area lengths for both ranges were determined based on the distances from the modeled source areas to the nearest surface water receptor. Although there is no known evidence that groundwater is discharging to surface water at the Site (CH2M Hill 2000, LRS 2018a), the surface water drainages are the closest potential receptors to the source areas, and thus provided a conservative estimate of groundwater concentrations at potential receptors.

Range C-52N

The modeled area length was 3,000 feet ensure the modeled plume would be captured along the centerline extending from monitoring wells MW-94-52-01 and MW-94-52-02 to the intersection with the Bay Head Branch (Figure 2). Modeled area widths were set to 1,500 feet, slightly longer than the modeled source area width (described below). However, this value is arbitrary and has no significant effect on the results, as only the centerline concentration was used in this evaluation. The simulation time was set to 100 years to model steady-state conditions.

Range C-62

Modeled area lengths of 600 feet for the ODU and 200 feet for the OBU were used to ensure the modeled plume would be captured along the centerline extending from monitoring wells MW-94-62-05 and MW-94-62-03, respectively, to their intersection with the headwaters of Blount Mill Creek (Figure 3). Modeled area widths were set equal to the modeled area lengths for these scenarios. However, this value is arbitrary and has no effect on the results, as only the centerline concentration was used in this evaluation. The simulation time was set to 100 years to model steady-state conditions.

Two additional model runs were conducted for the OB and OD units where the modeled area length was set to 5,000 feet to simulate the potential for RDX to migrate to potential receptor wells (currently located approximately 3.6 and 4.4 miles potentially downgradient from the Site). The simulation time for these models was set to 500 years to simulate steady-state conditions.

4.1.6 Source Data

Source Thickness in Saturated Zone and Width

The source zone thickness at Range C-52N was set to 30 feet, and the source zone thickness at Range C-62 was set to 75 feet, based on the FDEP Comments (FDEP 2001) and revisions to the previous BIOSCREEN model (CH2M Hill 2002a and 2002b). The source zone widths used in the previous BIOSCREEN model could not be independently verified (1,400 feet at Range C-52 and 625 and 665 feet for both the OD and OB units at Range C-62). For Range C-52N, the revised BIOSCREEN-AT model used the same source zone width as the previous model. For Range C-62, the revised BIOSCREEN-AT model a source zone width of 300 feet and 170 feet for the OD unit and OB unit, respectively. These values were based on the visually-distinguishable widths of the OD and OB units on aerial images from May 2018 (Figure 3). However, the modeled source width has almost no impact on the results of the BIOSCREEN-AT models at this site; increasing the source width by an order of magnitude results in no change in the steady-state concentrations at the downgradient edge of the modeled area. Given the low horizontal and vertical dispersivity and the reliance on the centerline concentration output, these parameters do not have significant effects on the results.

Source Zone Concentrations

At Range C-52, the source zone concentration was set to 0.0015 mg/L, which is the maximum concentration detected at MW-84-52-01 in the past four years of monitoring. At range C-62, the source concentration at the OB unit was set to 0.0043 mg/L (the maximum detected concentration at MW-94-62-03). At the OD Unit, given the uncertainty in the source area concentrations, the models were run with two source concentrations to provide an estimated range of the expected groundwater concentrations along the plume centerline. The more conservative source concentration estimates used the maximum detected RDX concentrations at MW-94-62-05 (0.072 mg/L). A lower estimate of source area RDX concentrations was estimated using the 95 UCL at MW-94-62-05 (0.054 mg/L) in the OD Unit model.

4.2 BIOSCREEN-AT Results

The results of the BIOSCREEN-AT model are presented in Table 3 and Attachment 2 and are discussed below.

4.2.1 Range C-52N

The BIOSCREEN-AT model for Range C-52N was simulated over 100 years in 5-year time steps. The model indicates that steady-state conditions would be achieved within 15 years. The groundwater analytical results coupled with the chemical transport velocities (i.e., RDX should have reached the downgradient POC wells given the historical usage of this site) indicated that attenuation is occurring between MW-94-52-01 and the Bay Head Branch drainage. The predicted groundwater concentration at the point where the groundwater flow path potentially intersects Bay Head Branch is predicted to be 0.00015 mg/L, below the FDEP GWCTL of 0.0003 mg/L (0.3 micrograms per liter [ug/L]). The model predicts that the groundwater RDX concentration would drop below the FDEP GWCTL by 1,800 feet downgradient from MW-94-52-01.

4.2.2 Range C-62

Open Burn Unit Results

The BIOSCREEN-AT OB Unit model was simulated over 100 years in 5-year time steps. The model indicates steady-state conditions would be achieved within 5 years. The results indicate that minimal attenuation is occurring in the OB Unit plume between MW-94-62-03 and the headwaters of Blount Mill Creek. This is likely due to the short distance of the plume from MW-94-62-03 and the surface water drainage. However, the maximum predicted concentration with first order decay is 0.0041 mg/L, which is above the FDEP GWCTL (0.0003 mg/L). However, this BIOSCREEN-AT assessment is conservative because it does not take into account any potential mixing of groundwater with unimpacted surface water or potential photodegradation of RDX in surface water. When the model was simulated for 500 years with a model area length of 5,000 feet to simulate the potential impact on downgradient groundwater receptors, steady-state conditions would be achieved in less than 25 years, with a predicted maximum RDX concentration at the downgradient edge of the modeled area (with first order decay) of 0.00064 mg/L, suggesting that RDX is likely to attenuate significantly within one mile downgradient of the OB Unit, and is not expected to contribute to exceedances of the FDEP GWCTL for RDX at downgradient receptors or offsite.

Open Detonation Unit Results

The BIOSCREEN-AT OD Unit model was simulated over 100 years in 5-year time steps, using two different source concentrations (maximum detected RDX concentration and the 95 UCL). The model indicates steady-state conditions would be achieved within 45 years. The results indicate that attenuation is occurring in the OD Unit plume between MW-94-62-05 and the headwaters of Blount Mill Creek, although the predicted groundwater concentration (with first order decay) is still above the FDEP GWCTL (between 0.011 and 0.015 mg/L). However, given that the model does not account for mixing of predicted groundwater concentrations with unimpacted surface water and that RDX readily photodegrades in surface waters, it is likely that groundwater that daylights in the headwaters of Blount Mill Creek would not pose a threat to potential receptors.

When the model was simulated for 500 years with a model area length of 5,000 feet, steady-state conditions would be achieved in less than 225 years, with a predicted RDX concentrations (with first order decay) dropping below the FDEP GWCTL in less than 2,000 feet downgradient of the OD Unit. These results indicated that RDX is likely to attenuate significantly within one mile downgradient of the OD Unit, and is not expected to contribute to of the FDEP GWCTL at downgradient receptors or offsite.

4.3 Modeling Assumptions and Uncertainty

The BIOSCREEN-AT model, like any model, requires the use of some simplifying assumptions regarding subsurface conditions, flow processes, and chemical processes that result in inherent limitations and uncertainty when compared to an actual flow system. In this case, uncertainty may be related to:

- assuming that the hydraulic conductivity of the aquifer is uniform; the actual hydraulic conductivity at the site may vary especially downgradient from the monitoring well, and heterogeneities are expected
- assuming monitoring well concentrations are representative of source area concentrations
- assuming an infinite source mass that may be increasing in the case of C-62 and decreasing in the case of C-52N
- uncertainties in the calculation of the RDX half-life

The model predictions are considered reasonable but may have a high bias considering the conservative assumptions used for some parameters. Thus, actual concentrations are expected to be less than or equal to the modeled concentrations.

5.0 ALTERNATIVE CONCENTRATION LIMIT CALCULATIONS

A series of industry standard chemical transport equations were used to calculate $ACLs$ for HMX and RDX in groundwater (ACL_{gw}) for point of compliance wells at each of the respective source areas as illustrated in Attachment 3 - Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors. The assessment was similar to a BIOSCREEN-AT evaluation, however, instead of predicting what concentrations will be in the future the assessment back-calculated a groundwater concentration at a monitoring well or point of compliance that will not result in a groundwater quality concentration greater than the targeted groundwater concentration at a receptor. For purposes of this assessment the receptor was the closest stream and the monitoring well was the monitoring well (point of compliance well) closest to the stream. It was also assumed the streams could be used for drinking water purposes and the Florida GWCTL was used as the target concentration at the receptor (stream). Figures 2 and 3 illustrate the monitoring well used and the distance to the stream.

The calculations accounted for chemical retardation and degradation in groundwater and were based on USEPA guidance and *Contaminant Hydrogeology*[1]. Many of the equations are also summarized in the GA EPD's Guidance: Groundwater Contaminant Fate and Transport Modeling[2]. The equations were combined in a stepwise approach as follows to estimate the ACL_{gw} for downgradient monitoring wells for each of the respective areas and chemicals:

1. **Average seepage water velocity (V_s)** in ft/day. The transport rate (velocity) of groundwater was calculated using site-specific groundwater properties K, i, and θ_e; $V_s=[K*i]\div \theta_e$). V_s was used in step 3.
2. **Soil-water partition coefficient (K_d) and chemical-specific retardation factor (r_f)** in liters per kilogram (L/kg) and dimensionless, respectively. The K_d along with soil properties (ρ_b and n) were used to calculate r_f in groundwater ($r_f=1+K_d[\rho_b \div n]$).
3. **Chemical-specific transport rate in groundwater (v_c) and the time to reach the receptor (t_x)** in ft/day and days, respectively. The r_f (from step 2) in conjunction with the v_s (from step 1) were used to calculate the chemical transport velocity in groundwater ($v_c=v_s \div r_f$). Then, the time (in days) to reach the receptor was calculated using the distance (feet) from the monitoring well to the receptor and the v_c ($t_x=d_x \div v_c$).
4. **Chemical degradation rate constant (k) and allowable initial groundwater concentration ($C_{0\text{-}gw}$ or ACL_{gw})** in days^{-1} and micrograms per liter (ug/L), respectively. The respective chemical half-life (λ) from the BIOSCREEN-AT model, the resulting degradation constant (k), the target groundwater concentration (C) equal to the respective

[1] Fetter, C.W. 1999. Contaminant Hydrogeology. Second Edition. Waveland Press, Inc. Long Grove, IL.

[2] GA EPD. 2016. Guidance: Groundwater Contaminant Fate and Transport Modeling, Revision 1. October.

Florida GWCTL, and the time to reach the receptor (t_x) were used to estimate the initial chemical concentration at the monitoring well needed to equal C downgradient at the receptor ($C_{0\text{-}gw}=ACL_{gw}=C \div e$^$[k \cdot t_x]$).

The equations, inputs, calculations, and assumptions are included in Attachment 3 and follow the four primary steps outlined above. The ACL_{gw} results for each chemical and area are summarized in Table 4.

The equation inputs and parameters were based on site-specific data, default USEPA values, or on literature values that were considered representative of the site conditions (soil type, etc.). The assumptions used in simulating fate and transport of target analytes are detailed in Attachment 3 and the primary assumptions are summarized below:

- Infinite soil source mass*
- V_s was based on site-specific i and the average K for respective source areas[3]
- foc of 0.002* for K_{oc} based on USEPA default values[4,5]
- Groundwater transport calculations do not include dispersion, diffusion, or volatile losses*
- Chemical degradation rate (first order decay)* in groundwater based on literature values and site-specific rates as estimated in the Biodegradation and Natural Attenuation Half-Life ($t_{1/2}$) Section.
- Calculations estimate a centerline, peak concentration*. Thus, the average groundwater discharge concentration (and equivalent mass flux) would be lower than estimated herein.
- Mixing and degradation in the creeks* were not assessed but would significantly dilute and degrade the discharge concentration.

Assumptions with an asterisk (*) are considered conservative (i.e., more protective of human health and the environment).

Site-specific groundwater concentrations at the downgradient monitoring wells at the C-52N area as well as environmental studies indicate that RDX and HMX will attenuate in groundwater and that relative attenuation rates are greater (faster) than estimated since those concentrations have decreased and been less than the laboratory reporting limit for 8 years (see Updated BIOSCREEN-AT Model discussion).

The groundwater flow advection equations are linear in nature with the exception of the degradation equation ($C_{0\text{-}gw}$) which is exponential. Therefore, the parameters generally will have

[3] LRS. 2018. Annual Environmental Monitoring Report, Open Burn/Open Detonation Units, Range C-52 North and Range C-62, Eglin Air Force Base, Florida, Operational Permit No. 006176-H)-007. July.

[4] USEPA 1996b. Soil Screening Guidance: User's Guide. Second Edition. July.

[5] USEPA, 2018. Chemical Specific Parameters Table, May 2018: https://www.epa.gov/risk/regionalscreening-levels-rsls-generic-tables. Accessed December 2018.

an exponential effect on the ACL_{gw}. However, given the conservative approach, the predictions likely underestimate the ACL_{gw} concentration.

6.0 CONCLUSIONS

CH2M Hill's BIOSCREEN (2000, 2002a, 2002b) and Arcadis's BIOSCREEN-AT model indicate that the RDX is attenuating and that RDX will not migrate off-site or reach groundwater receptors above the FDEP GWCTL. However, some of the groundwater could daylight in the headwaters of Blount Mill Creek downgradient of the OD Unit at C-62 at concentrations above the FDEP GWCTL of 0.0003 mg/L (0.3 micrograms per liter) but below the FDEP surface water cleanup target levels of 0.180 mg/L (180 ug/L). However, mixing with surface water and photodegradation of RDX are anticipated to mitigate any potential impacts to surface water over the FDEP GWCTL a short distance downstream from this source area. Given the potentially increasing RDX concentration trends in C-62 groundwater, continued groundwater monitoring of this area is recommended. If concentrations increase significantly, an update to the BIOSCREEN-AT model or equivalent may be appropriate.

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FIGURES

From Figure 1 in LRS (2018)

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE
1

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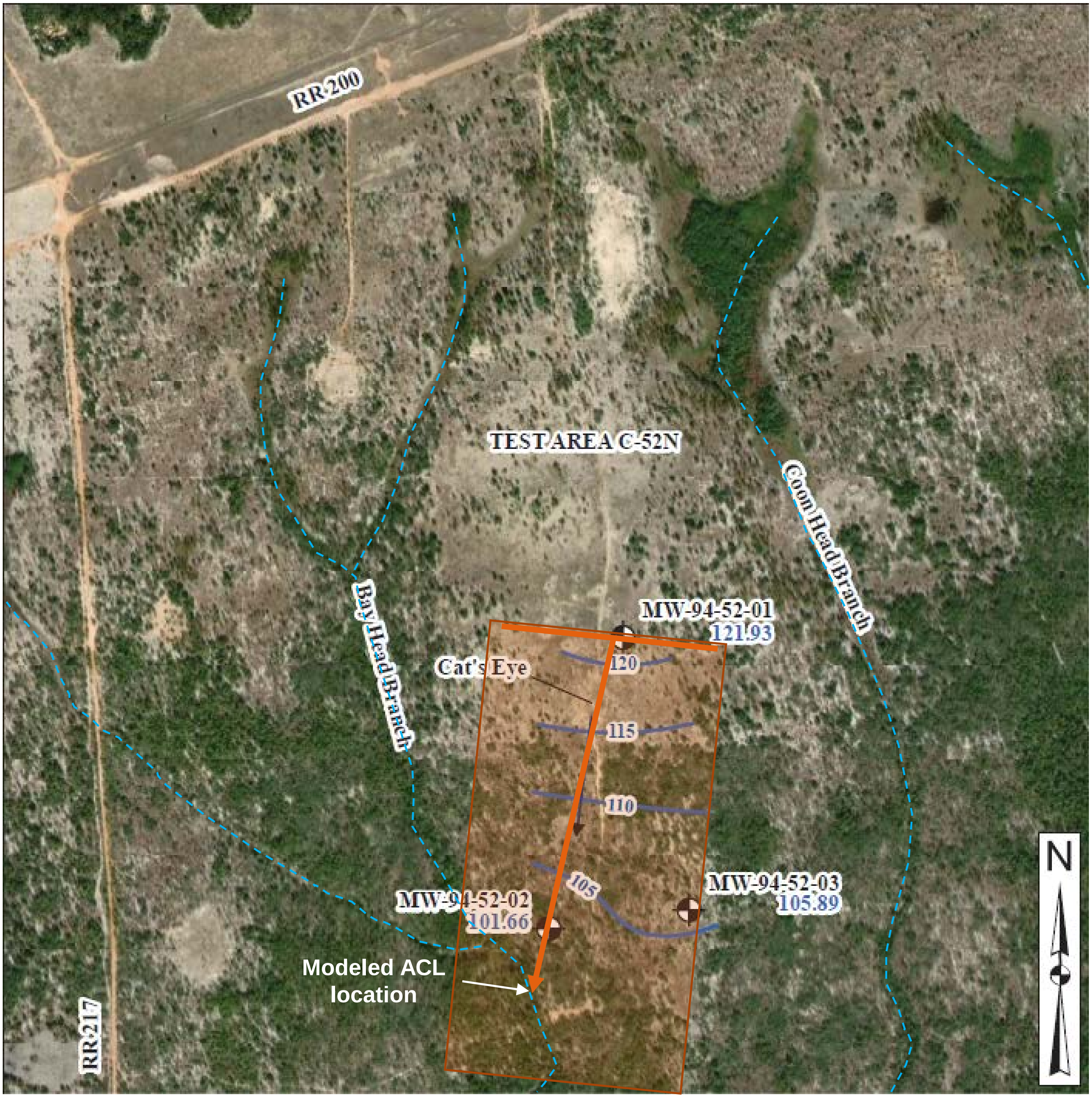

From Figure 8 in LRS (2018)

0 250 500 1,000 Feet

Monitoring Well

Estimated Groundwater Flow Direction

120 Groundwater Elevation Contour (ft NGVD)

Modeled Plume Length

Modeled Domain Area

Modeled Source Width

Surface Water Drainage

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

RANGE C-52N
POTENTIOMETRIC CONTOUR MAP
MAY 2018

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2

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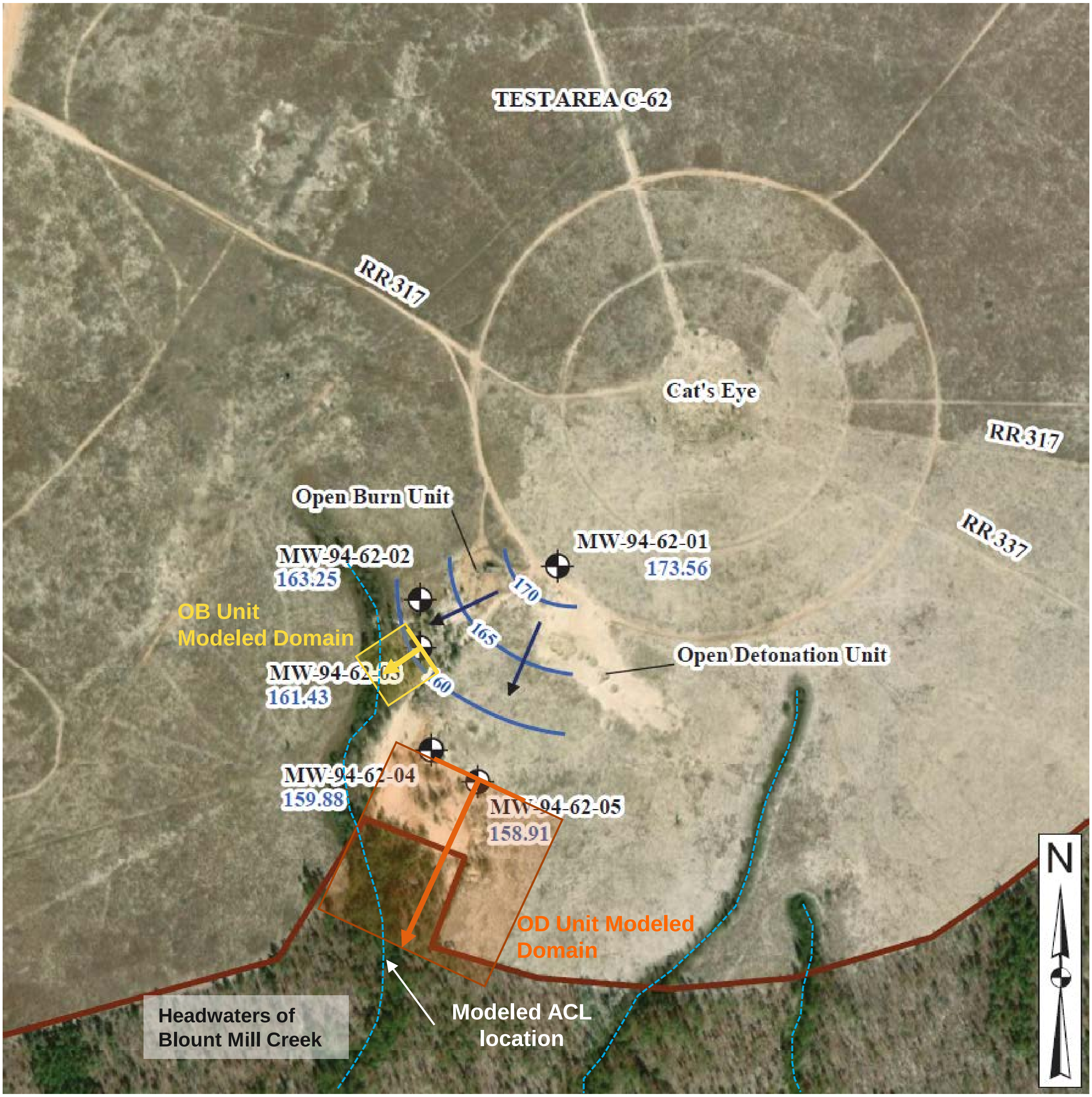

From Figure 9 in LRS (2018)

0 250 500 1,000 Feet

Legend:

- Monitoring Well
- 170 Groundwater Elevation Contour (ft NGVD)
- Estimated Groundwater Flow Direction
- Surface Water Drainage
- Modeled OB Unit Plume
- Modeled OD Unit Plume
- OB Unit Modeled Domain
- OD Unit Modeled Domain
- Modeled OB Unit Source Width
- Modeled OD Unit Source Width

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

RANGE C-62
POTENTIOMETRIC CONTOUR MAP
MAY 2018

ARCADIS Design & Consultancy for natural and built assets

FIGURE
3

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TABLES

Table 1
Historical Sampling Results - May 2003 through May 2018
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

Sampling Date	Range C-52 North										Range C-52 North				
	MW-94-52-01					MW-94-52-02					MW-94-52-03				
	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD
5/23/2003	0.40		4.6		126.74	0.20	U	0.20	U	104.41	0.20	U	0.22		109.53
11/13/2003	0.33		2.1		126.24	0.20	U	0.20	U	103.96	0.21	U	0.26		109.05
5/14/2004	0.18		1.1		121.94	0.17		1.1		101.86	0.21	U	0.21	U	106.03
11/22/2004															
5/16/2005	0.27		1.8		129.98	0.20	U	0.20	U	106.31	0.21	U	0.21	U	112.32
12/2/2005	0.11	J	0.79		122.18	0.19	U	0.19	U	101.81	0.20	U	0.20	U	105.78
5/24/2006	0.06	U	0.34		118.68	0.067	U	0.083	U	100.64	0.067	U	0.084	U	104.33
11/16/2006	0.27		3.9		120.43	0.057	U	0.071	U	100.36	0.058	U	0.072	U	104.02
5/21/2007	0.057	U	0.61		118.42	0.057	U	0.071	U	99.73	0.057	U	0.071	U	103.38
6/17/2008	0.11	U	1.3		122.24	0.11	U	0.074	U	102.24	0.11	U	0.27		106.01
5/12/2009	0.19	U	1.5		123.75	0.10	U	0.071	U	102.75	0.11	U	0.073	U	107.16
6/1/2010	0.035	U	0.99		124.98	0.035	U	0.695		103.74	0.035	U	0.067	U	108.4
6/10/2011	0.036	U	0.068	U	118.79	0.035	U	0.067	U	99.83	0.035	U	0.067	U	103.5
5/18/2012	0.214	U	0.191	U	120.99	0.214	U	0.191	U	101.01	0.223	U	0.199	U	104.87
5/3/2013	0.212	U	0.189	U	123.63	0.212	U	0.189	U	103.04	0.212	U	0.189	U	112.71
6/12/2014	0.13	U	0.17	U	129.48	0.13	U	0.17	U	105.95	0.13	U	0.17	U	111.91
6/19/2015	0.078	U	1.5		122.46	0.076	U	0.076	U	101.24	0.076	U	0.076	U	105.18
6/6/2016	0.085	U	1.4		125.97	0.086	U	0.052	U	103.61	0.085	U	0.21	B	108.43
5/11/2017	0.097	U	0.75		120.94	0.087	U	0.052	U	101.39	0.088	U	0.052	U	105.35
5/12/2018	0.084	U	0.72		121.93	0.084	U	0.05	U	101.66	0.084	U	0.05	U	105.89

Notes:

GCTL for HMX = 350 µg/L

GCTL for RDX = 10 µg/L

µg/L= micrograms per liter

B = Analyte detected in the method blank

ft NGVD = feet National Geodetic Vertical Datum

GCTL = groundwater concentraiton threshold limit

GWE = groundwater elevation

I = Reported value is between lab method detection limit and the laboratory practical quantitation limit.

J = Estimated Value

Q = qualifier

U = Compound was analyzed for but not detected

Shaded = detected concentration exceeds the screening level

Table 1
Historical Sampling Results - May 2003 through May 2018
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

Sampling Date	Range C-62														
	MW-94-62-01					MW-94-62-02					MW-94-62-03				
	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD
5/14/2003			0.53		175.37	0.20	U	1.9		163.85	0.21	U	1.5		161.95
11/6/2003	0.21	U	0.33		174.93	0.21	U	1.8		163.62	0.21	U	1.5		161.67
5/26/2004	0.20	U	0.52		171.51	0.20	U	1.9		162.11	0.20	U	2.0		160.34
11/22/2004	0.20	U	0.18			0.087		2.3			0.20	U	2.2		
5/23/2005	0.19	U	0.87		180.17	0.20	U	2.1		165.53	0.20	U	2.6		164.29
11/21/2005	0.19	U	0.34		173.71	0.20	U	2.1		163.23	0.20	U	1.96		161.26
5/17/2006	0.075	U	0.34		170.86	0.077	U	2.4		162.36	0.079	U	2.3		160.64
11/10/2006	0.057	U	0.54	J	170.1	0.083		2.0	J	161.75	0.057	U	1.9	J	160.35
6/8/2007	0.057	U	0.6		167.15	0.057	U	2.6		159.97	0.057	U	2.3		158.52
6/20/2008	0.11	U	0.33		173.73	0.11	U	2.7		162.76	0.1	U	2.9		160.91
5/14/2009	0.10	U	0.43		175.5	0.10	U	2.3		163.77	0.11	U	2.1		162.1
5/20/2010	0.035	U	0.918		178.4	0.058	I	3.53		164.68	0.061	I	3.8		162.58
5/9/2011	0.036	U	0.068	U	171.03	0.036	U	0.067	U	161.94	0.035	U	1.63		160.18
5/1/2012	0.149	U	0.095	U	172.78	0.152	U	0.097	U	162.08	0.146	U	0.093	U	160.71
5/23/2013	0.212	U	0.189	U	173.5	0.212	U	0.189	U	162.71	0.212	U	0.189	U	161.07
5/23/2014	0.13	U	0.864	I	181.23	0.13	U	2.56		165.75	0.44	I	2.31		163.68
5/19/2015	0.075	U	0.28		175.59	0.19	U	3.4		164.01	0.19	U	4		162.1
6/6/2016	0.092	U	0.42	I	176.43	0.14	I	3.6		164.3	0.19	I	3.9		162.22
5/11/2017	0.085	U	0.19		173.52	0.11	I	3.1		163.22	0.18	I	4.3		161.36
5/12/2018	0.084	U	0.30		173.56	0.13	I	3.1		163.25	0.13	I	3.8		161.43

Notes:
GCTL for HMX = 350 µg/L
GCTL for RDX = 10 µg/L
µg/L= micrograms per liter
B = Analyte detected in the method blank
ft NGVD = feet National Geodetic Vertical Datum
GCTL = groundwater concentraiton threshold limit
GWE = groundwater elevation
I = Reported value is between lab method detection limit and the laboratory practical quantitation limit.
J = Estimated Value
Q = qualifier
U = Compound was analyzed for but not detected
Shaded = detected concentration exceeds the screening level

Table 1
Historical Sampling Results - May 2003 through May 2018
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

Sampling Date	Range C-62									
	MW-94-62-04					MW-94-62-05				
	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD	HMX (µg/L)	Q	RDX (µg/L)	Q	GWE ft NGVD
5/14/2003	1.4		5.1		160.71	1.8		2.8		159.81
11/6/2003	1.6		5.1		159.99	1.2		2.4		158.8
5/26/2004	1.5		4.6		158.45	1.1		3.2		157.28
11/22/2004	2.1		6.2			0.82		3.6		
5/23/2005	1.9		5.8		162.99	0.86		3.9		162.72
11/21/2005	1.8		5.4		158.99	0.77		4.7		157.73
5/17/2006	1.9		9.3		158.53	0.71		7.1		156.31
11/10/2006	2.3		12.9	J	158.38	1.2		17.5	J	157.12
6/8/2007	2.3		14		156.55	2.0		26.2		154.19
6/20/2008	2.3		16.1		159.24	4.3		30.2		158.06
5/14/2009	3.0		23.2		161.14	2.3		16.8		160.48
5/20/2010	3.07		19.6		161.35	2.38		14		160.64
5/9/2011	0.039	U	0.073	U	158.38	0.036	U	0.068	U	155.86
5/1/2012	0.151	U	0.096	U	159.17	0.149	U	0.095	U	158.1
5/23/2013	0.212	U	0.189	U	159.58	0.212	U	0.189	U	158.61
5/23/2014	22.6		17.9		163.47	23		13.2		163.34
5/19/2015	28		26.4		160.97	27.8		14.1		160.19
6/6/2016	31		26.0		161.08	41		21.0		159.42
5/11/2017	32		26.0		159.89	46		33.0		158.83
5/12/2018	39		29.0		159.88	59		72.0		158.91

Notes:

GCTL for HMX = 350 µg/L

GCTL for RDX = 10 µg/L

µg/L= micrograms per liter

B = Analyte detected in the method blank

ft NGVD = feet National Geodetic Vertical Datum

GCTL = groundwater concentraiton threshold limit

GWE = groundwater elevation

I = Reported value is between lab method detection limit and the laboratory practical quantitation limit.

J = Estimated Value

Q = qualifier

U = Compound was analyzed for but not detected

Shaded = detected concentration exceeds the screening level

Table 2A
2018 BIOSCREEN-AT Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

	2018 C-52N BIOSCREEN-AT ASSESSMENT		
Parameter	**Value**	**Units**	**Notes/ Data Sources**
Hydrogeology			
Seepage velocity	538	ft/year	Calculated by model
Effective Porosity	0.20	--	Estimated using soil types on boring logs (EPA 1989)
Hydraulic Conductivity	1.04E-02	cm/sec	Average of slug test results at MW-94-52-01 , MW-94-52-02, and MW-94-52-03 as reported in the 2002 Human Health Risk Assessment (CH2M Hill 2002b)
Hydraulic Gradient	0.010	ft/ft	May 2018 Groundwater Elevations (calculated between MW-94-52-01 and MW-94-52-02)
Dispersion			
Longitudinal dispersivity	35.8	ft	Calculated by model
Transverse dispersivity	3.58	ft	Calculated by model
Vertical transverse dispersivity	1.79	ft	Equal to 0.05 times longitudinal dispersivity (ASTM1995)
Estimated Plume Length	2650	ft	Distance from MW-94-52-01 to Bay Head Brach along May 2018 flow path
Adsorption			
Retardation Factor	1.76	--	Calculated same as model excep used total porosity (not effecitve porosity)
Soil Bulk density	1.5	kg/L	USEPA 1996a default value
Partitioning coefficient (Kd)	0.18	L/kg	Calculated (Koc*foc)
Total Porosity	0.35	--	Sands with fines. Freeze and Cherry (1979)
Soil-Water partitioning coefficient (Koc)	89.07	L/kg	May 2018 EPA Chemical Parameters Tables
Fraction Organic Carbon (foc)	0.002	g/g	Equation 10 (USEPA 1996a). Soil Screening Level Paritioning Equation for Migration to Groundwater default foc value
Biodegradation			
First-order Decay Coefficient	8.70E-02	$year^{-1}$	Calculated by model if half-life input
Solute half-life	8.00	year	Calculated using site-specific data from Range C-52N
General			
Modeled Area Length	3000	ft	
Modeled Area Width	1500	ft	
Simulation Time	100	year	Attempt to model steady-state

Table 2A
2018 BIOSCREEN-AT Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

	2018 C-52N BIOSCREEN-AT ASSESSMENT		
Parameter	**Value**	**Units**	**Notes/ Data Sources**
Source Data			
Source Thickness in Saturated Zone	30	ft	Used in previous model based on FDEP comments (FDEP 2001)
Source Half-Life	infinite	year	Based on current and planned site operations
Source Width	1400	ft	Previous modeled width (CH2M Hill 2002b)
Source Concentration - Maximum	0.0015	mg/L	Maximum concentration detected at MW-94-52-01 in the past four years of monitoring data (June 2015)
Source Concentration - 95 UCL	--	mg/L	

Notes:
ASTM = American Society for Testing and Materials
cm/sec = centimeters per second
ft = feet
ft/year = feet per year
kg = kilograms
L = liters
mg = milligrams
95 UCL = 95 percent upper confidence limit
$year^{-1}$ = per year

Table 2A
2018 BIOSCREEN-AT Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

	2018 C-62 BIOSCREEN-AT ASSESSMENT					
Parameter	Open Detonation Unit Model			Open Burn Unit Model		
	Value	Units	Notes/ Data Sources	Value	Units	Notes/ Data Sources
Hydrogeology						
Seepage velocity	55.6	ft/year	Calculated by model	715	ft/year	Calculated by model
Effective Porosity	0.20	--	Estimated using soil types on boring logs (EPA 1989)	0.20	--	Estimated using soil types on boring logs (EPA 1989)
Hydraulic Conductivity	6.32E-04	cm/sec	Average of slug test results at MW-94-62-04 and MW-94-62-05 as reported in the 2002 Human Health Risk Assessment (CH2M Hill 2002b)	7.68E-03	cm/sec	Average of slug test results at MW-94-62-01, MW-94-62-02, and MW-94-62-03 as reported in the 2002 Human Health Risk Assessment (CH2M Hill 2002b)
Hydraulic Gradient	0.017	ft/ft	May 2018 Groundwater Elevations (calculated between MW-94-62-01 and MW-94-62-05)	0.018	ft/ft	May 2018 Groundwater Elevations (calculated between MW-94-62-01 and MW-94-62-03)
Dispersion						
Longitudinal dispersivity	17.9	ft	Calculated by model	10.0	ft	Calculated by model
Transverse dispersivity	1.79	ft	Calculated by model	1.00	ft	Calculated by model
Vertical transverse dispersivity	0.90	ft	Equal to 0.05 times longitudinal dispersivity (ASTM1995)	0.50	ft	Equal to 0.05 times longitudinal dispersivity (ASTM1995)
Estimated Plume Length	500	ft	Distance from MW-94-62-05 to headwaters of Blount Mill Creek along May 2018 flow path	170	ft	Distance from MW-94-62-03 to headwaters of Blount Mill Creek along May 2018 flow path
Adsorption						
Retardation Factor	1.76	--	Calculated same as model excep used total porosity (not effecitve porosity)	1.76	--	Calculated same as model excep used total porosity (not effecitve porosity)
Soil Bulk density	1.5	kg/L	USEPA 1996a default value	1.5	kg/L	USEPA 1996a default value
Partitioning coefficient (Kd)	0.18	L/kg	Calculated (Koc*foc)	0.18	L/kg	Calculated (Koc*foc)
Total Porosity	0.35	--	Sands with fines. Freeze and Cherry (1979)	0.35	--	Sands with fines. Freeze and Cherry (1979)
Soil-Water partitioning coefficient (Koc)	89.07	L/kg	May 2018 EPA Chemical Parameters Tables	89.07	L/kg	May 2018 EPA Chemical Parameters Tables
Fraction Organic Carbon (foc)	0.002	g/g	Equation 10 (USEPA 1996a). Soil Screening Level Paritioning Equation for Migration to Groundwater default foc value	0.002	g/g	Equation 10 (USEPA 1996a). Soil Screening Level Paritioning Equation for Migration to Groundwater default foc value
Biodegradation						
First-order Decay Coefficient	8.70E-02	$year^{-1}$	Calculated by model if half-life input	8.70E-02	$year^{-1}$	Calculated by model if half-life input
Solute half-life	8.00	year	Calculated using site-specific data from Range C-52N	8.00	year	Calculated using site-specific data from Range C-52N
General						
Modeled Area Length	600	ft	Plume length or slightly longer	200	ft	Plume length or slightly longer
Modeled Area Width	600	ft	No effect on centerline calcs	200	ft	No effect on centerline calcs
Simulation Time	100	year	Attempt to model steady-state	100	year	Attempt to model steady-state

Table 2A
2018 BIOSCREEN-AT Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

Parameter	2018 C-62 BIOSCREEN-AT ASSESSMENT					
	Open Detonation Unit Model			Open Burn Unit Model		
	Value	Units	Notes/ Data Sources	Value	Units	Notes/ Data Sources
Source Data						
Source Thickness in Saturated Zone	75	ft	Used in previous model based on FDEP comments (FDEP 2001)	75	ft	Used in previous model based on FDEP comments (FDEP 2001)
Source Half-Life	infinite	year	Based on current and planned site operations	infinite	year	Based on current and planned site operations
Source Width	300	ft	Width of Open Detonation Unit on aerial image, perpendicular to groundwater flow	170	ft	Width of Open Burn Unit on aerial image, perpendicular to groundwater flow
Source Concentration - Maximum	0.072	mg/L	Maximum concentration detected at MW-94-62-05 (May 2018)	0.0043	mg/L	Maximum concentration detected at MW-94-62-03 (May 2017)
Source Concentration - 95 UCL	0.054	mg/L	95 UCL at MW-94-62-05	--	mg/L	Not calculated since maximum detected concentration below screening level

Notes:
ASTM = American Society for Testing a
cm/sec = centimeters per second
ft = feet
ft/year = feet per year
kg = kilograms
L = liters
mg = milligrams
95 UCL = 95 percent upper confidence
$year^{-1}$ = per year

Table 2B
2002 BIOSCREEN Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

	Range C-52N (2002 Human Health Risk Assessment; CH2M Hill 2002b)			Range C-62 (2002 Human Health Risk Assessment; CH2M Hill 2002b)				
				Open Detonation Unit Model		Open Burn Unit Model		
Parameter	Value	Units	Notes/ Data Sources	Value	Units	Value	Units	Notes/ Data Sources
Hydrogeology								
Seepage velocity	279	ft/year		23.0	ft/year	23.0	ft/year	Calculated by model
Effective Porosity	0.3	--		0.30	--	0.30	--	Literature Estimate
Hydraulic Conductivity	8.10E-03	cm/sec	Revised based on FDEP (2001) comments	5E-04	cm/sec	5E-04	cm/sec	Aquifer testing results
Hydraulic Gradient	0.01	ft/ft	Water Level measurements	0.013	ft/ft	0.013	ft/ft	Water Level measurements
Dispersion								
Longitudinal dispersivity	37.2	ft		24.7	ft	24.7	ft	Calculated by model
Transverse dispersivity	3.7	ft		2.5	ft	2.5	ft	Calculated by model
Vertical transverse dispersivity	0	ft		0	ft	0	ft	
Estimated Plume Length	2950	ft	Based on RDX concentrations	1020	ft	1020	ft	Based on RDX concentrations
Adsorption								
Retardation Factor	2.4	--		1.00	--	1.00	--	
Soil Bulk density	--	kg/L	Typical default	1.6	kg/L	1.6	kg/L	Typical default
Total Porosity	--	--		--	--	--	--	
Soil-Water partitioning coefficient (Koc)	--	L/kg	Selim and Iskandar 1994	0.07	L/kg	0.07	L/kg	Selim and Iskandar 1994
Fraction Organic Carbon (foc)	--	g/g		1.00E-03	g/g	1.00E-03	g/g	
Biodegradation								
First-order Decay Coefficient	1.20E-01	$year^{-1}$		1.2E-02	$year^{-1}$	1.2E-02	$year^{-1}$	
Solute half-life	6	year		60	year	60		

Table 2B
2002 BIOSCREEN Model Input Parameters
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

Parameter	Range C-52N (2002 Human Health Risk Assessment; CH2M Hill 2002b)			Range C-62 (2002 Human Health Risk Assessment; CH2M Hill 2002b)				
				Open Detonation Unit Model		Open Burn Unit Model		
	Value	Units	Notes/ Data Sources	Value	Units	Value	Units	Notes/ Data Sources
General								
Modeled Area Length	3100	ft		1000	ft	1000	ft	
Modeled Area Width	1500	ft		700	ft	700	ft	
Simulation Time	51	year	Site C-52N in operation since 1950	51	year	51	year	Site C62 in operation since 1950
Source Data								
Source Thickness in Saturated Zone	30	ft		75	ft	75	ft	
Source Half-Life	infinite	year		infinite	year	infinite	year	
Source Width	1400	ft		625	ft	665	ft	
Source Concentration	0.0035	mg/L	Groundwater Monitoring results	0.0028	mg/L	0.00128	mg/L	Groundwater Monitoring results

Notes:
cm/sec = centimeters per second
ft = feet
ft/year = feet per year
kg = kilograms
L = liters
mg = milligrams
$year^{-1}$ = per year

References:
Selim, H.M and I.K. Iskandar. 1994. Sorption-desorption and transport of TNT and RDX in soils. CRREL Report 94-7. U.S. Army Corp of Engineers. May

Table 3
BIOSCREEN-AT Results
Ranges C-52N and C-62
Open Burn / Open Detonation (OB/OD) Units
Eglin Air Force Base, Florida

Model	Source Concentration (mg/L)	Modeled Area Length (feet)	RDX Concentration with First-order Decay (mg/L)	Time to Reach Steady-State (years)
Range C-52 N				
OB/OD Unit	0.0015	3,000	0.000150	15
Range C-62				
OB Unit	0.0043	200	0.0041	< 5
	0.0043	5,000	0.00064	< 25
OD Unit	0.072	600	0.015	45
	0.054	600	0.011	45
	0.072	5,000	< 0.00001	225

Notes:
OB = Open Burn
OD = Open Detonation
mg/L = milligrams per liter

Table 4
Alternate Concentration Limits for Downgradient Groundwater Monitoring Wells
Ranges C-52N and C-62
Eglin Air Force Base, Florida

ARCADIS Design & Consultancy for natural and built assets

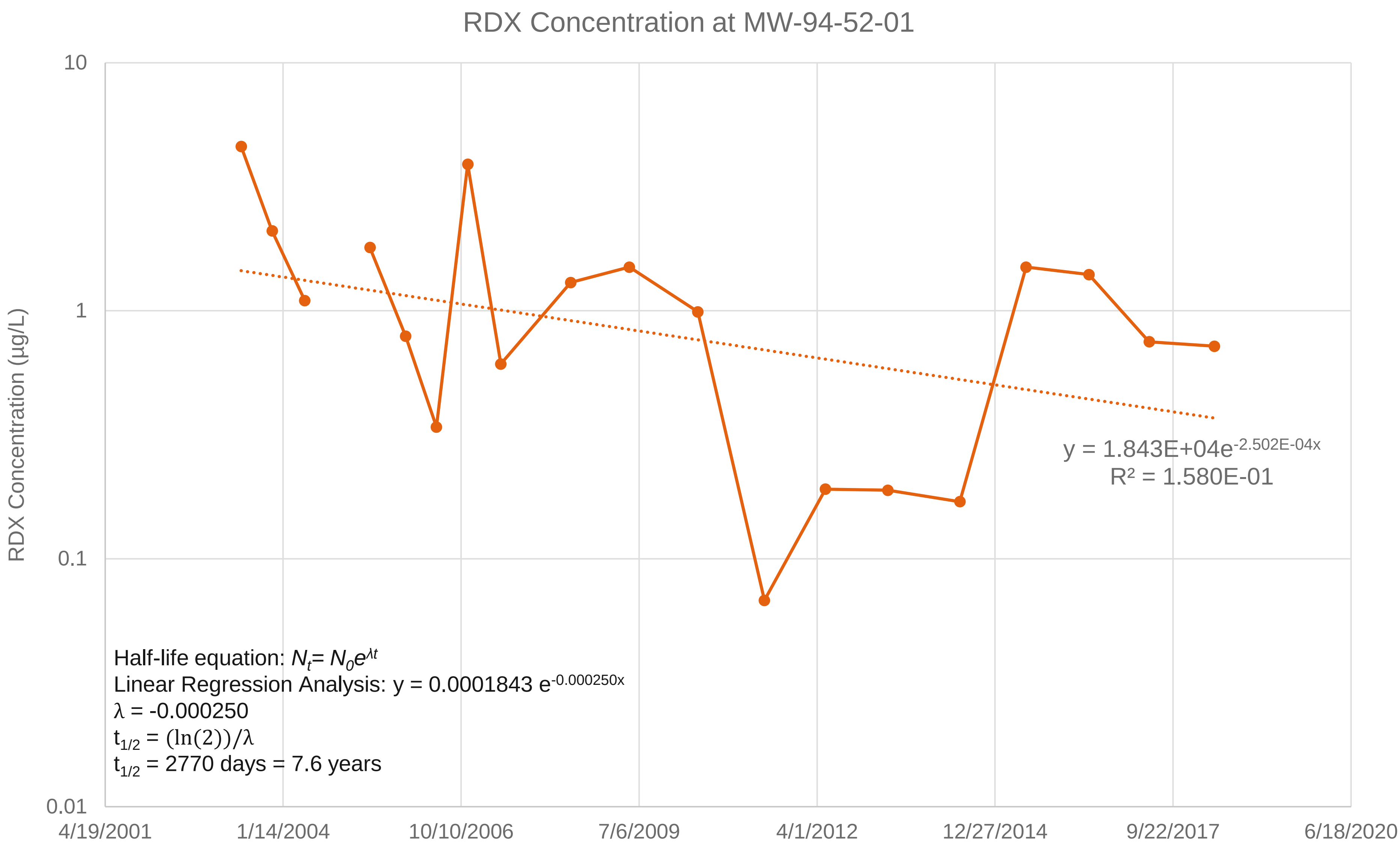
Area	Chemical	Distance to Receptor (feet)	Alternate Concentration Limit (ug/L)	Notes
Range C-52 N				
Cat's Eye	RDX	310	0.32	distance from well MW-94-C52-02 to creek
Cat's Eye	HMX	310	580	distance from well MW-94-C52-02 to creek
Range C-62 OBU				
OBU	RDX	150	0.31	distance from well MW-94-C62-03 to creek
OBU	HMX	150	430	distance from well MW-94-C62-03 to creek
Range C-62 ODU				
ODU	RDX	380	0.87	distance from well MW-94-C62-04 to creek
ODU	HMX	380	21,000	distance from well MW-94-C62-04 to creek

Notes:
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
OBU = Open Burn Unit
ODU = Open Detonation Unit
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
ug/L = micrograms per liter

ATTACHMENTS

Attachment 1

Linear Regression Analysis



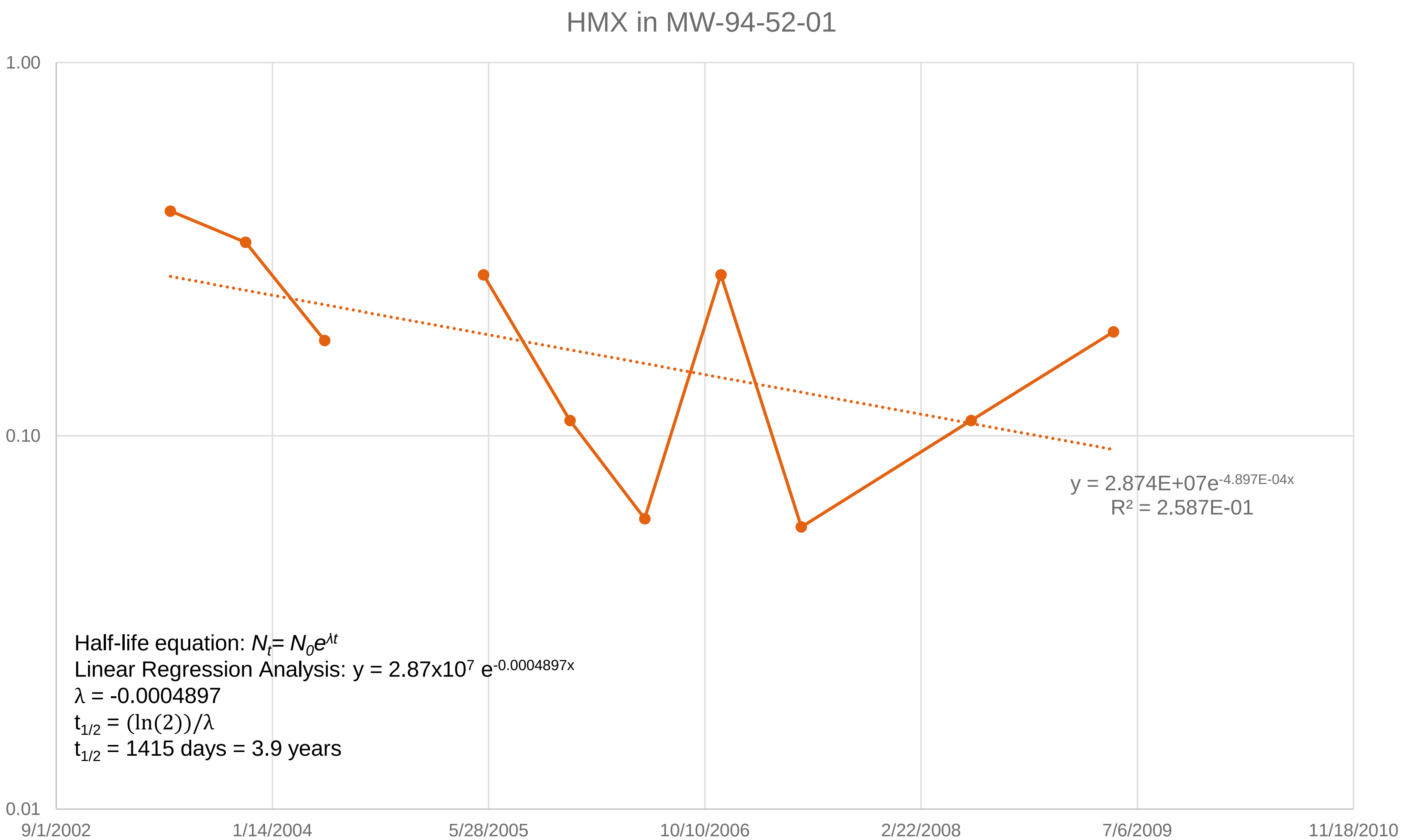
Notes:
µg/L = micrograms per liter
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

LINEAR REGRESSION ANALYSIS
MW-94-52-01

ARCADIS Design & Consultancy for natural and built assets

FIGURE
A1-1



Notes:
µg/L = micrograms per liter
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

RANGES C-52N AND C-62
OPEN BURN/OPEN DETONATION UNIT
EGLIN AIR FORCE BASE, FLORIDA

LINEAR REGRESSION ANALYSIS
MW-94-52-01

ARCADIS Design & Consultancy for natural and built assets

FIGURE
A1-2

Attachment 2

BIOSCREEN-AT Models

Attachment 2
BIOSCREEN-AT Models
Range C-52N
MW-94-52-01 to Bay Head Branch

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc. *Version 1.45*

C52 - Bay Head Branch

Data Input Instructions:

115 → 1. Enter value directly....or
or 2. Calculate by filling in grey
0.02 cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	538	(ft/yr)
or		or	
Hydraulic Conductivity	K	1.0E-02	(cm/sec)
Hydraulic Gradient	i	0.01	(ft/ft)
Porosity	n	0.2	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	35.8	(ft)
Transverse Dispersivity*	alpha y	3.58	(ft)
Vertical Dispersivity*	alpha z	1.79	(ft)
or		or	
Estimated Plume Length	Lp	2650	(ft)

3. ADSORPTION

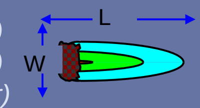
Retardation Factor*	R	1.76	(-)
or		or	
Soil Bulk Density	rho	1.5	(kg/l)
Partition Coefficient	Koc	89.07	(L/kg)
FractionOrganicCarbon	foc	2.0E-3	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E-2	(per yr)
or		or	
Solute Half-Life	t-half	8.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	3000	(ft)
Modeled Area Width*	1500	(ft)
Simulation Time*	100.00	(yr)

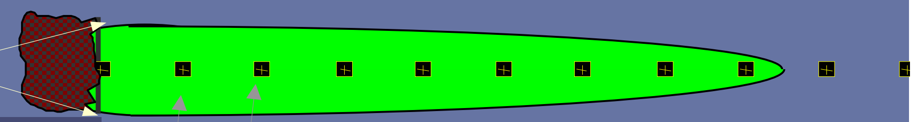


6. SOURCE DATA

Source Thickness 30 (ft)

Source	
Width (ft)	Conc.(mg/L)
1400	0.0015

Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	.0015						.0				
Dist. from Source (ft)	0	300	600	900	1200	1500	1800	2100	2400	2700	3000

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN **RUN**

View Centerline **View Plume**

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

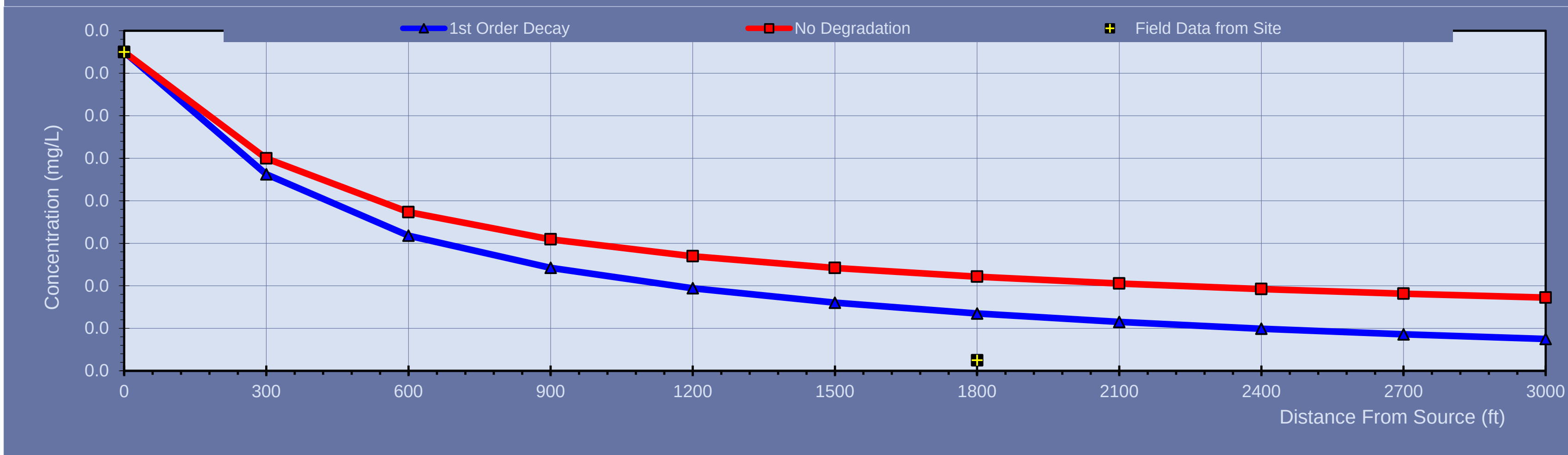
	0	300	600	900	1200	1500	1800	2100	2400	2700	3000
No Degradation	0.00150	0.00100	0.00075	0.00062	0.00054	0.00048	0.00044	0.00041	0.00038	0.00036	0.00034
1st Order Decay	0.00150	0.00092	0.00064	0.00048	0.00039	0.00032	0.00027	0.00023	0.00020	0.000172	0.000150
Field Data from Site	0.00150						0.00005				

# of TimeSteps 20

Displayed Time=100 years

Return to Input

View Plume Output



Attachment 2

BIOSCREEN-AT Models

Range C-62

OBU to Blount Mill Creek

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc.

Version 1.45

OBU to Blount Mill Creek

Data Input Instructions:

115	1. Enter value directly....or
or 0.02	2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable*	Data used directly in model.
20	Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	715.1	(ft/yr)
or		or	
Hydraulic Conductivity	K	7.7E-03	(cm/sec)
Hydraulic Gradient	i	0.018	(ft/ft)
Porosity	n	0.2	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	10.0	(ft)
Transverse Dispersivity*	alpha y	1.00	(ft)
Vertical Dispersivity*	alpha z	0.50	(ft)
or		or	
Estimated Plume Length	Lp	170	(ft)

3. ADSORPTION

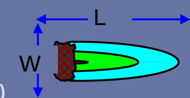
Retardation Factor*	R	1.76	(-)
or		or	
Soil Bulk Density	rho	1.5	(kg/l)
Partition Coefficient	Koc	89.07	(L/kg)
FractionOrganicCarbon	foc	2.0E-3	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E-2	(per yr)
or		or	
Solute Half-Life	t-half	8.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	200	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	100.00	(yr)

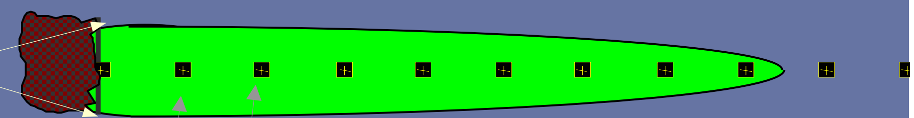


6. SOURCE DATA

Source Thickness	75	(ft)

Source	
Width (ft)	Conc.(mg/L)
170	0.0043

Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	0	20	40	60	80	100	120	140	160	180	200

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN | **RUN**

View Centerline | **View Plume**

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

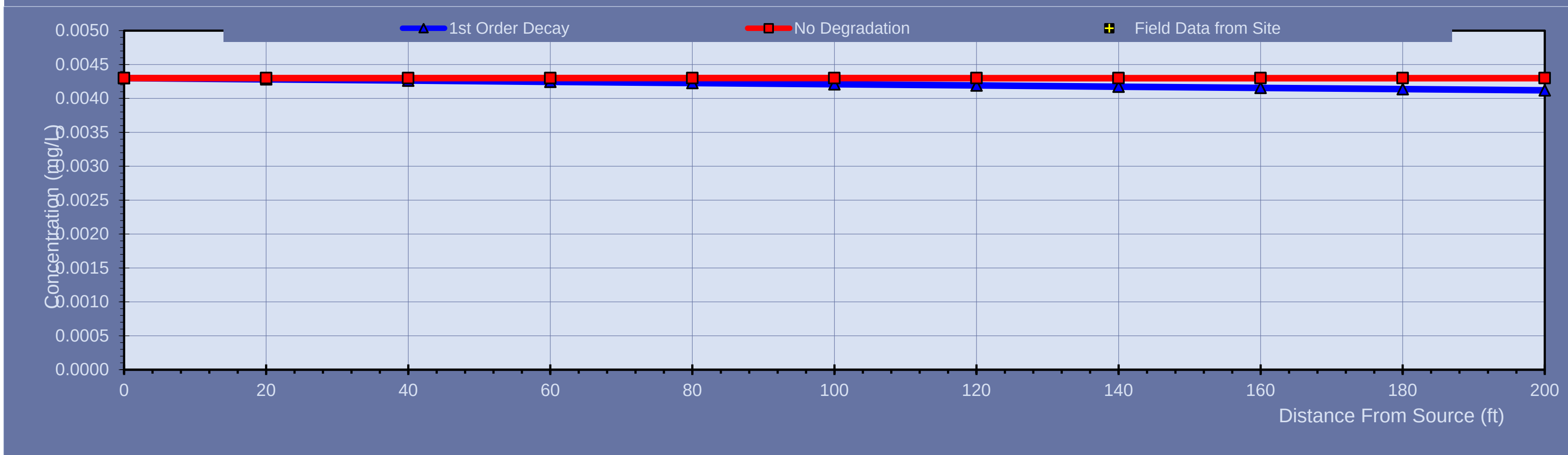
	0	20	40	60	80	100	120	140	160	180	200
No Degradation	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430	0.00430
1st Order Decay	0.00430	0.00428	0.00426	0.00425	0.00423	0.00421	0.00419	0.00417	0.00416	0.00414	0.00412
Field Data from Site											

\# of TimeSteps **20**

Displayed Time=100 years

Return to Input

View Plume Output



Attachment 2

BIOSCREEN-AT Models

Range C-62

OBU - 5000 feet

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc.

Version 1.45

OBU - 5000 ft model

Data Input Instructions:

115	1. Enter value directly....or
or 0.02	2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable*	Data used directly in model.
20	Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	715.1	(ft/yr)
or		or	
Hydraulic Conductivity	K	7.7E-03	(cm/sec)
Hydraulic Gradient	i	0.018	(ft/ft)
Porosity	n	0.2	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	10.0	(ft)
Transverse Dispersivity*	alpha y	1.00	(ft)
Vertical Dispersivity*	alpha z	0.50	(ft)
or		or	
Estimated Plume Length	Lp	170	(ft)

3. ADSORPTION

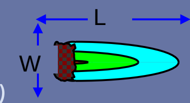
Retardation Factor*	R	1.76	(-)
or		or	
Soil Bulk Density	rho	1.5	(kg/l)
Partition Coefficient	Koc	89.07	(L/kg)
FractionOrganicCarbon	foc	2.0E-3	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E-2	(per yr)
or		or	
Solute Half-Life	t-half	8.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	5000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	500.00	(yr)

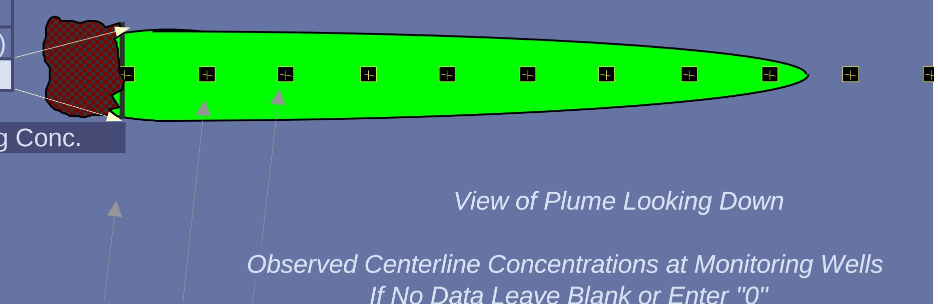


6. SOURCE DATA

Source Thickness	75	(ft)

Source	
Width (ft)	Conc.(mg/L)
170	0.0043

☐ Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN — **View Centerline**

RUN — **View Plume**

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

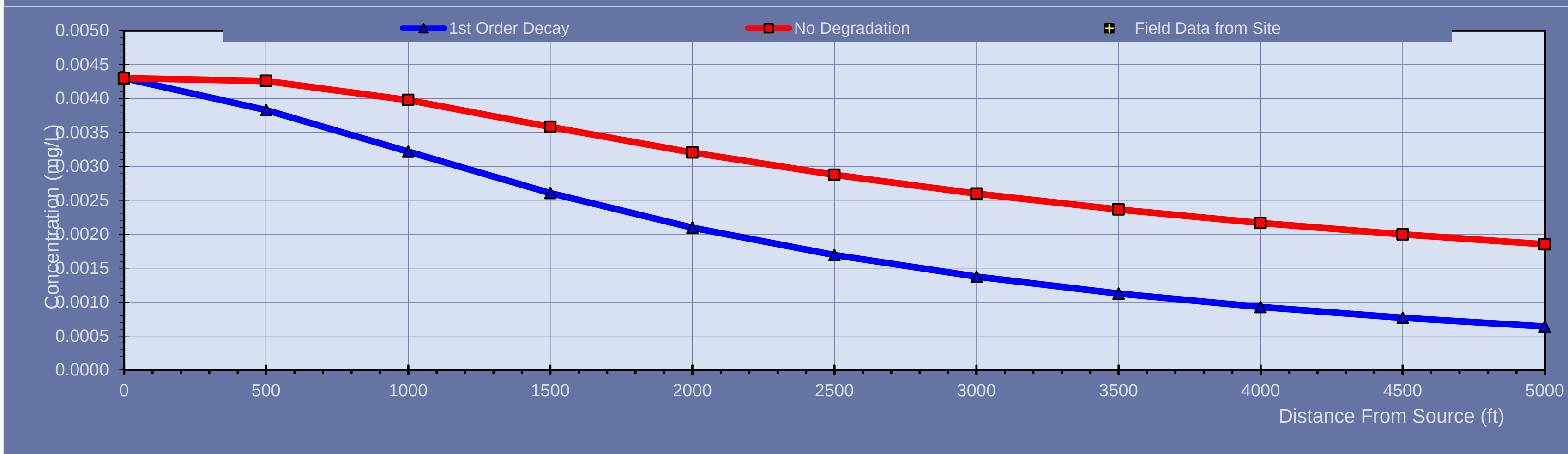
	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
No Degradation	0.00430	0.00426	0.00398	0.00358	0.00320	0.00288	0.00260	0.00236	0.00217	0.00200	0.00185
1st Order Decay	0.00430	0.00383	0.00322	0.00261	0.00210	0.00169	0.00138	0.00113	0.00093	0.00077	0.00064
Field Data from Site											

\# of TimeSteps **20**

Displayed Time=500 years

Return to Input

View Plume Output



Attachment 2

BIOSCREEN-AT Models

Range C-62

ODU to Blount Mill Creek

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc.

Version 1.45

ODU - Blount Mill Creek

Data Input Instructions:

115 → 1. Enter value directly....or
or
0.02 → 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Variable* → Data used directly in model.

20 → Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	55.6	(ft/yr)
or		or	
Hydraulic Conductivity	K	6.3E-04	(cm/sec)
Hydraulic Gradient	i	0.017	(ft/ft)
Porosity	n	0.2	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	17.9	(ft)
Transverse Dispersivity*	alpha y	1.79	(ft)
Vertical Dispersivity*	alpha z	0.90	(ft)
or		or	
Estimated Plume Length	Lp	500	(ft)

3. ADSORPTION

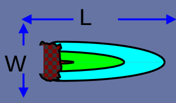
Retardation Factor*	R	1.76	(-)
or		or	
Soil Bulk Density	rho	1.5	(kg/l)
Partition Coefficient	Koc	89.07	(L/kg)
FractionOrganicCarbon	foc	2.0E-3	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.70E-2	(per yr)
or		or	
Solute Half-Life	t-half	8.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO		(mg/L)
Delta Nitrate*	NO3		(mg/L)
Observed Ferrous Iron*	Fe2+		(mg/L)
Delta Sulfate*	SO4		(mg/L)
Observed Methane*	CH4		(mg/L)

5. GENERAL

Modeled Area Length*	600	(ft)
Modeled Area Width*	600	(ft)
Simulation Time*	100.00	(yr)

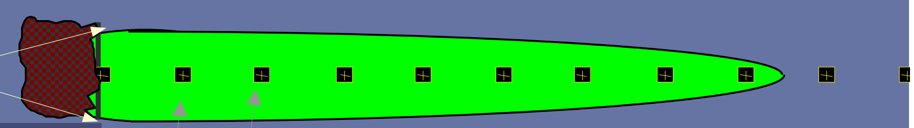


6. SOURCE DATA

Source Thickness	75	(ft)

Source	
Width (ft)	Conc.(mg/L)
300	0.072

Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	0	60	120	180	240	300	360	420	480	540	600

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN | RUN

View Centerline | View Plume

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

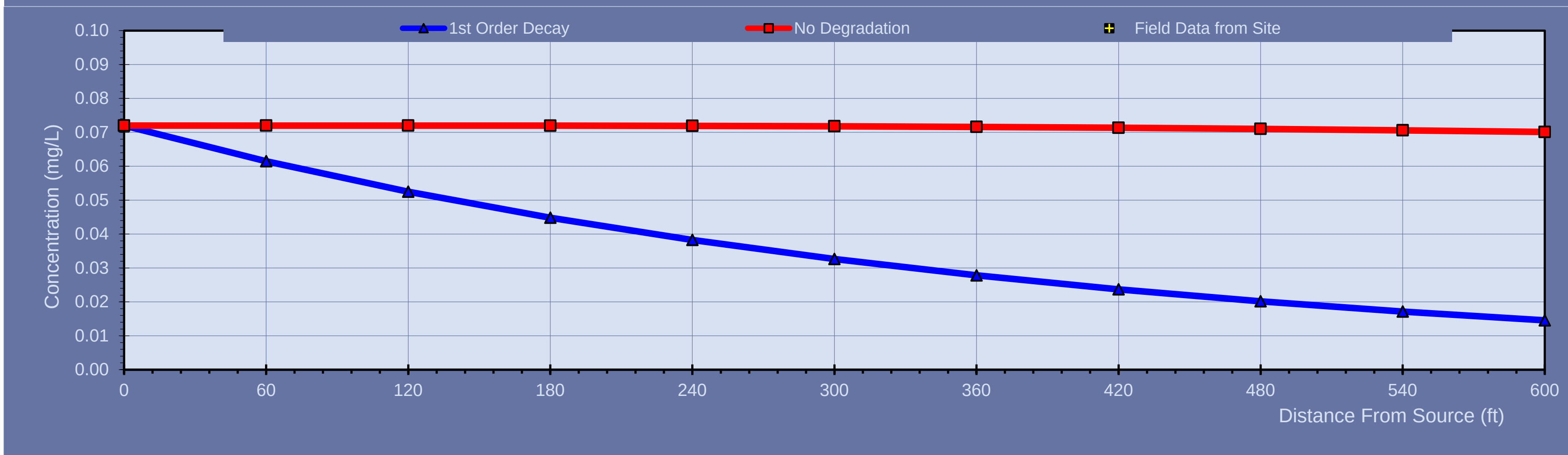
	0	60	120	180	240	300	360	420	480	540	600
No Degradation	0.0720	0.0720	0.0720	0.0720	0.0719	0.0718	0.0716	0.0714	0.0710	0.0706	0.0701
1st Order Decay	0.0720	0.0615	0.0525	0.0448	0.0383	0.0326	0.0278	0.0237	0.0202	0.0171	0.0146
Field Data from Site											

# of TimeSteps **20**

Displayed Time=100 years

Return to Input

View Plume Output



Attachment 2
BIOSCREEN-AT Models
Range C-62
ODU to Blount Mill Creek
95 UCL

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc.

Version 1.45

ODU - BMC 95UCL

Data Input Instructions:

115	1. Enter value directly....or
or 0.02	2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable*	Data used directly in model.
20	Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	55.6	*(ft/yr)*
or		*or*	
Hydraulic Conductivity	*K*	6.3E-04	*(cm/sec)*
Hydraulic Gradient	*i*	0.017	*(ft/ft)*
Porosity	*n*	0.2	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	17.9	*(ft)*
Transverse Dispersivity*	*alpha y*	1.79	*(ft)*
Vertical Dispersivity*	*alpha z*	0.90	*(ft)*
or		*or*	
Estimated Plume Length	*Lp*	500	*(ft)*

3. ADSORPTION

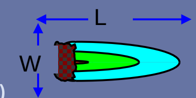
Retardation Factor*	*R*	1.8	*(-)*
or		*or*	
Soil Bulk Density	*rho*	1.5	*(kg/l)*
Partition Coefficient	*Koc*	89.07	*(L/kg)*
FractionOrganicCarbon	*foc*	2.0E-3	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	8.7E-2	*(per yr)*
or		*or*	
Solute Half-Life	*t-half*	8.00	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	600	*(ft)*
Modeled Area Width*	600	*(ft)*
Simulation Time*	100.00	*(yr)*

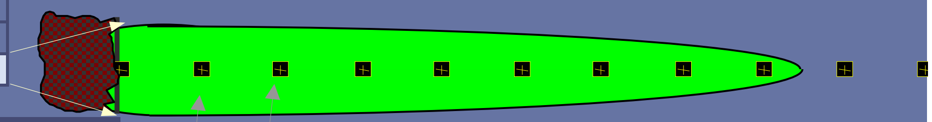


6. SOURCE DATA

Source Thickness 75 *(ft)*

Source	
Width (ft)	Conc.(mg/L)
300	0.054

Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	0	60	120	180	240	300	360	420	480	540	600

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN — View Centerline

RUN — View Plume

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

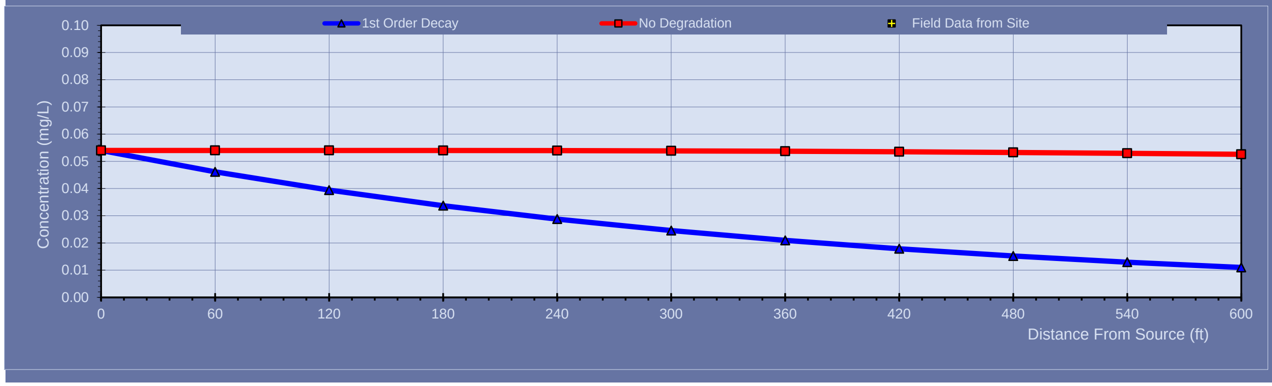
	0	60	120	180	240	300	360	420	480	540	600
No Degradation	0.0540	0.0540	0.0540	0.0540	0.0539	0.0538	0.0537	0.0535	0.0533	0.0530	0.0526
1st Order Decay	0.0540	0.0461	0.0394	0.0337	0.0288	0.0246	0.0210	0.0179	0.0152	0.0129	0.0110
Field Data from Site											

# of TimeSteps **20**

Displayed Time=100 years

Return to Input

View Plume Output



Attachment 2

BIOSCREEN-AT Models

Range C-62

ODU - 5000 feet

BIOSCREEN-AT Natural Attenuation Decision Support System

S.S. Papadopulos & Associates, Inc.

Version 1.45

ODU - 5000 ft plume

Data Input Instructions:

115	1. Enter value directly....or
or 0.02	2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable*	Data used directly in model.
20	Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	55.6	*(ft/yr)*
or		*or*	
Hydraulic Conductivity	*K*	6.3E-04	*(cm/sec)*
Hydraulic Gradient	*i*	0.017	*(ft/ft)*
Porosity	*n*	0.2	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	17.9	*(ft)*
Transverse Dispersivity*	*alpha y*	1.79	*(ft)*
Vertical Dispersivity*	*alpha z*	0.90	*(ft)*
or		*or*	
Estimated Plume Length	*Lp*	500	*(ft)*

3. ADSORPTION

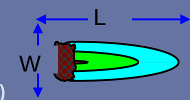
Retardation Factor*	*R*	1.76	*(-)*
or		*or*	
Soil Bulk Density	*rho*	1.5	*(kg/l)*
Partition Coefficient	*Koc*	89.07	*(L/kg)*
FractionOrganicCarbon	*foc*	2.0E-3	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	8.7E-2	*(per yr)*
or		*or*	
Solute Half-Life	*t-half*	8.00	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*		*(mg/L)*
Delta Nitrate*	*NO3*		*(mg/L)*
Observed Ferrous Iron*	*Fe2+*		*(mg/L)*
Delta Sulfate*	*SO4*		*(mg/L)*
Observed Methane*	*CH4*		*(mg/L)*

5. GENERAL

Modeled Area Length*	5000	*(ft)*
Modeled Area Width*	600	*(ft)*
Simulation Time*	500.00	*(yr)*

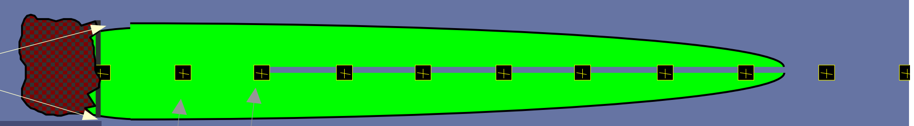


6. SOURCE DATA

Source Thickness	75	*(ft)*

Source	
Width (ft)	Conc.(mg/L)
300	0.072

Exponentialy Decaying Conc.



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)											
Dist. from Source (ft)	*0*	*500*	*1000*	*1500*	*2000*	*2500*	*3000*	*3500*	*4000*	*4500*	*5000*

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN **RUN**

View Centerline **View Plume**

View BIOSCREEN

Recalculate This Sheet

Paste Example Dataset

Paste Dataset from BIOSCREEN

Restore Formulas for Vs,

DISSOLVED HYDROCARBON CONCENTRATIONS IN PLUME (mg/L at Z=0)

Distance from Source (ft)

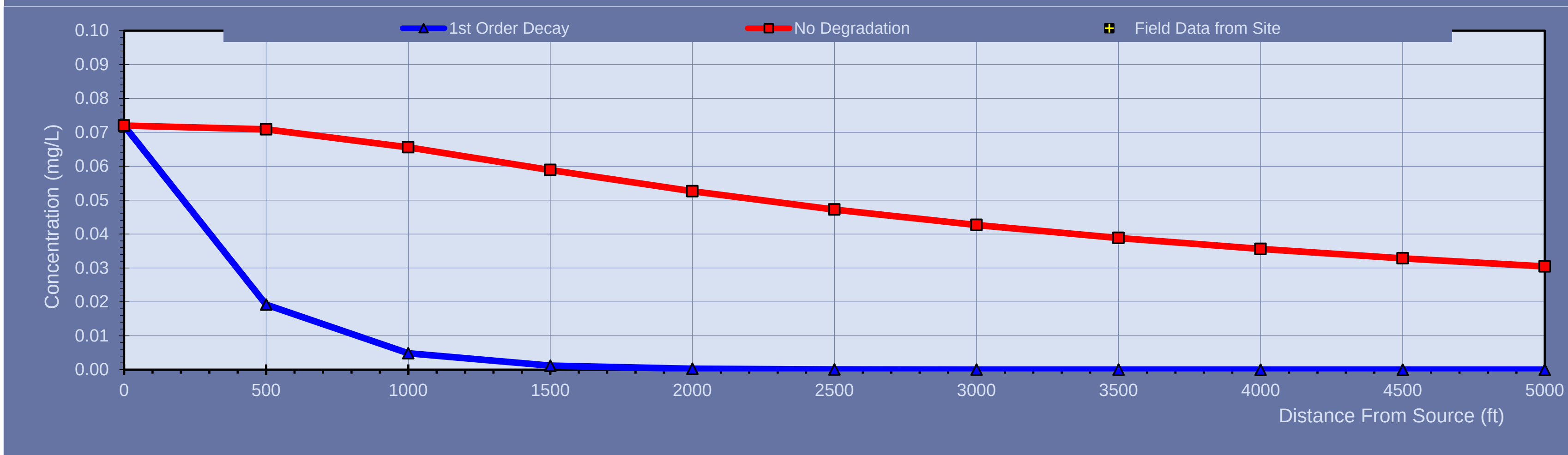
	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
No Degradation	0.0720	0.0709	0.0656	0.0589	0.0526	0.0472	0.0427	0.0389	0.0356	0.0328	0.0305
1st Order Decay	0.0720	0.0192	0.0049	0.0012	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
Field Data from Site											

\# of TimeSteps **20**

Displayed Time=500 years

Return to Input

View Plume Output



Attachment 3

Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Attachment 3

Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site:	Eglin Air Force Base - C-52 North	Calculated By:	Chris Shepherd
Location:	Florida	Checked By:	Ashley Nagle
Chemical(s):	See below	Date:	12/10/2018

Parameters:		RDX	HMX	Units	Source
1) Average Groundwater Linear Velocity:		$V_s = \frac{K \cdot i}{\theta_e}$			
Aquifer hydraulic conductivity	K	33	33	ft/day	a
Groundwater gradient	i	0.010	0.010	ft/ft	b
Effective porosity	θ_e	0.2	0.2	dimensionless	c
Seepage velocity	V_s	**1.65**	**1.65**	**ft/day**	
2) Soil-Water Partition Coefficient and Retardation Factor		$K_d = K_{oc} \cdot f_{oc}$	$r_f = 1 + K_d \frac{\rho_b}{n}$		
organic carbon coefficient	K_{oc}	89.07	532	dimensionless	d
fraction of organic carbon	f_{oc}	0.002	0.002	g/g	e
soil-water partition coefficient	K_d	1.78E-01	1.06E+00	L/kg	
bulk density	ρ_b	1.5	1.5	kg/L	e
soil porosity (total)	n	0.35	0.35	dimensionless	f
Retardation factor (saturated)	r_f	**1.76E+00**	**5.56E+00**	**dimensionless**	
3) Chemical Transport Rate, Distance, and Time		$V_c = \frac{V_s}{r_f}$	$t_x = \frac{d_x}{v_c}$		
Seepage velocity	v_s	1.65	1.65	ft/day	
Chemical velocity (retarded)	v_c	**9.4E-01**	**3.0E-01**	**ft/day**	
Chemical velocity (retarded)	v_c	342	109	ft/year	
Distance to receptor	d_x	**310**	**310**	ft	g
Transport time to reach receptor	t_x	**331**	**1,045**	**days**	
Transport time to reach receptor	t_x	1	3	years	
4) Degradation Rate and Allowable Initial Concentration		$k = \frac{ln(2)}{\lambda}$	$C_{0-GW} = \frac{C}{e^{-(k \cdot t_x)}}$		
Half-life	λ	2,920	1,415	days	h
Target concentration (GCTL)	C	0.3	350	ug/L	i
Chemical degradation constant	k	**2.37E-04**	**4.90E-04**	**days^{-1}**	
Initial groundwater concentration	$C_{0\text{-}GW}$	3.25E-01	5.84E+02	ug/L	j
Alternate concentration limit in groundwater	ACL_{gw}	**0.32**	**580**	**ug/L**	
Maximum groundwater concentration in last 4 years	C_{tmax}	< 0.21	< 0.088	ug/L	k
Maximum site exceedance factor	EF	n/a	n/a	dimensionless	

Attachment 3
Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site: Eglin Air Force Base - C-52 North
Location: Florida
Chemical(s): See below

Calculated By: Chris Shepherd
Checked By: Ashley Nagle
Date: 12/10/2018

Parameters:	**RDX**	**HMX**	**Units**	**Source**

Notes:
Calculations conservatively assumes an infinite source, no dispersion, and no diffusion
a = Source area average shallow groundwater hydraulic conductivity (CH2MHILL 2002)
b = Source area shallow groundwater gradient in May 2018 (LRS 2018)
c = based on sands with fines (USEPA 1989)
d = USEPA 2018
e = USEPA 1996 default value
f = based on representative soil, sands with fines (Fetter 1994, Freeze and Cherry 1979)
g = distance from monitoring well downgradient of the source area to the nearest stream (parallel to groundwater flow)
h = site-specific, calculated half-lives (see BIOSCREEN model)
j = calculated initial groundwater concentration at source area that would result in a concentration at or below the target receptor point concentration
k = maximum concentration or detection limit observed in the last four years at the downgradient monitoring well(s)

Acronyms
ft = feet
g = grams
GCTL = groundwater concentration target limit
FDEP = Florida Department of Environmental Protection
kg = kilograms
L = liters
mg = milligrams
ug = micrograms
USEPA = United States Environmental Protection Agency

References:

CH2M Hill. 2002. Human Health Risk Assessment for Groundwater at C-52N and C-62, Eglin AFB, Florida.
Fetter, C.W. 1993. Contaminant Hydrogeology. Macmillan Publishing, New York.
Freeze, R. Allen and John A. Cherry. 1979. Groundwater. Prentice Hall Inc., Upper Saddle River, NJ. 604p.
LRS. 2018. Annual Environmental Monitoring Report, Open Burn/Open Detonation Units, Range C-52 North and Range C-62, Eglin Air Force Base, Florida, Operational
USEPA 1996. Soil Screening Guidance: Technical Background Document. July.
USEPA 1998. Chemical Fate Half-Lives for Toxics Release Inventory (TRI) Chemicals. July
USEPA. May 2018 Chemical Parameters Tables. Website: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables . Accessed December 2018.

Attachment 3

Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site:	Eglin Air Force Base - C62 OBU	Calculated By:	Chris Shepherd
Location:	Florida	Checked By:	Ashley Nagle
Chemical(s):	See below	Date:	12/10/2018

Parameters:	RDX	HMX	Units	Source
1) Average Groundwater Linear Velocity: $V_s = \frac{K \cdot i}{\theta_e}$				
Aquifer hydraulic conductivity K	22	22	ft/day	a
Groundwater gradient i	0.018	0.018	ft/ft	b
Effective porosity θ_e	0.2	0.2	dimensionless	c
Seepage velocity V_s	**1.98**	**1.98**	**ft/day**	
2) Soil-Water Partition Coefficient and Retardation Factor $K_d = K_{oc} \cdot f_{oc}$ $\quad r_f = 1 + K_d \frac{\rho_b}{n}$				
organic carbon coefficient K_{oc}	89.07	532	dimensionless	d
fraction of organic carbon f_{oc}	0.002	0.002	g/g	e
soil-water partition coefficient K_d	1.78E-01	1.06E+00	L/kg	
bulk density ρ_b	1.5	1.5	kg/L	e
soil porosity (total) n	0.35	0.35	dimensionless	f
Retardation factor (saturated) r_f	**1.76E+00**	**5.56E+00**	**dimensionless**	
3) Chemical Transport Rate, Distance, and Time $V_c = \frac{V_s}{r_f}$ $\quad t_x = \frac{d_x}{v_c}$				
Seepage velocity v_s	1.98	1.98	ft/day	
Chemical velocity (retarded) v_c	1.1E+00	3.6E-01	ft/day	g
Chemical velocity (retarded) v_c	**410**	**130**	**ft/year**	
Distance to receptor d_x	150	150	ft	
Transport time to reach receptor t_x	**134**	**421**	**days**	
Transport time to reach receptor t_x	0.4	1.2	years	
4) Degradation Rate and Allowable Initial Concentration $k = \frac{ln(2)}{\lambda}$ $\quad C_{0-GW} = \frac{C}{e^{-(k \cdot t_x)}} = ACL_{gw}$				
Half-life λ	2,920	1,415	days	h
Target concentration (GCTL) C	0.3	350	ug/L	i
Chemical degradation constant k	**2.37E-04**	**4.90E-04**	**days^{-1}**	
Initial groundwater concentration C_{0-GW}	3.10E-01	4.30E+02	ug/L	j
Alternate concentration limit in groundwater ACL_{gw}	**0.31**	**430**	**ug/L**	
Maximum groundwater concentration in last 4 years C_{tmax}	3.6	0.14	ug/L	k
Maximum site exceedance factor EF	12	0.00	dimensionless	l

Attachment 3
Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site:	Eglin Air Force Base - C62 OBU		Calculated By:	Chris Shepherd
Location:	Florida		Checked By:	Ashley Nagle
Chemical(s):	See below		Date:	12/10/2018

Parameters:	**RDX**	**HMX**	**Units**	**Source**

Notes:

Calculations conservatively assumes an infinite source, no dispersion, and no diffusion

a = Source area average shallow groundwater hydraulic conductivity (CH2MHILL 2002)

b = Source area shallow groundwater gradient in May 2018 (LRS 2018)

c = based on sands with fines (USEPA 1989)

d = USEPA 2018

e = USEPA 1996 default value

f = based on representative soil, sands with fines (Fetter 1994, Freeze and Cherry 1979)

g = distance from monitoring well downgradient of the source area to the nearest stream (parallel to groundwater flow)

h = site-specific, calculated half-lives (see BIOSCREEN model)

j = calculated initial groundwater concentration at source area that would result in a concentration at or below the target receptor point concentration

k = maximum concentration or detection limit observed in the last four years at the downgradient monitoring well(s)

Acronyms

ft = feet

g = grams

GCTL = groundwater concentration target limit

FDEP = Florida Department of Environmental Protection

kg = kilograms

L = liters

mg = milligrams

OBU = open burn unit

ug = micrograms

USEPA = United States Environmental Protection Agency

References:

CH2M Hill. 2002. Human Health Risk Assessment for Groundwater at C-52N and C-62, Eglin AFB, Florida.

Fetter, C.W. 1993. Contaminant Hydrogeology. Macmillan Publishing, New York.

Freeze, R. Allen and John A. Cherry. 1979. Groundwater. Prentice Hall Inc., Upper Saddle River, NJ. 604p.

LRS. 2018. Annual Environmental Monitoring Report, Open Burn/Open Detonation Units, Range C-52 North and Range C-62, Eglin Air Force Base, Florida, Operational

USEPA 1996. Soil Screening Guidance: Technical Background Document. July.

USEPA 1998. Chemical Fate Half-Lives for Toxics Release Inventory (TRI) Chemicals. July

Attachment 3

Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site:	Eglin Air Force Base - C62 ODU	Calculated By:	Chris Shepherd
Location:	Florida	Checked By:	Ashley Nagle
Chemical(s):	See below	Date:	12/10/2018

Parameters:		**RDX**	**HMX**	**Units**	**Source**
1) Average Groundwater Linear Velocity:	$V_s = \frac{K \cdot i}{\theta_e}$				
Aquifer hydraulic conductivity	K	1.8	1.8	ft/day	a
Groundwater gradient	i	0.017	0.017	ft/ft	b
Effective porosity	θ_e	0.2	0.2	dimensionless	c
Seepage velocity	V_s	**0.15**	**0.15**	**ft/day**	
2) Soil-Water Partition Coefficient and Retardation Factor	$K_d = K_{oc} \cdot f_{oc}$; $r_f = 1 + K_d \frac{\rho_b}{n}$				
organic carbon coefficient	K_{oc}	89.07	266	dimensionless	d
fraction of organic carbon	f_{oc}	0.002	0.002	g/g	e
soil-water partition coefficient	K_d	1.78E-01	5.32E-01	L/kg	
bulk density	ρ_b	1.5	1.5	kg/L	e
soil porosity (total)	n	0.35	0.35	dimensionless	f
Retardation factor (saturated)	r_f	**1.76E+00**	**3.28E+00**	**dimensionless**	
3) Chemical Transport Rate, Distance, and Time	$V_c = \frac{V_s}{r_f}$; $t_x = \frac{d_x}{v_c}$				
Chemical velocity	v_c	8.5E-02	4.6E-02	ft/day	
Distance to receptor	d_x	380	380	ft	g
Transport time to reach receptor	t_x	**4,467**	**8,309**	**days**	
Transport time to reach receptor	t_x	12	23	years	
4) Degradation Rate and Allowable Initial Concentration	$k = \frac{ln(2)}{\lambda}$; $C_{0-GW} = \frac{C}{e^{-(k \cdot t_x)}} = ACL_{gw}$				
Half-life	λ	2,920	1,415	days	h
Target concentration (GCTL)	C	0.3	350	ug/L	i
Chemical degradation constant	k	**2.37E-04**	**4.90E-04**	**days^{-1}**	
Initial groundwater concentration	$C_{0\text{-}GW}$	8.7E-01	2.1E+04	ug/L	j
Alternate concentration limit in groundwater	ACL_{gw}	**0.87**	**21,000**	**ug/L**	
laximum groundwater concentration in last 4 years	C_{tmax}	72	59	ug/L	k
Maximum site exceedance factor	EF	83	0.00	dimensionless	

Attachment 3

Alternate Concentration Limits in Groundwater for the Protection of Surface Water Receptors

Site:	Eglin Air Force Base - C62 ODU		Calculated By:	Chris Shepherd
Location:	Florida		Checked By:	Ashley Nagle
Chemical(s):	See below		Date:	12/10/2018

Parameters:	**RDX**	**HMX**	**Units**	**Source**

Notes:

Calculations conservatively assumes an infinite source, no dispersion, and no diffusion

a = Source area average shallow groundwater hydraulic conductivity (CH2MHILL 2002)

b = Source area shallow groundwater gradient in May 2018 (LRS 2018)

c = based on sands with fines (USEPA 1989)

d = USEPA 2018

e = USEPA 1996 default value

f = based on representative soil, sands with fines (Fetter 1994, Freeze and Cherry 1979)

g = distance from monitoring well downgradient of the source area to the nearest stream (parallel to groundwater flow)

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j = calculated initial groundwater concentration at source area that would result in a concentration at or below the target receptor point concentration

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Acronyms

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GCTL = groundwater concentration target limit

FDEP = Florida Department of Environmental Protection

kg = kilograms

L = liters

ODU = open detonation unit

ug = micrograms

USEPA = United States Environmental Protection Agency

References:

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LRS. 2018. Annual Environmental Monitoring Report, Open Burn/Open Detonation Units, Range C-52 North and Range C-62, Eglin Air Force Base, Florida, Operational Permit No. 006176-H)-007. July.

USEPA 1996. Soil Screening Guidance: Technical Background Document. July.

USEPA 1998. Chemical Fate Half-Lives for Toxics Release Inventory (TRI) Chemicals. July