APPENDIX L

Ohio EPA Comments

THIS PAGE INTENTIONALLY LEFT BLANK.

Ohio
Ohio Environmental Protection Agency

Mike DeWine, Governor
Jon Husted, Lt. Governor
Laurie A. Stevenson, Director

January 18, 2019

Mr. David Connolly
Army National Guard Directorate
Environmental Programs Division
ARNGD-ILE -CR
111 South George Mason Drive
Arlington, VA 22204

Re: US Army Ammunition PLT RVAAP
Remediation Response
Project Records
Remedial Response
Portage County
267000859095

Subject: Ravenna Army Ammunition Plant, Portage/Trumbull Counties. "Comment Resolution on the Remedial Investigation/Feasibility Study Report" at RVAAP-06, C Block Quarry, Dated December 4, 2018.

Dear Mr. Connolly:

The Ohio Environmental Protection Agency (Ohio EPA) has received and reviewed the Comment Resolution on the Remedial Investigation/Feasibility Study Report for RVAAP-06 C Block Quarry for the Ravenna Army Ammunition Plant (RVAAP), Portage and Trumbull Counties. This document is dated and was received at Ohio EPA, Northeast District Office (NEDO) on December 4, 2018.

The comment resolution was reviewed by personnel from Ohio EPA and the responses are satisfactory. Please forward the final version of the report to Ohio EPA for review.

If you have any questions, please contact me at megan.oravec@epa.ohio.gov or at (330) 963-1168.

Sincerely,

Megan Oravec

RECEIVED
JAN 22 2019

Megan Oravec, Site Coordinator
Division of Environmental Response and Revitalization

MO/sc

ec:
Bob Princic, NEDO, DERR
Mark Johnson, NEDO, DERR
Tim Christman, CO, DERR
Kevin Palombo, NEDO, DERR
Nat Peters, USACE
Craig Coombs, USACE
David Connolly, ARNG
Vanessa Steigerwald-Dick, NEDO, DERR
Tom Schneider, SWDO, DERR
Al Muller, NEDO, DMWM
Megan Oravec, NEDO, DERR
Katie Tait/Kevin Sedlak, OHARNG RTLS
Rebecca Shreffler, Chenega
Jed Thomas, Leidos

Northeast District Office • 2110 East Aurora Road • Twinsburg, OH 44087-1924
epa.ohio.gov • (330) 963-1200 • (330) 487-0769 (fax)

NATIONAL GUARD BUREAU
111 SOUTH GEORGE MASON DRIVE
ARLINGTON VA 22204-1373

December 4, 2018

Ohio Environmental Protection Agency
DERR-NEDO
Attn: Ms. Vanessa Steigerwald-Dick
2110 East Aurora Road
Twinsburg, OH 44087-1924

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry, Comment Resolution on the Remedial Investigation/Feasibility Study Report (Work Activity No. 267-000-859-095)

Dear Ms. Steigerwald-Dick:

In response to the Ohio Environmental Protection Agency (Ohio EPA) letter dated August 14, 2018 regarding the *Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry* (Revised Draft RI/FS Report), the Army acknowledges Ohio EPA concurrence with the following:

1) The previously provided Army responses to "General Comments," provided on letters dated March 8, 2018 and July 12, 2018; and
2) The updated potentiometric surface interpretation using current data, provided in a letter dated July 12, 2018.

The Ohio EPA's August 14, 2018 letter provided the following comment:

"Considering the historic disposal of waste directly onto the fractured bedrock in the quarry bottom, the Army has not demonstrated that the groundwater-to-surface water pathway is incomplete. Ohio EPA recommends the sampling of surface water and/or springs/seeps downgradient from and discharging into Sand Creek and Hinkley Creek as part of the demonstration."

As presented in the Revised Draft RI/FS Report, C Block Quarry is an area of concern within a quarry bottom that is 25 ft below the surrounding grade. Surface water is not a permanent feature within C Block Quarry, nor is there surface water flow from the AOC to neighboring surface water bodies. As such, the potential impact that C Block Quarry would have on Sand Creek and Hinkley Creek would be from lateral transport via groundwater.

During comment resolution of this Revised Draft RI/FS Report, Ohio EPA requested monitoring wells CBLmw-001, CBLmw-002, CBLmw-003, and CBLmw-004 be sampled for metals (including hexavalent chromium), PCBs, explosives, nitrate/nitrite, sulfate/sulfide, and pH. Accordingly, the Army collected groundwater samples from these monitoring wells in June 2018.

A review of the data from the groundwater samples indicated the following:

1) Chromium was detected in monitoring well CBLmw-001 at 0.0044 mg/L in the primary sample and at 0.0023 mg/L in the field duplicate sample. Both concentrations are well below the USEPA MCL (0.1 mg/L). Chromium was not detected in the other three monitoring wells.
2) Hexavalent chromium was not detected in any of the samples.
3) PCBs were not detected in any of the samples.
4) Explosives were not detected in any of the samples.
5) Nitrate/nitrite – Nitrite was not detected in any of the samples. Nitrate was detected in all samples ranging from 0.37 mg/L in CBLmw-004 to 1.2 mg/L in CBLmw-002. These concentrations are below the MCL of 10 mg/L.
6) Sulfate/sulfide – Sulfide was not detected in any sample. Sulfate was detected in all samples ranging from 12 mg/L in CBLmw-001 to 30 mg/L in CBLmw-003. Sulfate does not have an enforceable MCL; however, these concentrations are below the secondary MCL of 250 mg/L.

Regarding pH at C Block Quarry, Table 1 presents the minimum, maximum, and average pH from monitoring wells CBLmw-001 to CBLmw-005 using field measurements collected from 2005 to 2018. Based on the potentiometric surface created using water level measurements from April 2017 (provided in a letter dated July 12, 2018), monitoring wells CBLmw-003 and CBLmw-004 are either considered upgradient of or not impacted by groundwater in C Block Quarry.

Table 1. C Block Quarry Monitoring Wells – pH Summary Statistics

		pH Statistics			
Monitoring Well	**Number of Samples**	**Samples Less than pH = 6**	**Minimum (S.U.)**	**Maximum (S.U.)**	**Average (S.U.)**
Upgradient or non-impacted monitoring wells					
CBLmw-003	8	8/8	4.73	5.93	5.37
CBLmw-004	9	8/9	4.93	6.78	5.64
Downgradient monitoring wells					
CBLmw-001	9	8/9	4.94	7.16	5.40
CBLmw-002	12	12/12	4.45	5.71	5.05
CBLmw-005	4	4/4	5.08	5.59	5.34

As shown, the pH is consistent among the upgradient, non-impacted, and downgradient monitoring wells. Consequently, it can be concluded that C Block Quarry is not negatively impacting the pH in groundwater at and downgradient of the site.

Using these lines of evidence, the Army does not believe sampling of surface water and/or springs/seeps downgradient from and discharging into Sand Creek and Hinkley Creek is warranted for further evaluation of C Block Quarry.

Upon your concurrence with this final resolution to comments, the Army will distribute the final version of this report. Please contact the undersigned at (703) 607-7589 or david.m.connolly8.civ@mail.mil if there are issues or concerns with this submission.

Sincerely,

Mr. David Connolly
RVAAP Restoration Program Manager
Army National Guard Directorate

cc: Mark Johnson, Ohio EPA, NEDO
Bob Princic, Ohio EPA, NEDO
Tom Schneider, Ohio EPA, SWDO
Tim Christman, Ohio EPA, CO
Al Muller, Ohio EPA, NEDO
Kevin Palombo, Ohio EPA, NEDO
Kevin Sedlak, ARNG, Camp Ravenna
Katie Tait, OHARNG, Camp Ravenna
Craig Coombs, USACE Louisville
Nathaniel Peters, II, USACE Louisville
Jed Thomas, Leidos
Gail Harris, Vista Sciences Corporation
Rebecca Shreffler, Chenega

Ohio Environmental Protection Agency

John R. Kasich, Governor
Mary Taylor, Lt. Governor
Craig W. Butler, Director

August 14, 2018

Mr. David Connolly
Army National Guard Directorate
Environmental Programs Division
ARNG-ILE-CR
111 South George Mason Drive
Arlington, VA 22204

Re: US Army Ammunition PLT RVAAP
Remediation Response
Project Records
Remedial Response
Portage County
267000859095

Subject: Ravenna Army Ammunition Plant, Portage/Trumbull Counties. "Comment Resolution on the Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry" Dated July 12, 2018

Dear Mr. Connolly:

The Ohio Environmental Protection Agency (Ohio EPA) has received and reviewed the "Comment Resolution on the Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry" for the Ravenna Army Ammunition Plant (RVAAP), Portage/Trumbull Counties. This document is dated July 12, 2018 and was received at Ohio EPA, Northeast District Office (NEDO) on July 16, 2018. Please find below Ohio EPA's comments on the Army's responses.

General Comments

All general comments have been adequately addressed.

Fate and Transport Model/Groundwater Comments

Considering the historic disposal of waste directly onto the fractured bedrock in the quarry bottom, the Army has not demonstrated that the ground water-to-surface water pathway is incomplete. Ohio EPA recommends the sampling of surface water and/or springs/seeps down-gradient from and discharging into Sand Creek and Hinkley Creek as part of the demonstration.

Ohio EPA agrees that the Army's submitted contaminant fate and transport SESOIL model supports a demonstration that soil leaching to ground water pathway is incomplete (with the possible exception of pH) pending confirmation of that model with the spring 2018 sample results for the C-Block Quarry wells (CBL-mw-001, CBL-mw-002, CBL-mw-

003, and CBL-mw-004). All of the C-Block wells (CBL-mw-001, CBL-mw-002, CBL-mw-003, CBL-mw-004, and CBL-mw-005) have historical pH measurements near or below 5, which illustrate the impacts of the disposal of acid wastes (e.g., pickle liquor and sulfuric acid) In C-Block Quarry. Ohio EPA agrees with the additional ground water sampling of C-Block Quarry referred to in the response. Ohio EPA is aware that that sampling event has been completed.

Ohio EPA agrees that the Army has adequately updated the potentiometric surface interpretation using current data in Figures 3-1 and 3-4.

Summary

The issue regarding surface water sampling must be resolved prior to approval of the RI/FS.

If you have any questions, please call me at (330) 963-1207.

Sincerely,

Vicki Deppisch

Vicki Deppisch
Environmental Scientist
Division of Environmental Response and Revitalization

VD/nvp

ec: Katie Tait/Kevin Sedlak, OHARNG RTLS
Craig Coombs, USACE
Rebecca Shreffler, Chenega
Josh Koch, ODH
Brian Ng, ARAQMD
David Connolly, ARNG
Nat Peters, USACE
Bob Princic, Ohio EPA, NEDO, DERR
Mark Johnson, Ohio EPA, NEDO, DERR
Tom Schneider, Ohio EPA, SWDO, DERR
Vanessa Steigerwald-Dick, Ohio EPA, NEDO, DERR
Tim Christman, Ohio EPA, CO, DERR
Al Muller, Ohio EPA, NEDO, DDAGW
Kevin Palombo, NEDO, DERR
Frederick Jones, Ohio EPA, CO, DAPC
Chris Williams, Ohio EPA, NEDO, DAPC

NATIONAL GUARD BUREAU
111 SOUTH GEORGE MASON DRIVE
ARLINGTON VA 22204-1373

July 12, 2018

Ohio Environmental Protection Agency
DERR-NEDO
Attn: Ms. Vanessa Steigerwald-Dick
2110 East Aurora Road
Twinsburg, OH 44087-1924

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry, Comment Resolution on the Remedial Investigation/Feasibility Study Report (Work Activity No. 267-000-859-095)

Dear Ms. Steigerwald-Dick:

The Army appreciates your time to meet and discuss follow-up comments (dated May 17, 2018) on the *Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry*. As discussed during the meeting on May 22, 2018, the Army is providing additional responses in this letter in accordance with the resolution achieved.

Upon your concurrence with this final resolution to comments, the Army will distribute the final version of this report. Please contact the undersigned at (703) 607-7955 or david.m.connolly8.civ@mail.mil if there are issues or concerns with this submission.

Sincerely,

Mr. David Connolly
RVAAP Restoration Program Manager
Army National Guard Directorate

cc: Mark Johnson, Ohio EPA, NEDO
Bob Princic, Ohio EPA, NEDO
Tom Schneider, Ohio EPA, SWDO
Tim Christman, Ohio EPA, CO
Al Muller, Ohio EPA, NEDO
Vicki Deppisch, Ohio EPA, NEDO
Kevin Palombo, Ohio EPA, NEDO
Kevin Sedlak, ARNG, Camp Ravenna
Katie Tait, OHARNG, Camp Ravenna
Craig Coombs, USACE Louisville
Nathaniel Peters, II, USACE Louisville
Jed Thomas, Leidos
Gail Harris, Vista Sciences Corporation

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry (Work Activity No. 267-000-859-095)

REFERENCE PREVIOUS SUBMITTALS, COMMENTS, AND MEETINGS

For the reviewer's convenience and ease of reference, the Army provides the following timeline for comment response and resolution for the C Block Quarry RI/FS Report:

08/04/17 – The Army submitted the Revised Draft RI/FS for C Block Quarry.
11/28/17 – Ohio EPA provided comments on Revised Draft RI/FS Report.
03/08/18 – The Army submits responses to 11/28/17 comments.
05/18/18 – Ohio EPA provided feedback on the Army's 3/8/18 response letter.
05/22/18 – The Army conducted a resolution meeting with Ohio EPA.

RESPONSES TO GENERAL OHIO EPA COMMENTS, DATED 18 MAY 2018

Ohio EPA General Comment 5, feedback dated 5/18/18: Revise the text to incorporate the information provided in this comment response.

Army Response: Agree. Section 12.3.3 Remedial Design (Alternative 3) has been revised as follows:

> *"An RD will be developed prior to initiating remedial actions. This RD will outline construction permitting requirements; site preparation activities (e.g., staging and equipment storage areas, truck routes, and storm water controls); requirements for removing, controlling, and transporting ACM; extent of the excavation; sequence and description of excavation and site restoration activities; decontamination; and segregation, transportation, and disposal of various waste streams. Engineering and administrative controls (e.g., erosion and health and safety) will be developed during the active construction period to ensure remediation workers and the environment are protected. In addition, the RD will specify the sampling protocol and analytical methods to be used for asbestos analysis and chemical analysis of the soil.*
>
> *As part of the development of the RD, the site will undergo a new, updated inspection to ensure exposed ACM is identified. Additionally, this RD will contain an Asbestos Soil Abatement Plan to outline requirements specific to the removal of ACM, including identifying key personnel and PPE, specifying air monitoring requirements, and stating the site control measures."*

Ohio EPA General Comment 8, feedback dated 5/18/18: Ohio EPA concurs with the Army's response for the RI/FS. However, an updated asbestos inspection will need to be conducted during the Remedial Design (RD) phase prior to implementation of the Remedial Action (RA). The condition and location of the observed ACM, as noted in the 2011 asbestos survey, needs to be reassessed, as eight years of weathering has most likely changed the condition, the location and ability to locate the material.

Army Response: Agree. The revision to Section 12.3.1 (Alternative 3, Remedial Design) is presented above in response to General Comment 5. Section 12.2.1 Surficial Asbestos-Containing Material Removal (Alternative 2) has been revised as follows:

> *"Alternative 2 will include the removal of ACM that was observed on the ground surface at C Block Quarry. An estimated 10 yd3 of exposed ACM (e.g., transite/shingle and steel panels with block insulation and paper) were observed to be in surface soil at C Block Quarry. As part of the ACM removal, the site will undergo a new, updated inspection to ensure exposed ACM is identified.*
>
> *The ACM will be removed by a …"*

Ohio EPA General Comment 9, feedback dated 5/18/18: Ohio EPA concurs with the Army's response for the RI/FS. However, an updated asbestos inspection will need to be conducted during the Remedial Design (RD) phase prior to implementation of the Remedial Action (RA). Ohio EPA recommends that additional Seibert stakes be incorporated into the RD/RA phase to ensure high visibility of the barrier for site receptors.

Army Response: Agree. Text revisions to specify the updated asbestos inspections are presented in responses to Ohio EPA General Comments 5 and 8. As discussed during the 5/22/18 resolution meeting, Alternative 3 will not require land use controls such as Seibert stakes after implementation. However, Alternative 2 will have land use controls after implementation. Accordingly, Section 12.2.3 Land Use Controls has been revised as follows:

> *Section 12.2.3 Land Use Controls*
>
> *Under this remedial alternative, the Army will implement the LUCs listed below to achieve the performance objectives for C Block Quarry:*
>
> 1. *Prevent Resident Receptor use of the site, as hexavalent chromium in soil above the residential RSL of 3 mg/kg will remain on-site.*
> 2. *Prevent intrusive and digging activities, as friable ACM potentially exists in the subsurface soil.*
> 3. *Install signs to enhance compliance with digging restrictions at the site.*
> 4. *Installation of Seibert stakes to ensure high visibility of site boundary.*
> 5. *Maintain the LUC training program.*

RESPONSES TO OHIO EPA COMMENTS PROVIDED ON 28 OCTOBER 2016 (FATE AND TRANSPORT MODEL, GROUNDWATER COMMENTS)

Ohio EPA reviewed the responses to the seven fate and transport model/ground water comments (FTGW Comments) and determined that the responses to three of the FTGW Comments (FTGW Comments 4, 5, and 7) are adequate. However, the comment responses to the remaining four FTGW Comments (FTGW Comments 1, 2, 3, and 6) are inadequate and remain a concern. Ohio EPA concurs that the SESOIL™/AT123D™ models utilized in the Draft RI/FS do not accurately predict contaminant migration, even for screening purposes beneath C Block Quarry given the hydrogeology. The use of the models for C-Block Quarry need to be resolved. The following are Ohio EPA comments on the FTGW are as follows:

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry (Work Activity No. 267-000-859-095)

1. The Army has not adequately responded to Ohio EPA's FTGW Comments 1, 2, and 3 dated November 28, 2017, regarding the appropriateness of the SESOIL™/AT123D™ fate and transport model used in the RVAAP-06 C Block Quarry RI/FS Report given the hydrogeology beneath C Block Quarry. Considering that the response to Ohio EPA's FTGW Comment 4 dated November 28, 2017, acknowledges that the SESOIL™/AT123D™ does not accurately predict contaminant migration through a highly heterogenous hydrogeologic system such as exists beneath C Block Quarry, the responses to Ohio EPA's, FTGW Comments 1, 2, and 3 dated November 28, 2017, are not adequate. Revise this section accordingly. Also, refer to Comment 2 below.

2. Ohio EPA concurs with the Army's response to FTGW Comment 4 and agrees that the SESOIL™/ AT123D™ model does not accurately predict contaminant migration through a highly heterogenous hydrogeologic system, such as exists beneath C Block Quarry. The geology beneath C Block Quarry consists of a thin layer of soil/unconsolidated material over fractured and weathered Homewood Sandstone. While part of the vadose zone consists of unconsolidated material/soil, most of the vadose zone is in the fractured and weathered Homewood Sandstone. According to Pfingston (2002), this area was also likely subject to blasting during quarrying. SESOIL™/AT123D™ are not appropriate screening tools to model fate and transport in bedrock (New Jersey DEP, 2014) or in non-homogenous or fractured geologic media (Kauffman and McLane, 2015).

The Army can demonstrate potential for impact to ground water in evaluating ground water to surface water pathway by sampling the four RI wells (CBLmw-001, CBLmw-002, CBLmw-003, and CBL-004). The four aforementioned wells have not been sampled since 2013, and according to the 2016 RI Work Plan for Ground Water will need to be sampled to support the Facility-Wide Ground Water (FWGW) RI. Ohio EPA recommends that these four wells be sampled for the parameters specified in the 2016 RI Work Plan for Ground Water for C Block Quarry wells including: SVOCs, metals including hexavalent chromium, and PCBs. Considering the history, disposal practices and pH issues in the C Block, Ohio EPA recommends that these four wells also be sampled for: explosives, nitrate/nitrite, sulfate/sulfide, and pH. Further, Ohio EPA recommends that the four C Block Quarry RI wells be sampled for a minimum of two consecutive sampling events and be added to the list of wells to be sampled in 2018 in the Facility-Wide Ground Water Monitoring Addendum.

3. Ohio EPA concurs with the response to FTGW Comment 5. In the response, the Army acknowledges the fact that the SESOIL™/AT123D™ model does not take into account the direct disposal of wastes onto the weathered and fractured bedrock, as was reported to have been historically practiced in the 1950's and 1960's in C Block Quarry. Therefore, Ohio EPA recommends that the four C Block RI wells be added to the list of wells to be sampled in 2018 in the Facility Wide Ground Water Monitoring Addendum, as recommended in Comment 2 above.

4. The Army's response to Ohio EPA's FTGW Comment 6 dated November 28, 2017, is inadequate. The ground water flow interpretations in Figures 3, 3-1, 4, and 4-1 are incorrect. Ground water flow on the knob of the Homewood Sandstone was re-interpreted a number of years ago to be radial, and not as shown on the figures. Attached is the most recent April 2017 Potentiometric Map, which shows radial flow in that hydrostratigraphic unit in the vicinity of C Block Quarry. While the aforementioned flow map only shows one flow arrow, the potentiometric map shows an arced potentiometric line, which follows the contour of the Homewood Knob in the vicinity C Block Quarry, where ground water flow in the Homewood is radial. Ground water flow interpretations in the RI report need to be modified to accurately show ground water flow in the vicinity of C Block Quarry.

5. The Army has adequately responded to Ohio EPA’s Comment 7, dated November 28, 2017. The response indicates that the Geologic Bedrock Map (Figure 3-3) will be corrected to show the correct geologic units.

Army Response: As agreed during the 5/22/18 comment resolution meeting, Section 6 has been revised to present the C Block Quarry groundwater results and SESOIL modeling results. The previously presented AT123D model has been removed from the document. The revised Section 6 is attached to this response letter and includes a summary of additional C Block Quarry samples agreed to be collected under the FWGWMP.

To supplement the SESOIL modeling results now summarized in Section 6, Appendix E has been modified to now include the SESOIL model methodology, details, and results. The revised Appendix E is attached to this response letter.

The groundwater flow interpretations on Figures 3-1, 4-1, and all other applicable figures have been revised to reflect the groundwater elevations collected in April 2017 and the potentiometric map presented in the FWGWMP Annual Report for 2017. Revised Figure 3-1 is presented as an attachment to this response letter.

ATTACHMENT A.

C Block Quarry RI/FS Report – Revised Section 6

6.0 CONTAMINANT FATE AND TRANSPORT

Contaminant fate and transport at C Block Quarry is evaluated using 1) groundwater data collected to date at the AOC and 2) contaminant fate and transport modeling to assess the potential for SRCs to leach from surface and subsurface soil sources and impact groundwater beneath the sources. This evaluation is included in the decision-making process to determine whether remedial actions may be necessary to protect groundwater resources.

6.1 GROUNDWATER CHEMICAL CONCENTRATIONS

6.1.1 Groundwater Sampling Summary

Groundwater samples were collected from 5 monitoring wells around C Block Quarry during 13 separate sampling events under the Characterization of 14 AOCs (MKM 2005) and the FWGWMP from January 2005 to November 2016 to assess the potential impact historical site activities may have had on groundwater. Table 6-1 summarizes the C Block Quarry monitoring well sampling and the laboratory analyses that were performed during those sampling events.

From December 2004 through January 2005, monitoring wells CBLmw-001 to CBLmw-004 were installed during the Characterization of 14 AOCs. After the well installation, these wells were sampled and analyzed for the RVAAP full-suite analytes in January 2005. Additional analyses were performed for RVAAP full-suite analytes as part of the FWGWMP for four quarters from April 2008 to January 2009. The monitoring wells have been periodically sampled since January 2009 and analyzed for the select parameters presented in Table 6-1.

Under the FWGWMP, an additional monitoring well (CBLmw-005) was installed near C Block Quarry in 2012. CBLmw-005 was sampled for four quarters from April 2012 to June 2013 and analyzed for RVAAP-full-suite parameters.

6.1.2 Groundwater Sample Results

Groundwater samples have been analyzed for metals, explosives, propellants, SVOCs, VOCs, PCBs, pesticides, perchlorate, and cyanide. Monitoring wells CBLmw-001 to CBLmw-004 had five sample events in which groundwater samples were analyzed for the RVAAP full-suite analytes. Monitoring well CBLmw-005 had four sample events in which groundwater samples were analyzed for RVAAP full-suite analytes.

Table 6-2 presents a summary of chemicals detected within the C Block Quarry monitoring wells from January 2005 to January 2013. This table includes duplicate sample results and only includes results from metal analyses that were filtered at the time of sample collection. Table 6-2 does not include data from the November 2016 sample event, as that data was not available at the time for inclusion in the data summary. However, none of the November 2016 samples had detectable concentrations of PCBs or SVOCs, and the maximum concentration of cyanide was an estimated 0.003J mg/L, well below the MCL of 0.2 mg/L.

Table 6-2 also presents screening criteria at a risk level of HQ of 0.1, TR of 10-6 for comparison purposes. The initial screening criterion used was the USEPA MCL. If a chemical did not have a USEPA MCL, the Resident Receptor FWCUG at a risk level of HQ of 0.1, TR of 10-6 was used. If a chemical did not have an MCL or Resident Receptor FWCUG, the Resident Tap Water RSL at a risk level of HQ of 0.1, TR of 10-6 was used.

Explosives, propellants, VOCs, pesticides, perchlorate, and cyanide results were all below the screening levels provided. Seven chemicals had at least one exceedance of the screening level, and a discussion of these chemicals is presented below.

- **Hexavalent chromium** – Hexavalent chromium was detected in four of five samples collected in 2005 at concentrations ranging from 0.0052B–0.0077B mg/L. Hexavalent chromium does not have an MCL or Resident Receptor FWCUG, consequently the Resident Tap Water RSL (0.000035 mg/L) was used for the screening criteria. The results of these 2005 samples were “B qualified,” indicating the result was above the instrument detection limit but below the contract required detection limit. In July 2012, groundwater samples were collected from CBLmw-002 and CBLmw-005 (downgradient of the AOC). These samples did not have detectable concentrations of hexavalent chromium.
- **Manganese** – Only 4 of 32 samples exceeded the Resident Receptor FWCUG at HQ of 0.1, TR of 10-6 (0.0463 mg/L). Three of these samples were collected in January 2005, including the maximum concentration of 0.19 mg/L at CBLmw-001. All four samples that exceeded this screening level had a subsequent groundwater sample collected at that well that was below the screening level.
- **PCB-1248** – Of the 30 groundwater samples analyzed for PCBs, only 1 sample had a detectable concentration. This detectable concentration was PCB-1248 at CBLmw-004 with an estimated concentration of 0.00011J mg/L in October 2008, which is below the MCL (0.0005 mg/L). The samples collected from CBLmw-004 in January 2009 and April 2011 did not have detectable concentrations of any PCBs.
- **Benz(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene –** These chemicals each had one exceedance of the Resident Receptor FWCUG in the January 2005 sample at CBLmw-001. All other C Block Quarry groundwater samples, including subsequent samples from monitoring well CBLmw-001, did not have detectable concentrations of these three chemicals.
- **Bis(2-ethylhexyl)phthalate** – Of the 30 groundwater samples analyzed for bis(2-ethylhexyl)phthalate, only 8 samples had a detectable concentration, and only 2 samples exceeded the MCL of 0.006 mg/L. The maximum concentration was 0.4 mg/L at CBLmw-002 in January 2005; however, all subsequent samples from CBLmw-002 were well below the MCL.

6.2 FATE AND TRANSPORT EVALUATION

Contaminant fate and transport modeling to assess the potential for SRCs to leach from surface and subsurface soil sources at C Block Quarry and impact groundwater beneath the sources was performed as part of this RI Report. The detailed evaluation is provided in Appendix E.

6.2.1 Approach

The fate and transport evaluation assesses the potential for SRCs to leach from surface and subsurface soil sources at C Block Quarry and impact groundwater beneath the sources. The surface and subsurface soil SRCs include chemicals that were identified as potential contaminants from previous site usage and chemicals that were identified from the SRC screening process using available data. All SRCs were evaluated to determine if residual concentrations in soil may potentially impact groundwater quality and warrant evaluation in an FS.

The principal migration pathway at C Block Quarry is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). However, because of the very heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within the unconsolidated soil are difficult to predict. Precipitation that does not leave the AOC as surface runoff percolates into the subsurface. Some of the percolating water leaves this environment via evapotranspiration after little or no vertical migration.

The five steps for the soil leachability analysis are described below and are discussed in further detail in Appendix E.

- Step 1. Identify SRCs for evaluation.
- Step 2. Compare maximum concentrations of SRCs with MCL-based generic soil screening levels (GSSLs).
- Step 3. Compare the maximum chemical concentrations with the site-specific soil screening level (SSSLs). SRCs that are not eliminated at this step are considered initial CMCOPCs.
- Step 4. Eliminate initial CMCOPCs identified in the SSSL evaluation from further consideration that require more than 1,000 years to leach through the unsaturated zone before reaching the water table.
- Step 5. Perform contaminant fate and transport modeling (SESOIL modeling) for remaining initial CMCOPCs to predict chemical concentrations in the leachate immediately beneath the selected source areas and just above the water table and identify final CMCOPCs.
- Step 6. Perform dilution attenuation modeling for the final CMCOPCs to predict chemical concentrations in groundwater just beneath the selected source areas and identify the initial contaminant migration chemicals of concern (CMCOCs).

6.2.2 Results

Among the potential contaminants from previous use, chromium and mercury were eliminated from potentially impacting groundwater through soil screening analysis (i.e., by comparing their maximum soil concentrations to the MCL-based GSSLs). Lead and hexavalent chromium were eliminated since their travel times to reach the water table from the source area exceeds 1,000 years.

Evaluation of modeling results identified TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT as final CMCOPCs. These final CMCOPCs were predicted to exceed the screening criteria in groundwater beneath the source area and were identified as initial CMCOCs; however, none of these initial CMCOCs were detected in AOC groundwater samples collected from 2009–2013.

A qualitative assessment of the sample results was performed and the limitations and assumptions of the models were considered to identify if any CMCOCs are present in soil at C Block Quarry that may potentially impact groundwater at C Block Quarry. Modeling results indicated that the predicted concentrations in groundwater beneath the source area could potentially exceed the RSLs and the Resident Receptor Adult FWCUGs within 10–15 years. Based on the AOC period of operations, these constituents should have already been detected in groundwater. However, none of these constituents were detected in groundwater, likely due to biodegradation, which is not accounted for in the conservative modeling. This qualitative assessment concluded that CMCOPCs are not adversely impacting groundwater quality based on current data and are not predicted to have future impacts.

6.3 CONCLUSIONS

Contaminant fate and transport at C Block Quarry is evaluated using 1) groundwater data collected to date at the AOC and 2) contaminant fate and transport modeling to assess the potential for SRCs to leach from surface and subsurface soil and impact groundwater beneath the sources.

Groundwater samples were collected from 5 monitoring wells around C Block Quarry during 13 separate sampling events under the Characterization of 14 AOCs (MKM 2005) and the FWGWMP from January 2005 to November 2016 to assess potential impact historical site activities may have had on groundwater. Explosives, propellants, VOCs, pesticides, perchlorate, and cyanide results were all below the screening level (MCL, Resident Receptor FWCUG, or Resident Tap Water RSL). Only seven chemicals [hexavalent chromium, manganese, PCB-1248, benz(a)anthracene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, and bis(2-ethylhexyl)phthalate] exceeded the screening levels. Further evaluation in Section 6.1.2 indicates that the chemicals in groundwater do not warrant additional action.

The fate and transport evaluation concluded that chromium and mercury were not potentially impacting groundwater through soil screening analysis (i.e., by comparing their maximum soil concentrations to the MCL-based GSSLs), and lead and hexavalent chromium were not expected to reach the water table from the source area within 1,000 years. The fate and transport evaluation identified TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT as final CMCOPCs. Based on soil concentrations, these final CMCOPCs were predicted to exceed the screening criteria in groundwater beneath the source area. However, none of these final CMCOPCs were detected in AOC groundwater samples collected from 2009–2013. A qualitative assessment of the groundwater sample results was performed and the limitations and assumptions of the models were considered to identify if any CMCOCs are present in soil at C Block Quarry that may potentially impact groundwater. This qualitative assessment concluded that CMCOPCs are not adversely impacting groundwater quality based on current data and are not predicted to have future impacts.

The contaminant fate and transport evaluation concludes that no further action is required for soil to be protective of groundwater. In a letter from the Army to Ohio EPA dated June 1, 2018, the Army agreed to further assess this conclusion and concentrations in groundwater by analyzing groundwater samples from CBLmw-001, CBLmw-002, CBLmw-003, and CBLmw-004 for SVOCs, metals (including hexavalent chromium), PCBs, explosives, nitrate/nitrite, sulfate/sulfide, and pH as part of the FWGWMP in 2018.

Table 6–1. Historical Monitoring Well Sampling Summary at C Block Quarry

Sample Event	Well	Explosives/ Propellants	Metals	SVOCs	VOCs	PCBs	Pesticides	Hexavalent Chromium	Perchlorate	Cyanide
January 2005	CBLmw-001	x	x	x	x	x	x	x	--	--
	CBLmw-002	x	x	x	x	x	x	x	--	--
	CBLmw-003	x	x	x	x	x	x	x	--	--
	CBLmw-004	x	x	x	x	x	x	x	--	--
April 2008	CBLmw-001	x	x	x	x	x	x	--	--	x
	CBLmw-002	x	x	x	x	x	x	--	--	x
	CBLmw-003	x	x	x	x	x	x	--	--	x
	CBLmw-004	x	x	x	x	x	x	--	--	x
July 2008	CBLmw-001	x	x	x	x	x	x	--	x	x
	CBLmw-002	x	x	x	x	x	x	--	x	x
	CBLmw-003	x	x	x	x	x	x	--	x	x
	CBLmw-004	x	x	x	x	x	x	--	x	x
October 2008	CBLmw-001	x	x	x	x	x	x	--	--	x
	CBLmw-002	x	x	x	x	x	x	--	--	x
	CBLmw-003	x	x	x	x	x	x	--	--	x
	CBLmw-004	x	x	x	x	x	x	--	--	x
January 2009	CBLmw-001	x	x	x	x	x	x	--	--	x
	CBLmw-002	x	x	x	x	x	x	--	--	x
	CBLmw-003	x	x	x	x	x	x	--	--	x
	CBLmw-004	x	x	x	x	x	x	--	--	x
October 2009	CBLmw-001	--	x	--	--	--	--	--	--	--
	CBLmw-002	--	x	--	--	--	--	--	--	--
	CBLmw-003	--	x	--	--	--	--	--	--	--
	CBLmw-004	--	x	--	--	--	--	--	--	--
April 2011	CBLmw-004	x	x	x	x	x	x	--	--	x
February 2012	CBLmw-002	--	--	x	--	x	--	--	--	--
May 2012	CBLmw-005	x	x	x	x	x	x	--	--	x
July 2012	CBLmw-002	--	--	x	--	x	--	--	--	--
	CBLmw-005	x	x	x	x	x	x	x	--	x
October 2012	CBLmw-005	x	x	x	x	x	x	--	--	x
January 2013	CBLmw-002	--	--	x	--	x	--	--	--	--
	CBLmw-005	x	x	x	x	x	x	--	x	x

Table 6–1. Historical Monitoring Well Sampling Summary at C Block Quarry (continued)

Sample Event	Well	Explosives/ Propellants	Metals	SVOCs	VOCs	PCBs	Pesticides	Hexavalent Chromium	Perchlorate	Cyanide
November 2016	CBLmw-001	--	--	x	--	x	--	--	--	x
	CBLmw-002	--	--	x	--	x	--	--	--	x
	CBLmw-003	--	--	x	--	x	--	--	--	x
	CBLmw-004	--	--	x	--	x	--	--	--	x

PCB = Polychlorinated biphenyl.
SVOC = Semi-volatile organic compound.
VOC = Volatile organic compound.
x = Parameter was included in sampling event.
-- = Parameter was not included in sampling event.

THIS PAGE INTENTIONALLY LEFT BLANK

Table 6–2. Screening of Groundwater Sample Results at C Block Quarry

Chemical (mg/L)	CAS Number	Results >Detection Limit	Minimum Detect	Maximum Detect	Average Result	Screening Level	Screening Level Source[1]	Number of Samples Exceeding Screening Level	Station at Max Detect	Date Collected at Max Detect	Most Recent Result	Most Recent Sample Date
Cyanide	57-12-5	1/ 22	0.007	0.007	0.00509	0.2	MCL	0	CBLmw-001	10/10/2008	<0.01U	1/20/2009
1,3,5-Trinitrobenzene	99-35-4	1/ 27	0.000048	0.000048	0.0000612	0.059	Tap RSL	0	CBLmw-004	1/21/2009	<0.00011U	4/7/2011
Nitrobenzene	98-95-3	1/ 27	0.000056	0.000056	0.0000604	0.000521	RES CUG	0	CBLmw-004	10/9/2008	<0.00011U	4/7/2011
Nitrocellulose	9004-70-0	2/ 27	0.14	0.15	0.3	6000	Tap RSL	0	CBLmw-003	7/10/2008	<0.5UJ	1/20/2009
Chromium, hexavalent	**18540-29-9**	**4/ 7**	**0.01**	**0.01**	**0.00643**	**0.000035**	**Tap RSL**	**4**	**CBLmw-001**	**1/20/2005**	**0.01**	**1/20/2005**
Aluminum	7429-90-5	18/ 32	0.0192	0.469	0.047	1.028	RES CUG	0	CBLmw-004	4/10/2008	<0.05U	4/7/2011
Barium	7440-39-3	32/ 32	0.0117	0.0668	0.0431	2	MCL	0	CBLmw-002	10/21/2009	0.0668	10/21/2009
Beryllium	7440-41-7	2/ 32	0.000069	0.00012	0.000524	0.004	MCL	0	CBLmw-005	7/24/2012	<0.00009U	1/24/2013
Cadmium	7440-43-9	5/ 32	0.00013	0.0002	0.000327	0.005	MCL	0	CBLmw-002	1/20/2009	0.00016J	10/21/2009
Calcium	7440-70-2	32/ 32	2.84	14.3	7.35			0	CBLmw-003	7/10/2008	7.12	10/22/2009
Cobalt	7440-48-4	4/ 32	0.0013	0.0069	0.0025	0.0208	RES CUG	0	CBLmw-005	5/2/2012	<0.0025U	1/24/2013
Copper	7440-50-8	4/ 32	0.0022	0.011	0.00334	1.3	MCL	0	CBLmw-001	1/20/2005	<0.005U	10/21/2009
Iron	7439-89-6	8/ 32	0.0281	0.178	0.0393	0.31	RES CUG	0	CBLmw-004	10/22/2009	<0.05U	4/7/2011
Magnesium	7439-95-4	32/ 32	1.5	5.5	3.37			0	CBLmw-005	7/24/2012	4.1	1/24/2013
Manganese	**7439-96-5**	**27/ 32**	**0.0027**	**0.19**	**0.0292**	**0.0463**	**RES CUG**	**4**	**CBLmw-001**	**1/20/2005**	**0.0094J**	**10/21/2009**
Mercury	7439-97-6	2/ 32	0.00013	0.00018	0.000101	0.002	MCL	0	CBLmw-003	10/9/2008	<0.0002U	10/22/2009
Nickel	7440-02-0	27/ 32	0.0033	0.02	0.00708	0.0208	RES CUG	0	CBLmw-005	5/2/2012	0.0099	1/24/2013
Potassium	7440-09-7	30/ 32	0.739	1.91	1.14			0	CBLmw-004	7/11/2008	1.12	4/7/2011
Silver	7440-22-4	1/ 32	0.0032	0.0032	0.00285	0.0094	Tap RSL	0	CBLmw-001	4/10/2008	<0.005U	10/21/2009
Sodium	7440-23-5	28/ 32	0.633	3.7	1.6			0	CBLmw-005	7/24/2012	2.7	1/24/2013
Vanadium	7440-62-2	1/ 32	0.0018	0.0018	0.00454	0.00638	RES CUG	0	CBLmw-001	4/10/2008	<0.01U	10/21/2009
Zinc	7440-66-6	18/ 32	0.0059	0.0372	0.0135	0.312	RES CUG	0	CBLmw-002	4/10/2008	<0.0356B	10/21/2009
PCB-1248	**12672-29-6**	**1/ 30**	**0.00011**	**0.00011**	**0.000294**	**0.0000078**	**Tap RSL**	**1**	**CBLmw-004**	**10/9/2008**	**<0.0005UJ**	**4/7/2011**
Perchlorate	14797-73-0	5/ 5	0.000045	0.000088	0.0000662	0.0014	Tap RSL	0	CBLmw-002	7/10/2008	0.00009	7/10/2008
beta-BHC	319-85-7	2/ 27	0.0000088	0.00001	0.0000195	0.000047	RES CUG	0	CBLmw-004	10/9/2008	<0.00003UJ	4/7/2011
2-Methylnaphthalene	91-57-6	1/ 27	0.00025	0.00025	0.000122	0.0036	Tap RSL	0	CBLmw-002	1/12/2005	<0.0002U	1/20/2009
Benz(a)anthracene	**56-55-3**	**1/ 30**	**0.00016**	**0.00016**	**0.0000914**	**0.000004**	**RES CUG**	**1**	**CBLmw-001**	**1/20/2005**	**<0.0002U**	**1/20/2009**
Benzo(a)pyrene	50-32-8	1/ 30	0.00017	0.00017	0.000105	0.0002	MCL	0	CBLmw-001	1/20/2005	<0.0002U	1/20/2009
Benzo(b)fluoranthene	**205-99-2**	**1/ 30**	**0.00013**	**0.00013**	**0.000104**	**0.000002**	**RES CUG**	**1**	**CBLmw-001**	**1/20/2005**	**<0.0002U**	**1/20/2009**
Benzo(k)fluoranthene	207-08-9	1/ 30	0.00022	0.00022	0.000107	0.0025	Tap RSL	0	CBLmw-001	1/20/2005	<0.0002U	1/20/2009
Chrysene	218-01-9	2/ 30	0.00012	0.00014	0.000107	0.025	Tap RSL	0	CBLmw-001	1/20/2005	<0.0002U	1/20/2009
Fluoranthene	206-44-0	1/ 30	0.00032	0.00032	0.000149	0.08	Tap RSL	0	CBLmw-002	1/12/2005	<0.0001U	1/23/2013
Indeno(1,2,3-cd)pyrene	**193-39-5**	**1/ 30**	**0.00014**	**0.00014**	**0.000104**	**0.000002**	**RES CUG**	**1**	**CBLmw-001**	**1/20/2005**	**<0.0002U**	**1/20/2009**
Phenanthrene	85-01-8	1/ 30	0.00024	0.00024	0.000147	0.012	Tap RSL	0	CBLmw-002	1/12/2005	<0.0001U	1/23/2013
Pyrene	129-00-0	1/ 30	0.0004	0.0004	0.000152	0.012	Tap RSL	0	CBLmw-002	1/12/2005	<0.0001U	1/23/2013
Bis(2-ethylhexyl)phthalate	**117-81-7**	**8/ 30**	**0.00092**	**0.4**	**0.017**	**0.006**	**MCL**	**2**	**CBLmw-002**	**1/12/2005**	**<0.0011B**	**1/23/2013**
Acetone	67-64-1	2/ 27	0.0012	0.0015	0.00337	1.4	Tap RSL	0	CBLmw-004	4/10/2008	<0.01U	4/7/2011

Summary of chemicals detected within the C Block Quarry monitoring wells from January 2005 to January 2013.

Table includes duplicate sample results and only includes results from metal analyses that were filtered at the time of sample collection.

Bold = Chemical had at least one exceedance of screening level.

[1] For the screening level source, the U.S. Environmental Protection Agency MCL is used. If the chemical does not have an MCL, the Resident Receptor facility-wide cleanup goal (FWCUG) at a risk level of hazard quotient (HQ) of 0.1, target risk (TR) of 10-6 is used. If a chemical does not have an MCL or Resident Receptor FWCUG, the Resident Tap Water RSL at a risk level of HQ of 0.1, TR of 10-6 is used.

B = Blank contamination: The chemical was detected above one-half the reporting limit in an associated blank
CAS = Chemical Abstract Service.
CUG = Cleanup goal.
J = Indicates the chemical was positively identified, but the associated numerical value is an approximate concentration of the chemical in the sample.
MCL = Maximum contaminant level.
mg/L = Milligrams per liter.
RES = Resident
RSL = Regional screening level.
U = Non-detectable concentration.
UJ = Non-detectable concentration and reporting limit estimated.
< = Less than.
> = Greater than.

THIS PAGE INTENTIONALLY LEFT BLANK

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry (Work Activity No. 267-000-859-095)

ATTACHMENT B.

C Block Quarry RI/FS Report – Revised Appendix E

E. CONTAMINANT FATE AND TRANSPORT

Contaminant fate and transport modeling assesses the potential for SRCs to leach from surface and subsurface soil sources at C Block Quarry and impact groundwater beneath the sources and downgradient receptor locations. Modeling results were included in the decision-making process to determine whether remedial actions may be necessary to protect groundwater resources. Surface water exposure pathways are evaluated in the HHRA and ERA presented in Sections 7.2 and 7.3 of the RI Report, respectively. A summary of the principles of contaminant fate and transport are presented in this section along with the results of the modeling.

Section E.1 describes physical and chemical properties of SRCs found in soil and sediment at the AOC. Section E.2 presents a conceptual model for contaminant fate and transport that considers AOC topography, hydrogeology, contaminant sources, and release mechanisms. Section E.3 presents a soil screening analysis to identify SRCs with the potential to migrate from soil to groundwater as initial CMCOPCs. Section E.4 describes fate and transport modeling using SESOIL to develop the final CMCOPCs and presents the initial CMCOCs based on dilution modeling. Section E.5 provides a list of the remaining CMCOCs and a qualitative assessment of the results and considerations of the limitations and assumptions. Section E.6 presents a summary and conclusions of the fate and transport analysis.

E.1 PHYSICAL AND CHEMICAL PROPERTIES OF SITE-RELATED CONTAMINANTS

The major contaminants of the former RVAAP are TNT, composition B (a combination of TNT and RDX), sulfates, nitrates, lead styphnate, and lead azide. Site-specific contaminants include lead, chromium, and mercury from dumping annealing process waste and spent pickle liquor from brass finishing operations. ACM was also identified in the quarry bottom. This evaluation of contaminant fate and transport evaluates not only those chemicals identified as potential contaminants from previous use but also includes an evaluation of chemicals that were evaluated as part of the overall RI for C Block Quarry. The comprehensive list of surface and subsurface soil SRCs (including 8 inorganic chemicals and 17 organic chemicals) were detailed in Section 4.0 of the RI Report and are summarized below:

- Inorganic SRCs in surface and subsurface soil include arsenic, cadmium, chromium, hexavalent chromium, copper, lead, mercury, and thallium.
- Organic SRCs in surface and subsurface soil include TNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; anthracene; benz(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; benzo(ghi)perylene; benzo(k)fluoranthene; bis(2-ethylhexyl)phthalate; chrysene; fluoranthene; fluorene; indeno(1,2,3-cd)pyrene; nitrocellulose; phenanthrene; and pyrene.

Chemicals released into the environment are susceptible to several degradation pathways, including hydrolysis, oxidation, reduction, isomerization, photolysis, photo-oxidation, biotransformation, and biodegradation. Transformed products resulting from these processes may behave differently than their parent chemical in the environment.

The migration of chemicals is governed by their physical and chemical properties and the surface and subsurface media through which chemicals are transferred. In general, chemicals and structures with similar physical and chemical characteristics will show similar patterns of transformation, transport, or attenuation in the environment. Solubility, vapor pressure data, chemical partitioning coefficients, degradation rates, and Henry's Law Constant (HLC) provide information that can be used to evaluate contaminant mobility in the environment. Partitioning coefficients are used to assess relative affinities of chemicals for solution or solid phase adsorption. However, the synergistic effects of multiple migrating chemicals and complexity of soil/water interactions, including pH and oxidation-reduction potential, grain size, and clay mineral variability, are typically unknown.

The physical properties of the chemicals defined as SRCs in surface and subsurface soil are summarized in Attachment E.1, Tables E.1-1 and E.1-2. These properties are used to assess the anticipated behavior of each chemical under environmental conditions. The physical properties of the chemicals defined as SRCs detected in soil are summarized in Sections E.1.1 through E.1.5.

E.1.1 Chemical Factors Affecting Fate and Transport

The water solubility of a chemical is a measure of the saturated concentration of the chemical in water at a given temperature and pressure. The tendency for a chemical to be transported by groundwater is directly related to its solubility and inversely related to its tendencies to adsorb to soil and volatilize from water (OGE 1988). Chemicals with high water solubilities tend to desorb from soil, are less likely to volatilize from water, and are susceptible to biodegradation. The water solubility of a chemical varies with temperature, pH, and the presence of other dissolved chemicals (including organic carbon and humic acids).

The octanol-water partition coefficient (K_{ow}) can be used to estimate the tendency for a chemical to partition between environmental phases of different polarity. The K_{ow} is a laboratory-determined ratio of the concentration of a chemical in the n-octanol phase of a two-phase system to the concentration in the water phase. Chemicals with log K_{ow} values less than one are highly hydrophilic, while chemicals with log K_{ow} values greater than four will partition to soil particles (Lyman et al. 1990).

The water/organic carbon partition coefficient (K_{oc}) is a measure of the tendency of an organic chemical to partition between water and organic carbon in soil. The K_{oc} is defined as the ratio of the absorbed chemical per unit weight of organic carbon to the aqueous solute concentration.

This coefficient can be used to estimate the degree to which an organic chemical will adsorb to soil and thus not migrate with groundwater. The higher the K_{oc} value, the greater is the tendency of the chemical to partition into soil (OGE 1988). The soil/water partitioning coefficient (K_d) is calculated by multiplying the K_{oc} value by the fraction of organic carbon in the soil.

Vapor pressure is a measure of the pressure at which a chemical and its vapor are in equilibrium. The value can be used to determine the extent to which a chemical would travel in air, as well as the rate of volatilization from soil and solution (OGE 1988). In general, chemicals with vapor pressures lower than 10^{-7} mm mercury will not be present in the atmosphere or air spaces in soil in significant amounts, while chemicals with vapor pressures higher than 10^{-2} mm mercury will exist primarily in the air (Dragun 1988).

The HLC value for a chemical is a measure of the ratio of the chemical's vapor pressure to its aqueous solubility. The HLC value can be used to make general predictions about a chemical's tendency to volatilize from water. Chemicals with HLC values less than 10^{-7} atm-m^3/mol will generally volatilize slowly, while chemicals with a HLC greater than 10^{-3} atm-m^3/mol will volatilize rapidly (Lyman et al. 1990).

E.1.2 Biodegradation

Organic chemicals with differing chemical structures will biodegrade at different rates. Primary biodegradation consists of any biologically induced structural change in an organic chemical. Complete biodegradation is the biologically mediated degradation of an organic chemical into carbon dioxide, water, oxygen, and other metabolic inorganic products (Dragun 1988). The first order biodegradation rate of an organic chemical is proportional to the concentration:

$$-dC/dt = kC \qquad \text{(Equation E-1)}$$

Where:

C = concentration
t = time
k = biodegradation rate constant = ln $2/t_{1/2}$
$t_{1/2}$ = biodegradation half-life

The biodegradation half-life is the time necessary for half of the chemical to degrade. The biodegradation rate of an organic chemical generally depends on the presence and population size of soil microorganisms that are capable of degrading the chemical.

E.1.3 Inorganic Chemicals

Inorganic chemicals detected in soil samples are associated with the aqueous phase and leachable metal ions on soil particles. The transport of this material from unsaturated soil to the underlying water table is controlled by the physical processes of precipitation percolation, chemical interaction with the soil, and downward transport of metal ions by continued percolation. The chemistry of inorganic chemical interactions with percolating precipitation and varying soil conditions is complex and includes numerous chemical transformations that may result in altered oxidation states, including ion exchange, adsorption, precipitation, or complexation. The chemical reactions, which are affected by environmental conditions (pH, oxidation/reduction conditions, type and amount of organic matter, clay content, and the presence of hydrous oxides), may act to enhance or reduce the mobility and toxicity of metal ions. In general, these reactions are reversible and add to the variability commonly observed in distributions of inorganic chemicals in soil.

The chemical form of an inorganic chemical determines its solubility and mobility in the environment; however, chemical speciation is complex and difficult to delineate in routine laboratory analysis. Inorganic chemicals in soil are commonly found in several forms, including dissolved concentrations in soil pore water, metal ions occupying exchange sites on inorganic soil constituents (adsorbed to inorganic soil constituents), metal ions associated with insoluble organic matter, precipitated inorganic chemicals as pure or mixed solids, and metal ions present in the structure of primary or secondary minerals.

The dissolved (aqueous) fraction and its equilibrium sorbed fraction are important when considering the migration potential of inorganic chemicals through soil. Of the inorganic chemicals that are likely to form, chlorides, nitrates, and nitrites are commonly the most soluble. Sulfate, carbonate, and hydroxides generally have low to moderate solubility. Soluble chemicals are transported in aqueous forms subject to attenuation, whereas less soluble chemicals remain as a precipitate and limit the overall dissolution of metal ions. The solubility of the metal ions is also regulated by ambient chemical conditions, including pH and oxidation/reduction.

The attenuation of metal ions in the environment can be estimated numerically using the retardation factor (R), dispersion in higher flow systems (high conductivity environments), and diffusion in low conductivity environments. R defines the extent to which the velocity of the contaminant is slowed, which is largely derived from the K_d. R is calculated using the following equation:

$$R = 1 + (K_d \rho_b)/\theta_w \qquad \text{(Equation E-2)}$$

Where:

ρ_b = the soil bulk dry density (g/cm^3)
θ_w = soil moisture content (dimensionless)

Metal ion concentrations in the environment do not attenuate by natural or biological degradation because of low volatility and solubility of the ions. Inorganic chemicals may be biotransformed or bioconcentrated through microbial activity.

E.1.4 Organic Chemicals

Organic chemicals, such as SVOCs or VOCs, may be transformed or degraded in the environment by processes including hydrolysis, oxidation/reduction, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic chemicals in transport media can vary from minutes to years, depending on environmental conditions and chemical structures. Some types of organic chemicals are very stable, and degradation rates can be very slow. Organic degradation may either enhance (by producing more toxic byproducts) or reduce (reducing concentrations) the toxicity of a chemical in the environment.

E.1.5 Explosives – Related Chemicals

Several explosive compounds were detected in soil at C Block Quarry. Microbiological and photochemical transformation may affect the fate and transport of explosive compounds in the environment. For example, based on the results of culture studies involving the removal of TNT by activated sludge microorganisms, it has been concluded that TNT undergoes biotransformation but not biodegradation (USABRDL 1989). Biotransformation of TNT occurs with the reduction of the nitro groups by microbial reduction, typically under anaerobic conditions. Beneficial bacteria in these reactions include *Pseudomonas, Escherichia, Bacillus, Citrobacter, Enterobacter, Klebseilla, Veillonella,* and *Clostridium* (USACHPPM 2000). It has been found that anaerobic metabolism occurs in two stages (Funk et al. 1993). The first stage is the reductive stage in which TNT is reduced to its amino derivatives. In the second stage, degradation to non-aromatic products begins after the reduction of the third nitro group.

The biotransformation rate of TNT has been found to be rapid at most sites (ERDC 2007) and may be increased with the presence of carbon (USACHPPM 2000). Fungi and photolysis can also biotransform TNT. The predominant transformation products 1,3,5-trinitrobenzene; 4,6-dinitroanthranil; 2,4,6-trinitrobezadehyde; and 2,4,6-trinitrobenzonitrite are due to photolysis of TNT (USACHPPM 2000). The biotransformation pathway for TNT is shown in Attachment E.1, Figure E.1-1 (Kaplan and Kaplan 1982). The nitro groups of TNT are reduced to form 2-amino-4,6-DNT and 4-amino-2,6-DNT, and the nitro groups can undergo further reduction to form 2,4,6-triaminotoluene (Cockerham and Shane 1994).

Nitrocellulose is an aliphatic nitrate ester that will gelatinize when mixed with nitroglycerin. Nitrocellulose occurs as a fibrous solid that can act as a sorbent that will dissolve in water under highly basic conditions with high temperatures. Nitrocellulose can undergo denitrification as a degradation pathway. Degradation of nitrocellulose to non-reactive nitrocellulose has been observed under methanogenic and fungus-mediated reducing conditions (USACE 2006).

E.2 CONCEPTUAL MODEL FOR FATE AND TRANSPORT

The CSM, which defines the framework for fate and transport modeling, describes conditions at C Block Quarry, including the contaminant sources, surficial and subsurface hydrogeologic conditions, contaminant migration and pathways, and contaminant release mechanisms.

AOC conditions described in Sections 2.0 through 5.0 of the RI Report include contaminant source information, the surrounding geologic and hydrologic conditions, and the magnitude of SRCs and their current spatial distribution. Information from Section 3.0 and the nature and extent evaluation in Section 5.0 were used to develop the CSM for fate and transport modeling by identifying SRCs and migration pathways. The CSM is based on information and data collected for historical investigations, this RI Report, and informed assumptions about the AOC. Assumptions contained in the CSM are reiterated throughout this section. The better the information and the greater the accuracy of the assumptions, the more accurately the CSM describes the AOC; therefore, the more reliable the fate and transport modeling predictions can be. A summary of the salient elements of the CSM that apply to fate and transport modeling are summarized in the following sections.

E.2.1 Contaminant Sources

Primary contaminant sources on the AOC such as ACM are not expected to impact groundwater at the site. Secondary sources (contaminated media) identified in previous investigations are further evaluated in this report.

E.2.2 Hydrogeology

A description of regional and AOC-specific geology and hydrology are are summarized below.

- The topography at C Block Quarry ranges from approximately 1,150 ft amsl near the center of the quarry bottom to 1,174 ft amsl at the top of the quarry walls. Surface water drainage associated with heavy rainfall events would follow the topography and drain to the low point in the quarry near the center. There is no perennial standing water in the quarry.
- Soil beneath the AOC consists mostly of silty sands [as observed in subsurface borings installed during the PBA08 RI (Appendix A)]. Soil accumulation at the bottom of the quarry is attributed to historical RVAAP activities, erosion, and/or plant matter decay. Thickness of the soil (observed during the PBA08 RI) at the bottom of the quarry is 0.75–7 ft bgs.
- Five groundwater monitoring wells were installed near the AOC around the edges of the quarry with surface elevations ranging from 1,155.6–1,178.5 ft amsl. The average depth of the monitoring wells is 1,128 ft amsl. This is approximately 46 ft below the topographic high within the AOC (1,172 ft amsl) and approximately 22 ft below the topographic low within the AOC (1,150 ft amsl). These monitoring wells monitor the bedrock zone and are screened in the Homewood Sandstone (TEC-Weston 2018).
- Similar to the general direction of groundwater flow through the Homewood formation, the predominant flow direction at C-Block Quarry is east-southeast towards Sand Creek (TEC-Weston 2018) (Figure E-3).
- April 2017 water level elevations at the AOC ranged from 1,132.02–1,138.96 ft amsl with the highest elevation at well CBLmw-003, as shown in Figure E-3 (TEC-Weston 2018). Potentiometric data indicate the groundwater table occurs within bedrock throughout the AOC at an average elevation of 1137 ft amsl. The groundwater table is approximately 32 ft below the topographic high within the AOC (1,172 ft amsl) and approximately 13 ft below the topographic low within the AOC (1,150 ft amsl).

E.2.3 Contaminant Release Mechanisms and Migration Pathways

Based on the information presented above, the following contaminant release mechanisms and migration pathways have been identified at the AOC:

- Contaminant leaching from soil to the water table (vertical migration) and lateral transport to downgradient receptors (i.e., Sand Creek and east/southeast of C Block Quarry).

The principal migration pathway at the AOC is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). However, because of the very heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within the unconsolidated soil are difficult to predict. Precipitation that does not leave the AOC as surface runoff percolates into the subsurface. Some of the percolating water leaves this environment via evapotranspiration after little or no vertical migration.

The remainder of the water percolates into the water table. As discussed in Section E.2.4, the rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Figure E-1 illustrates the contaminant migration conceptual model.

Once the contaminant leachate percolates through the soil and reaches the water table, it migrates with the local groundwater and discharges at the downgradient receptors. The groundwater flow direction was based on five wells gauged in 2017, which creates a radial water table surface (Figure E-3) (TEC-Weston 2018). Groundwater flow likely occurs along preferential pathways (e.g., sand seams, channel deposits, or other stratigraphic discontinuities including discrete fractures) having higher permeabilities. For inorganic chemicals, lateral migration through groundwater will be very limited due to their high retardation by the bedrock material (USACE 2003).

Additional factors that affect the leaching rate include a chemical's solubility, sorption capacity (expressed by the K_d), and the amount of percolation. Insoluble chemicals will precipitate out of the solution in the subsurface or remain in insoluble forms with little leaching.

Another factor that affects whether a chemical will reach the water table through percolation of precipitation is the chemical's rate of decay. Most organic compounds decay at characteristic rates proportional to the chemical's half-life. For a given percolation rate, those chemicals with long half-lives have a greater potential for contaminating groundwater than those with shorter half-lives. For this analysis, the rate of decay/half-life was not considered.

Contaminant releases through gaseous emissions and airborne particulates are not significant at C Block Quarry. VOCs were not found and were either never present, or had already volatilized. The AOC is vegetated, located in a humid temperate climate, and soil moisture is typically high, which prevents dust borne contaminant migration. Therefore, there is likely little to no gaseous emission, and contaminant levels in the air pathway are minor to nonexistent.

E.2.4 Water Budget

The potential for contaminant transport begins with precipitation. Percolation is the driving mechanism for leaching of soil contaminants to groundwater. The actual amount of rainwater available for flow and percolation to groundwater is highly variable and depends upon soil type and climatic conditions. A water balance calculation can be used as a tool to quantitatively account for all components of the hydrologic cycle. The quantified elements of the water balance are used for inputs to the soil leaching and groundwater transport models discussed later. The components of a simple steady-state water balance model include precipitation, evapotranspiration, surface runoff, and groundwater recharge or percolation.

These terms are defined as follows:

$$P = ET + Sr + q \qquad \text{(Equation E-3)}$$

or

$$\text{Rainwater available for flow} = Sr + q = P - ET \qquad \text{(Equation E-4)}$$

Where:

P = precipitation
Sr = surface runoff
ET = evapotranspiration
q = groundwater recharge or percolation

It is expected that loss of runoff also occurs in the form of evaporation. The remaining water, after runoff and evaporation, is available for percolation which includes loss to the atmosphere by evapotranspiration. The water balance estimations were developed using the Hydrologic Evaluation of Landfill Performance (HELP) model (USEPA 1994). See Attachment E.1, Table E.1-3 for parameters used in the HELP model to develop the water budget estimates used in the evaluation. Calculations using precipitation and temperature data for a 100-year period were generated synthetically using coefficients for Cleveland, Ohio (e.g., the nearest weather station to Camp Ravenna with HELP model coefficients).

The annual average water balance estimates indicate an evapotranspiration of 28% (10.3 inches) of total precipitation (37 inches). The remaining 72% (27 inches) of rainwater is available for surface water runoff and percolation to groundwater. Of the 72% (27 inches) of water available for runoff or percolation, groundwater recharge (percolation) accounts for 13% (3.6 inches), and surface runoff (along downgradient topography to nearest surface water bodies) accounts for the remaining 87% (23.4 inches).

E.3 SOIL SCREENING ANALYSIS

Soil screening analyses are screening evaluations performed to identify SRCs with the potential to leach to groundwater as initial CMCOPCs. This section describes the soil screening analysis approach and presents the limitations and assumptions.

E.3.1 Analysis Approach

The five steps for the soil leachability analysis are illustrated in Figure E-2 and are described below.

The first step of the soil screening analysis is developing SRCs, as presented Section 4.0 of the RI Report. A summary of SRCs identified for soil is presented in Section E.1.

The second step of the soil screening process (Figure E-2) involves comparing maximum concentrations of SRCs with MCL-based generic soil screening levels (GSSLs). GSSLs were developed for Superfund sites for contaminant migration to groundwater (USEPA 1996, USEPA 2015). The GSSL is defined as the concentration of a chemical in soil that represents a level of contamination below which there is no concern for impacts to groundwater under CERCLA, provided conditions associated with USEPA risk-based soil screening level (SSLs) are met. Generally, if chemical concentrations in soil fall below the GSSL, and there are no groundwater receptors of concern or anticipated exposures, then no further study or action is warranted for that chemical. If the GSSL for a chemical is not available, the USEPA risk-based SSL for groundwater migration, dated June 2015 (USEPA 2015), obtained from the USEPA RSL website is used. If neither the GSSL nor the USEPA risk-based SSL for a chemical are available, then no further evaluation of the chemical is performed and it is eliminated from the list of initial CMCOPCs. However, some chemicals have been assigned surrogates by risk assessors if the chemical without an SSL is similar to another chemical with an SSL. Surrogates used for this analysis include pyrene for benzo(ghi)perylene and phenanthrene.

The initial CMCOPC screen, as presented in Attachment E.1, Table E.1-4, eliminates 3 inorganic SRCs, including trivalent chromium and mercury, and 12 organic SRCs from further consideration. There were five inorganic and five organic SRCs carried forward to the third step of the initial soil CMCOPC screening process.

The third step of the soil screening process (Figure E-2) involves comparing the maximum chemical concentrations with the site-specific soil screening level (SSSLs). The SSSL is defined as the GSSL (or the USEPA risk-based SSL for groundwater protection if a GSSL is not available) multiplied by the AOC-specific dilution attenuation factor (DAF). Direct partitioning is used to derive the GSSLs, assuming groundwater is in contact with the chemicals in soil and the groundwater concentration is equal to the leachate concentration. However, as leachate moves through soil, chemical concentrations are attenuated by adsorption and degradation. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations. This concentration reduction can be expressed by a DAF. DAFs can vary based on AOC-specific characteristics (e.g., hydrogeologic properties, contaminated source area, and depth to contamination). As described in the *Soil Screening Guidance: Technical Background Document* (USEPA 1996), chemical dilution in groundwater is estimated at each AOC from an AOC-specific DAF. The DAF, which is defined as the ratio of soil leachate concentration to receptor point concentration, is minimally equal to one. Dilution in groundwater is derived from a simple mixing zone equation (Equation E-5) and relies upon estimating the mixing zone depth (Equation E-6).

$$\mathrm{DAF} = 1 + \frac{(\mathrm{K} \times i \times \mathrm{d})}{(\mathrm{q} \times \mathrm{L})} \qquad \text{(Equation E-5)}$$

Where:

DAF = dilution attenuation factor
K = aquifer hydraulic conductivity (m/yr)
i = horizontal hydraulic gradient (m/m)
q = percolation rate (m/yr)
L = source length parallel to groundwater flow (m)
d = mixing zone depth (m) (which is defined below)

and

$$d = \sqrt{0.0112 \times L^2} + d_a \times \left[1 - \exp\left(\frac{-L \times I}{K \times i \times d_a} \right) \right] \qquad \text{(Equation E-6)}$$

Where:

d_a = aquifer thickness (m)

$d \leq d_a$

As stated above, if the aquifer thickness is less than the calculated mixing zone depth, then the aquifer thickness is used for “d” in the DAF calculation. The DAF calculation for the AOC is presented in Attachment E.1, Table E.1-5. It should be noted that the purpose of this screen is not to identify chemicals that may pose risk at downgradient locations, but to target those chemicals that pose the greatest problem if they migrate from the AOC.

Based on this screening and an AOC-specific DAF of 1.85, benzo(b)fluoranthene was eliminated from further consideration. All the remaining SRCs exceeded their respective SSSLs and were identified as initial CMCOPCs based on leaching to groundwater. The SRCs identified as initial CMCOPCs are presented in Attachment E.1, Table E.1-6. The horizontal hydraulic gradient (0.0028 ft/ft) used in this analysis was based on a groundwater potentiometric surface using water level data collected in 2012. This hydraulic gradient is significantly lower than the gradient (0.005 ft/ft) based on a revised groundwater potentiometric surface using 2017 water level data. The DAF would increase to 2.41 if the hydraulic gradient from 2017 water level data was used, thereby increasing the SSSL values and potentially decreasing the number of initial CMCOPCs.

The fourth step of the soil screening process (Figure E-2) involves eliminating initial CMCOPCs identified in the SSSL evaluation from further consideration that require more than 1,000 years to leach through the unsaturated zone before reaching the water table. A period of 1,000 years was conservatively selected to evaluate eventual migration of the contaminant front to the water table despite uncertainties in vadose zone hydraulic parameters and groundwater recharge over time. Additionally, USACE suggests a screening value of 1,000 years be used due to the high uncertainty associated with predicting conditions beyond that time frame (USACE 2003). Therefore, the initial CMCOPCs at the selected sources were screened against a travel time of greater than 1,000 years. The travel time in this screen is the time required for an initial CMCOPC to migrate vertically from the base of the soil interval detected above the background concentration to the water table. This distance is the leaching zone, as evaluated in Attachment E.1, Table E.1-7, which may vary across the AOC based on the varying depths of soil sample concentrations above the facility-wide background concentrations or SSSLs and the elevation of the water table. The estimated travel time for each initial CMCOPC to reach the water table is determined using the following equations:

$$T = \frac{Lz \times R}{V_p} \qquad \text{(Equation E-7)}$$

Where:

T = leachate travel time (year)

Lz = thickness of attenuation zone (ft)

R = retardation factor (dimensionless) (Equation 6-2)
V_p = porewater velocity (ft/year)

and

$$V_p = \frac{q}{\theta_w} \qquad \text{(Equation E-8)}$$

Where:
q = percolation rate (ft/year)
θ_w = fraction of total porosity that is filled by water

If the travel time for a chemical from a source area exceeded 1,000 years, then the chemical was eliminated from the list of initial CMCOPCs. Six inorganic SRCs, including hexavalent chromium and lead, and organic SRCs were eliminated from further consideration based on their travel times exceeding 1,000 years. Initial CMCOPCs with travel times less than 1,000 years (TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT) were retained for further evaluation (Attachment E.1, Table E.1-7) using the Seasonal Soil Compartment (SESOIL) model. The constituents selected for further evaluation with SESOIL modeling are listed in Table E-1.

In the fifth step (Figure E-2), the initial CMCOPCs (presented in Table E-1) were further evaluated using fate and transport models provided in Section E.4.

E.3.2 Limitations and Assumptions of Soil Screening Analysis

It is important to recognize that acceptable soil concentrations for individual chemicals are highly AOC-specific. The GSSLs used in this screening are based on a number of default assumptions chosen to be protective of human health for most AOC conditions (USEPA 1996). These GSSLs are expected to be more conservative than SSSLs based on AOC conditions. The conservative assumptions included in this analysis are: (1) no adsorption in the unsaturated zone or in the aquifer, (2) no biological or chemical degradation in the soil or aquifer, and (3) contamination is uniformly distributed throughout the source. However, the GSSL does not incorporate the contamination already existing within the aquifer.

E.4 FATE AND TRANSPORT MODELING

Contaminant fate and transport modeling represents the fifth step in the fate and transport screening and evaluation process (Figure E-2). SESOIL modeling was performed for chemicals identified as initial CMCOPCs from the soil screening analysis presented in Section E.3 and summarized in Table E-1. SESOIL modeling was performed to predict chemical concentrations in the leachate immediately beneath the selected source areas and just above the water table. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL), it was identified as a final CMCOPC and was further evaluated qualitatively based on its mobility, potential dispersion and degradation, and its observed concentration in recent groundwater sampling data to identify whether the CMCOPC would be impacting site groundwater.

The Analytical Transient 1-, 2-, 3-Dimensional (AT123D) model, which is generally used to predict future maximum concentrations in groundwater beneath a source and at downgradient receptor locations for RVAAP AOCs in order to identify the initial CMCOCs, will not be applied for C Block Quarry because the model would not adequately predict contaminant migration through this AOC's highly heterogenous hydrogeologic system.

E.4.1 Modeling Approach

Contaminant transport includes the movement of water and dissolved material from the source areas to groundwater. This occurs as rainwater infiltrates the surface and percolates through the area of contamination, its surrounding soil, and into the saturated zone. The downward movement of water, driven by gravitational potential, capillary pressure, and other components of total fluid potential mobilizes the contaminants and carries them through the soil into the mixing zone with the water table. Lateral transport within the shallow bedrock is controlled by the groundwater gradient, fractures, and hydraulic conductivity. Vertical transport through the overburden to the water table is evaluated with the SESOIL model, and the concentration in the groundwater beneath the source due to mixing of leachate with flowing groundwater in the shallow bedrock is estimated by applying DAF to the leachate concentration. The lateral transport to downgradient receptor locations, conceptually illustrated in Figure E-1, is not simulated.

The output of the contaminant fate and transport modeling is presented as the expected maximum concentration of modeled contaminants at the selected receptor locations. For SESOIL, the receptor location is the groundwater table beneath the source area. For this analysis, one ISM Area (CBLss-004M-SO) was considered as the source of contamination based on the results of the soil screening analysis. A separate SESOIL analysis was performed for each initial CMCOPC listed in Table E-1 and is presented in Figure E-3.

The predicted maximum leachate concentration just above the water table, observed in the SESOIL results, was compared against its applicable RVAAP facility-wide background concentration, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCLs, and RSLs. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL), the initial CMCOPC was identified as a final CMCOPC and was further evaluated using WOE discussion, including a comparison to groundwater monitoring results for the AOC (if available).

If a predicted maximum leachate concentration was lower than the screening criteria, the chemical was no longer considered a CMCOPC.

For chemicals identified as final CMCOPCs, the SESOIL predicted maximum concentrations in the leachate just above the water table were divided by the DAF to estimate the concentrations in groundwater directly below the source areas and the estimated concentrations were compared to the applicable RVAAP facility-wide background concentrations, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCLs, and RSLs. If the predicted maximum concentration of a final CMCOPC was higher than its facility-wide background concentration and the lowest risk-based screening value (i.e., Resident Receptor Adult FWCUG, MCL, or RSL), the chemical was retained as an initial CMCOC for WOE evaluation.

The initial CMCOCs identified by modeling results were evaluated with respect to WOE for retaining or eliminating CMCOCs from further consideration as a basis for potential soil remedial actions. Lines of evidence include validating modeling results using available AOC-specific groundwater monitoring data. Modeled timelines for potential leaching were evaluated with respect to estimated times for contaminant releases during RVAAP operations to determine if peak leaching concentrations would likely have occurred in the past. Some initial CMCOCs present at or below RVAAP soil background concentrations may have predicted leachate or groundwater concentrations exceeding risk-based criteria due to conservative model assumptions; therefore, these were also identified and considered in the evaluation. Additionally, identified initial CMCOCs were compared to COCs identified in the HHRA to determine if they had an associated risk related to direct exposure to soil or if initial CMCOCs and COCs were co-located and may be addressed simultaneously under a potential remedial action.

E.4.2 Model Applications

The SESOIL model (GSC 1998) used for leachate modeling, when applicable, estimates pollutant concentrations in the soil profile following introduction via direct application and/or interaction with transport media. The application of the model is discussed in the following subsections.

E.4.2.1 SESOIL Modeling

The SESOIL model defines the soil column as compartments extending from the ground surface through the unsaturated zone and to the upper level of the saturated soil zone or top of bedrock. Processes simulated in SESOIL are categorized in three cycles: hydrologic, sedimentation, and pollutant. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, percolation, soil-water content, evapotranspiration, and groundwater recharge. The sediment washload cycle includes erosion and sediment transport. The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A chemical in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure). Data requirements for SESOIL are not extensive and utilize a minimum of AOC-specific soil and chemical parameters and monthly or seasonal meteorological values as input.

The SESOIL model output includes pollutant concentrations at various soil depths and pollutant loss from the unsaturated soil zone in terms of surface runoff, percolation to groundwater, volatilization, and degradation. The mathematical representations in SESOIL generally consider the rate at which the modeled processes occur, the interaction of different processes with each other, and the initial conditions of the waste area and surrounding subsurface matrix material.

The input data for SESOIL can be grouped into four types: climatic, chemical, soil, and application. There are 61 separate parameters contained in these four data groups. Wherever possible, AOC-specific parameter values were used for modeling. However, certain parameters were not available for the source areas and were estimated based on pertinent scientific literature, geochemical investigations, and checks for consistency between model results and historical data. Conservative estimates were used when a range of values existed or parameter values were not available.

E.4.2.2 Climate Data

The climatic data file of SESOIL consists of an array of mean monthly temperature, mean monthly cloud cover fraction, average monthly relative humidity, average monthly reflectivity of the earth's surface (i.e., shortwave albedo), average daily evapotranspiration, monthly precipitation, mean number of storm events per month, mean duration of rainfall, and mean length of rainy season. The climatic data are presented in Attachment E.1, Table E.1-8. The data set was taken from the Youngstown National Weather Service Office weather station at the Youngstown-Warren Regional Airport in Vienna, Ohio, as it was determined to be most appropriate in corresponding to the latitude and longitude at Camp Ravenna.

Climate data from the Youngstown weather station did not have all of the necessary climatic parameters for the HELP model simulation. Accordingly, the water balance evaluation presented in Section E.2.4 was based on the nearest available weather station data with all necessary coefficients stored within the HELP model (Cleveland, Ohio). Inputs for the SESOIL model (Youngstown station) and HELP model (Cleveland station) produced virtually the same recharge rate (9.40 cm/yr for Cleveland and 9.42 cm/yr for Youngstown) for each location. Therefore, using the two different weather station data sets did not impact modeling results.

E.4.2.3 Chemical Data

The pollutant fate cycle of SESOIL focuses on various chemical transport and transformation processes that may occur in the soil zone. These processes include volatilization/diffusion, adsorption/desorption, cation exchange, biodegradation and hydrolysis, and metal complexation. The chemical-specific parameters used for SESOIL are presented in Attachment E.1, Table E.1-9. The distribution coefficients (K_ds) for inorganic chemicals and the K_{oc} values for organic chemicals were obtained from the chemical-specific parameter table associated with the USEPA risk-based generic screening tables (USEPA 2015). The K_ds for organic chemicals were estimated from organic, carbon-based K_{oc} using the relationship $K_d = (f_{oc})(K_{oc})$, where f_{oc} = mass fraction of the organic carbon soil content obtained from AOC-specific measurements. In general, biodegradation rates are not applicable for inorganic CMCOPCs and biodegradation was not considered for the organic chemicals in this evaluation.

E.4.2.4 Soil Data

The soil data file of SESOIL contains input parameters describing the physical characteristics of the subsurface soil and is presented in Table E-2. These parameters include soil bulk density, intrinsic permeability, soil disconnectedness index, soil porosity, organic carbon content, and cation exchange capacity. AOC-specific data were used from geotechnical samples collected at the AOC during the PBA08 RI. There is, however, no measurement method for the soil disconnectedness index or a measured value of the Freundlich exponent. Soil disconnectedness index is a parameter that relates the soil permeability to the moisture content. Thus, SESOIL default values were used for these two parameters.

An average intrinsic permeability for the vadose zone, representing the unconsolidated zone above the water table, was calibrated using the percolation rate of 9.42 cm/yr (3.6 inches/year) as the calibration target. The model was calibrated against the percolation rate by varying the intrinsic permeability and keeping all other AOC-specific geotechnical parameters fixed. The final hydrogeologic parameter values used in this modeling are shown in Table E-2. The soil porosity was set to the AOC-specific value. The intrinsic permeability, calibrated in SESOIL to the percolation rate (determined from a water balance estimated in HELP), was found to match the AOC-specific measurements from geotechnical samples.

The soil disconnectedness index replaces the moisture retention curves (or characteristic curves) used by other unsaturated zone leaching models. SESOIL's User Guide defines this parameter to be the exponent relating the "wetting" and "drying" time-dependent permeability of soil to its saturated permeability (Hetrick and Scott 1993). This "one variable" approach of using the soil disconnectedness index in SESOIL simplifies the data estimation process and reduces computational time. In addition, this parameter was calibrated for four different soil types ranging from sandy loam to clay (Hetrick et al. 1986), and calibrated values fell within the default range specified in the SESOIL's User Guide.

E.4.2.5 Source Terms

Analytical data from surface and subsurface soil collected at the AOC were used as source terms for SESOIL modeling. All the samples collected at different depth intervals were compiled to provide a detailed loading option for the SESOIL model. The maximum soil concentrations for each initial CMCOPC, listed in Table E-1, were used as source term concentrations for the SESOIL model.

E.4.2.6 Application Data

One layering scheme was developed for the source area based on soil sample data and depths to groundwater. Details of the model layers utilized in this modeling are presented in Attachment E.1, Table E.1-10.

The model was arranged in four layers. The top layer (Layer 1) was 1.5 ft thick and divided into three sublayers that were each 0.5 ft thick. The top sublayer (the top 0.5 ft) was the contaminant loading zone, and the remaining two sublayers of Layer 1 served as the leaching zone (as did Layers 2 and 3, which were each 11.5 ft thick). Layer 4, which was 0.5 ft thick was included just above the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater). The depth to groundwater (~25 ft) used in this analysis was based on the groundwater potentiometric surface from 2012 groundwater elevations. This depth to groundwater is still applicable using the 2017 groundwater potentiometric surface that occurs approximately 32 ft below the topographic high within the AOC (1,172 ft amsl) and approximately 13 ft below the topographic low within the AOC (1,150 ft amsl).

E.4.3 SESOIL Modeling Results

SESOIL modeling was performed for initial CMCOPCs (i.e., TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT) that have the potential to reach the water table within 1,000 years based on the soil screening analysis results (Table E-1). Table E-3 presents the predicted peak leachate concentrations beneath the source area corresponding to the time of peak leachate concentrations. The Resident Receptor Adult FWCUGs, RVAAP facility-wide background concentrations, and MCL/RSL values for the initial CMCOPCs, if available, are also shown in this table for comparison purposes. The predicted leachate concentrations below the source and just above the water table for all initial CMCOPCs were above their respective screening criteria; therefore, they were selected as final CMCOPCs. Attachment E.1, Figures E.1-2 through E.1-4 show the leachate concentrations versus time plots predicted by SESOIL that were divided by the DAF to estimate the concentrations in groundwater beneath the source versus time.

TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT were identified as final soil CMCOPCs based on SESOIL modeling results for the sample location within the AOC where the leachate concentration exceeded its screening criteria. This leachate concentration does not reflect the groundwater concentration beneath the source. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations. Figures E.1-5 through E.1-7 in Attachment E.1 show the estimated groundwater concentrations versus time curves based on dilution of leachate concentrations.

E.4.4 Limitations/Assumptions

In general, a conservative modeling approach was used, which may overestimate the contaminant concentration in the leachate for migration from observed soil concentrations. Listed below are important assumptions used in this analysis:

- The contaminant fate and transport evaluation included not only chemicals identified as being previously used during historical operations, but also included all chemicals identified as soil SRCs during the data screening and reduction process.
- Some soil SRCs were identified due to the absence of a background concentration or as having limited or slight exceedances of the established background concentrations.
- Chemical and biological degradation rates for organic CMCOPCs were not considered in the SESOIL model.
- Using K_d and R to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid-phase and solution-phase concentrations and that the relationship is linear and reversible.
- Since AOC-specific data are not available, the K_d and K_{oc} values used in this analysis for all CMCOPCs represent literature or calculated values and may not represent conditions at the AOC.

- The K_d for inorganic chemicals used in the modeling evaluation assumed a pH of 6.8 [i.e., the middle value in USEPA's evaluation presented in the soil screening guidance document (USEPA 1996)]. The K_d for inorganic chemicals varies with pH (generally decreasing with decreasing pH, although there are few exceptions); therefore, if AOC-specific pH measurements are greater or less than 6.8, the K_d and calculated screening parameters (such as R) will deviate from those presented here.
- Flow and transport in the vadose zone is one-dimensional (i.e., only in the vertical direction). This modeling used the current soil concentrations that were collected approximately 65 years after historical operations were terminated at the AOC. Therefore, it does not account for constituents that have already leached to groundwater.
- Flow and transport are not affected by density variations. Variability in the distribution of soil contamination and overall impacts to predicted groundwater concentrations were not considered in the models. A realistic distribution of soil contamination was not considered. The maximum concentration value was used as the source term concentrations for SESOIL model layers; this is a highly conservative assumption that is expected to produce higher leachate concentrations for CMCOPCs than the average condition. The horizontal distribution of soil contamination was assumed based on concentration levels from nearby sample locations as opposed to taking into account the entire area.
- The water balance represents an overall average rainwater recharge and assumes an even distribution of infiltration in the modeled area. An average water balance assumes some areas will have higher or lower recharge based on the heterogeneity of the soil and varying topography.
- The horizontal gradient and depth to groundwater used in this analysis were based on the potentiometric surface generated from 2012 water level data. Using these parameters results in a more conservative or equivalent assessment compared to using water level data from 2017.

The inherent uncertainties associated with using these assumptions must be recognized. K_d values are highly sensitive to changes in the major chemistry of the solution phase. Therefore, it is important that the values be measured or estimated under conditions that will closely represent those of the contaminant plume. Deviations of actual AOC-specific parameter values from assumed literature values may significantly affect contaminant fate predictions. It is also important to note that the contaminant plume will change over time and will be affected by multiple solutes present at the AOC. The effects of heterogeneity, anisotropy, and spatial distribution of fractures are not addressed in these simulations. The present modeling study using SESOIL does not address the effects of flow and contaminant transport across interfaces in rapidly varying heterogeneous media.

E.5 EVALUATION TO IDENTIFY CMCOCS

This evaluation of contaminant fate and transport uses a soil screening analysis to identify SRCs that have potential to leach to groundwater, performs SESOIL modeling to conservatively estimate final CMCOPC leachate concentrations before the SRCs enter the groundwater system beneath the sources with highest level of contamination, and uses a simple dilution factor to present a conservative maximum concentration in groundwater of final CMCOPCs beneath the sources.

The limitations and assumptions of the overall process are presented in Section E.4.6. The text below provides a list of the remaining CMCOCs after applying a dilution factor to SESOIL modeling results. This qualitative assessment of the results and considerations of the limitations and assumptions will determine if C Block Quarry has CMCOCs.

TNT – The maximum surface soil concentration for TNT (22 mg/kg) was below the Resident Receptor Adult FWCUG at a TR of 1E-06, but slightly above at HQ of 0.1 (i.e., 21.1 mg/kg), and TNT was not considered a COC in the HHRA. TNT modeling results indicate concentrations in groundwater beneath the source area could potentially exceed its RSL and the Resident Receptor Adult FWCUG within 12 years. Based on the AOC period of operations, TNT should have already been detected in the existing groundwater. However, TNT was not detected in groundwater samples collected at the AOC; therefore, this evaluation concludes that the model-predicted concentrations are conservative, and TNT would be expected to be below its SL based on its estimated site-specific biodegradation rate.

2-Amino-4,6-DNT – The maximum surface soil concentration for 2-amino-4,6-DNT (0.54 mg/kg) was below the Resident Receptor Adult FWCUG at a HQ of 0.1, TR of 1E-06 (12.8 mg/kg), and 2-amino-4,6-DNT was not considered a COPC in the HHRA. 2-Amino-4,6-DNT modeling results indicate concentrations in groundwater beneath the source area could potentially exceed its RSL and the Resident Receptor Adult FWCUG within 10 years. Based on the AOC period of operations, 2-amino-4,6-DNT should have already been detected in the existing groundwater. However, 2-amino-4,6-DNT was not detected in groundwater samples collected at the AOC; therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 2-amino-4,6-DNT would be expected to be below its SL based on its estimated site-specific biodegradation rate.

4-Amino-2,6-DNT – The maximum surface soil concentration for 4-amino-2,6-DNT (0.64 mg/kg) was below the Resident Receptor Adult FWCUG at a HQ of 0.1, TR of 1E-06 (12.8 mg/kg), and 4-amino-2,6-DNT was not considered a COPC in the HHRA. 4-Amino-2,6-DNT modeling results indicate concentrations in groundwater beneath the source area could potentially exceed its RSL and the Resident Receptor Adult FWCUG within 10 years. Based on the AOC period of operations, 4-amino-2,6-DNT should have already been detected in the existing groundwater. However, 4-amino-2,6-DNT was not detected in groundwater samples collected at the AOC; therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 4-amino-2,6-DNT would be expected to be below its SL based on its estimated site-specific biodegradation rate.

This qualitative assessment concludes that the soil contaminants identified as initial CMCOCs for evaluation, due to predicted groundwater concentrations beneath a source, are not adversely impacting groundwater quality based on current data and are not predicted to have future impacts. Potential additional investigation under the Facility-wide Groundwater AOC may be warranted, but based on the fate and transport evaluation, CMCOCs are not identified for C Block Quarry, and no further action is required of soil to be protective of groundwater.

E.6 SUMMARY AND CONCLUSIONS

Inorganic and organic SRCs exist in surface and subsurface soil at C Block Quarry. These SRCs include chemicals that were identified as potential contaminants from previous site usage and chemicals that were identified from the SRC screening process using available data. All SRCs were further evaluated to determine if residual concentrations in soil may potentially impact groundwater quality and warrant evaluation in an FS.

All SRCs identified in surface and subsurface soil at C Block Quarry were evaluated through the stepwise fate and transport evaluation. Among the potential contaminants from previous use, chromium and mercury were eliminated from potentially impacting groundwater through soil screening analysis (i.e., by comparing their maximum soil concentrations to the MCL-based GSSLs); and lead and hexavalent chromium were eliminated since their travel times to reach the water table from the source area exceeded 1,000 years.

Evaluation of modeling results identified TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT as initial CMCOCs. These initial CMCOCs were predicted to exceed the screening criteria in groundwater beneath the source area; however, none of these were detected in historical AOC groundwater samples collected.

A qualitative assessment of the sample results was performed and the limitations and assumptions of the models were considered to identify if any CMCOCs are present in soil at C Block Quarry that may potentially impact groundwater at C Block Quarry. Modeling results indicated that the predicted concentrations in groundwater beneath the source area could potentially exceed the RSLs and the Resident Receptor Adult FWCUGs within 10 to 15 years. Based on the AOC period of operations, these constituents should have already been detected in groundwater. However, none of these constituents are detected in groundwater, likely due to biodegradation, which is not accounted in the conservative modeling. This qualitative assessment concluded that CMCOPCs are not adversely impacting groundwater quality based on current data and are not predicted to have future impacts. No further action is required for soil to be protective of groundwater.

Table E–1. Initial CMCOPCs Evaluated with SESOIL Modeling

Initial CMCOPCs	Maximum Concentrations (mg/kg)	ISM Area	Sample Depth (ft bgs)	Leachate Modeling Required? (Yes/No)
Organic Chemicals – Explosives				
2,4,6-Trinitrotoluene	2.20E+01	CBLss-004M-SO	0–0.5	Yes
2-Amino-4,6-dinitrotoluene	5.40E-01	CBLss-004M-SO	0–0.5	Yes
4-Amino-2,6-dinitrotoluene	6.40E-01	CBLss-004M-SO	0–0.5	Yes

bgs = Below ground surface.
CMCOPC = Contaminant migration chemical of potential concern.
ft = Feet.
ISM = Incremental sampling methodology.
mg/kg = Milligrams per kilogram.

Table E–2. Unit-Specific Parameters Used in SESOIL and Dilution Modeling

Parameters	**Symbol**	**Units**	**Value**	**Source for Value**
				SESOIL
Percolation Rate (Recharge Rate)	q	m/yr	9.42E-02	0.1 SESOIL Precipitation for Youngstown, Ohio
Horizontal Area of Aggregate	A_p	cm^2	4.04E+06	Based on CBLss-004M ISM area at C Block Quarry
Intrinsic Permeability - clayey sand	p	cm^2	1.05E-10	Calibrated from SESOIL model
Disconnectedness Index	c	unitless	11	Calibrated from SESOIL model
Freundlich Equation Exponent	n	unitless	1	SESOIL default
Fraction Organic Carbon	f_{oc}	unitless	6.70E-04	Average from the PBA08 RI Geotechnical Sample CBLSB-010-5269-SO
Bulk Density	ρ_b	kg/L	1.74	
Moisture Content	w	wt %	13.6	
Water-filled Soil Porosity	Tw	unitless	0.237	
Air-filled Soil Porosity	Ta	unitless	0.114	
Porosity – total	n_T	unitless	0.351	
Vadose Zone Thickness	Vz	m	7.62	Average based on ground surface elevations and depth to water table from potentiometric surface from 2012 water level data.
Leaching Zone Thickness	Th	m	7.47	Average based on ground surface elevations and depth to water table from potentiometric surface from 2012 water level data.
Aquifer Thickness	h	m	6	Conservative assumption for sallow bedrock aquifer. Facility-wide assumption for the unconsolidated aquifer presented the Load Line 1 investigation was 6 meters (USACE 2003)
Hydraulic Conductivity in Saturated Zone	K_S	cm/s	3.80E-04	Average of slug test results (MKM 2007)
Hydraulic Gradient	i	unitless	2.82E-03	Average gradient determined from potentiometric surface from 2012 water level data.

Table E-2. Unit-Specific Parameters Used in SESOIL and Dilution Modeling (continued)

Parameters	Symbol	Units	Value	Source for Value
Effective porosity	n_e	unitless	0.2	Assumed for sandstone (USEPA 1985)

MKM 2007. Characterization of 14 AOCs at Ravenna Army Ammunition Plant (March 2007).

USACE (U.S. Army Corps of Engineers) 2003b. Phase II Remedial Investigation Report for the Load Line 1 at the Ravenna Army Ammunition Plant, Ravenna, Ohio. June 2003.

USEPA (U.S. Environmental Protection Agency) 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water, Revised 1985 Parts 1 and 2, EPA/600/6-85/002. Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. September 1985.

cm^2 = Square centimeters.
cm/s = Centimeters per second.
kg/L = Kilograms per liter.
m = Meter.
m/yr = Meters per year.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
SESOIL = Seasonal Soil Compartment Model.
wt % = Weight by percent.

Table E–3. Summary of SESOIL Modeling Results

Initial CMCOPC	Maximum Soil Concentration (mg/kg)	ISM Area	Maximum Depth of Contamination (ft bgs)	Depth to Groundwater (ft bgs)	Predicted $C_{\text{leachate, max}}$ Beneath Source (mg/L)	Time Required to Reach $C_{\text{leachate, max}}$ (years)	MCL/RSL (mg/L)	Resident Receptor Adult FWCUG[a] (mg/L)	Facility-wide Background Bedrock Groundwater (mg/L)	Final CMCOPC?[b] (yes/no)
2,4,6-Trinitrotoluene	**2.20E+01**	**CBLss-004M**	**0.5**	**25**	**1.16E+01**	**11**	**2.50E-03**	**1.83E-03**	**None**	**Yes**
2-Amino-4,6-Dinitrotoluene	**5.40E-01**	**CBLss-004M**	**0.5**	**25**	**3.28E-01**	**10**	**3.90E-02**	**7.30E-04**	**None**	**Yes**
4-Amino-2,6-Dinitrotoluene	**6.40E-01**	**CBLss-004M**	**0.5**	**25**	**3.87E-01**	**10**	**3.90E-02**	**7.30E-04**	**None**	**Yes**

[a] The Resident Receptor Adult FWCUG is based on a target risk of 10^{-6} and a hazard quotient of 0.1.

[b] The Final CMCOPC was identified comparing predicted maximum leachate concentration to MCL/RSL, Resident Receptor Adult FWCUGs, and facility-wide background concentrations. A constituent is a final CMCOPC if its predicted leachate concentration is higher than its facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL) within 1,000 years.

bgs = Below ground surface.
CMCOPC = Contaminant migration chemical of potential concern.
ft = Feet.
FWCUG = Facility-wide cleanup goal.
ISM = Incremental sampling methodology.
MCL = Maximum contaminant level.
mg/kg = Milligram per kilogram.
mg/L = Milligram per liter.
RSL = Regional screening level.
SESOIL = Seasonal soil compartment model.
Bold = CMCOPCs exceeding MCL/RSL, Resident Receptor Adult FWCUGs, and facility-wide background concentrations.

Table E–4. Summary of Groundwater Modeling Results

Final CMCOPC	Maximum Leachate Concentration[a] ($C_{leachate, max}$) (mg/L)	Predicted Maximum Groundwater Concentration[b] Beneath Source (mg/L)	Observed Maximum Groundwater Concentrations[c] (mg/L)	MCL/RSL (mg/L)	Resident Receptor Adult FWCUG[d] (mg/L)	Facility-wide Background Bedrock Groundwater (mg/L)	CMCOC for Further WOE Evaluation?[e] (yes/no)
2,4,6-Trinitrotoluene	**1.16E+01**	**6.25E+00**	**ND**	**2.50E-03**	**1.83E-03**	**None**	**Yes**
2-Amino-4,6-Dinitrotoluene	**3.28E-01**	**1.77E-01**	**ND**	**3.90E-02**	**7.30E-04**	**None**	**Yes**
4-Amino-2,6-Dinitrotoluene	**3.87E-01**	**2.09E-01**	**ND**	**3.90E-02**	**7.30E-04**	**None**	**Yes**

[a] Represents SESOIL predicted maximum leachate concentration just above the water table.

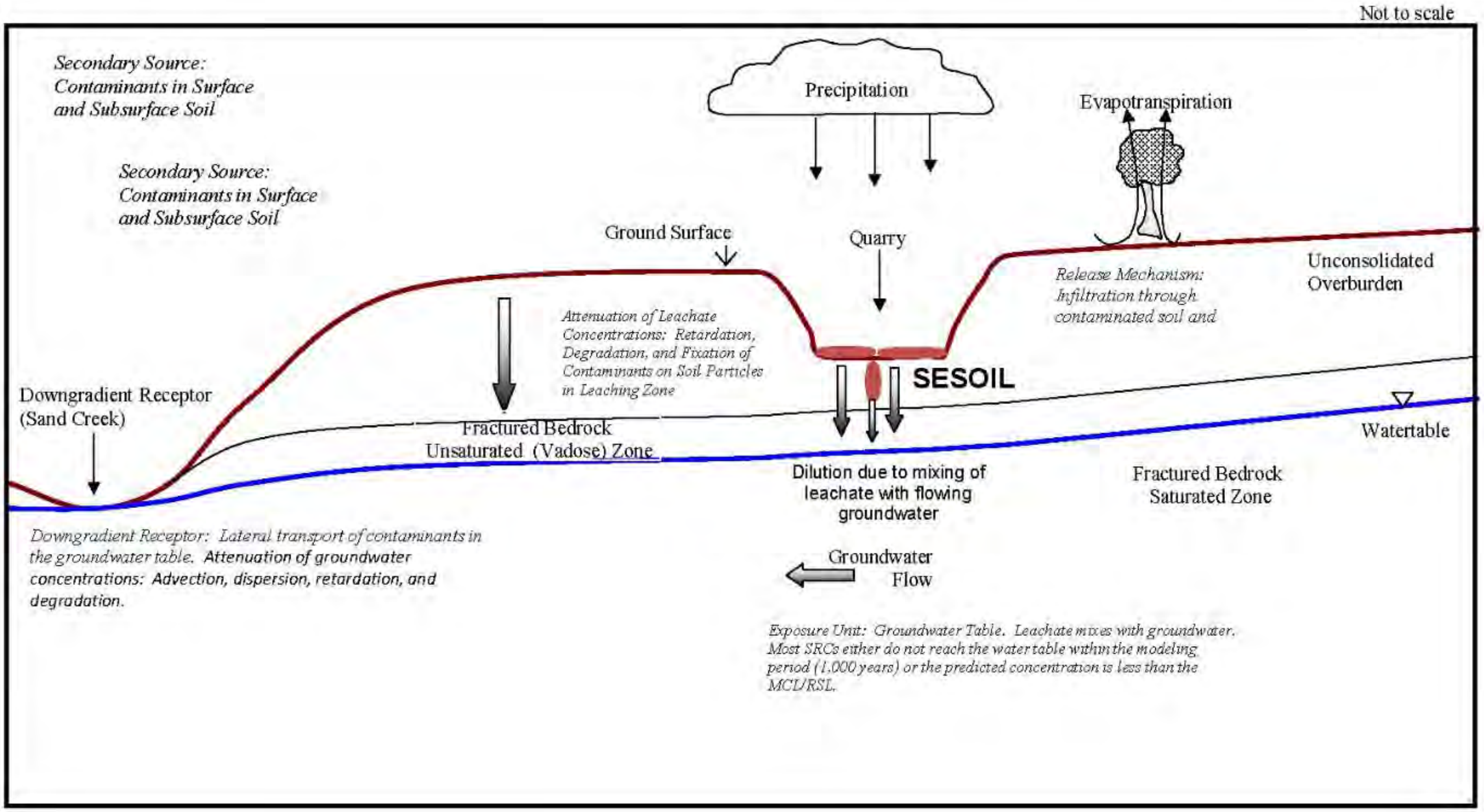
[b] The predicted concentration was estimated using the results from SESOIL and applying DAF.

[c] Observed groundwater concentrations were reported in the *RVAAP Facility-wide Groundwater Monitoring Program 2009 Annual Report* (EQM 2010) and sampling events through 2015 (EQM 2015).

[d] The Resident Receptor Adult FWCUG is based on a target risk of 1E-06 and a hazard quotient of 0.1.

[e] The CMCOC retained for further WOE evaluation was identified by comparing the predicted concentration in groundwater to MCL/RSL, Resident Receptor Adult FWCUGs, and facility-wide background concentrations. A constituent is a CMCOC retained for WOE evaluation if its predicted concentration in groundwater was higher than its facility-wide background concentration, and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL) within 1,000 years.

CMCOC = Contaminant migration chemical of concern.
CMCOPC = Contaminant migration chemical of potential concern.
ft = Feet.
FWCUG = Facility-wide cleanup goal.
MCL = Maximum contaminant level.
mg/L = Milligrams per liter.
ND = Not detected.
RSL = Regional screening level.
SESOIL = Seasonal Soil Compartment Model.
WOE = Weight-of-Evidence
Bold = CMCOPCs exceeding MCL/RSL, FWCUGs, and facility-wide background concentrations.



Secondary Source: Contaminants in Surface and Subsurface Soil

Secondary Source: Contaminants in Surface and Subsurface Soil

Attenuation of Leachate Concentrations: Retardation, Degradation, and Fixation of Contaminants on Soil Particles in Leaching Zone

Release Mechanism: Infiltration through contaminated soil and

Dilution due to mixing of leachate with flowing groundwater

Downgradient Receptor: Lateral transport of contaminants in the groundwater table. *Attenuation of groundwater concentrations: Advection, dispersion, retardation, and degradation.*

Exposure Unit: Groundwater Table. Leachate mixes with groundwater. Most SRCs either do not reach the water table within the modeling period (1,000 years) or the predicted concentration is less than the MCL/RSL.

Figure E–1. Contaminant Migration Conceptual Model

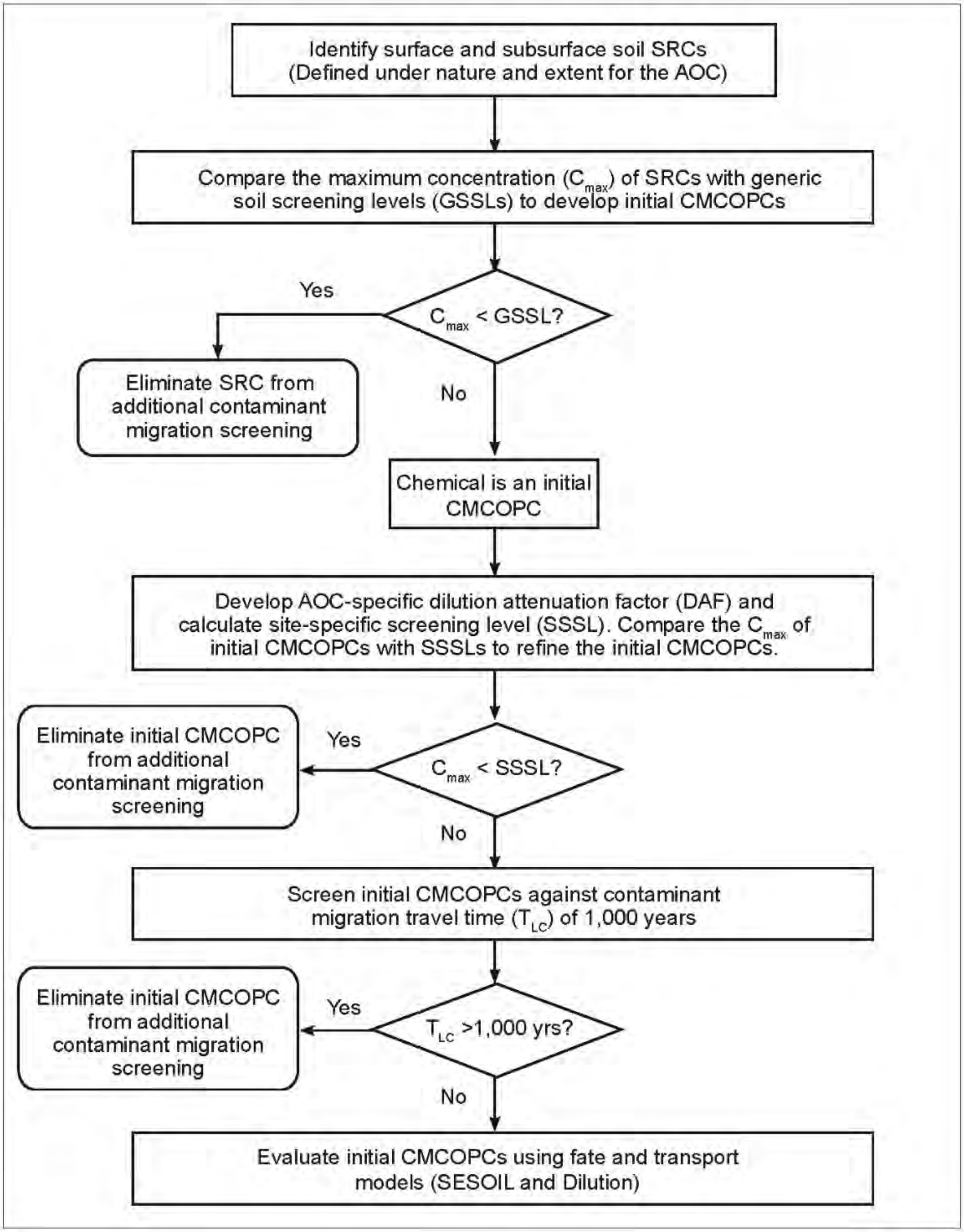


Figure E–2. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation

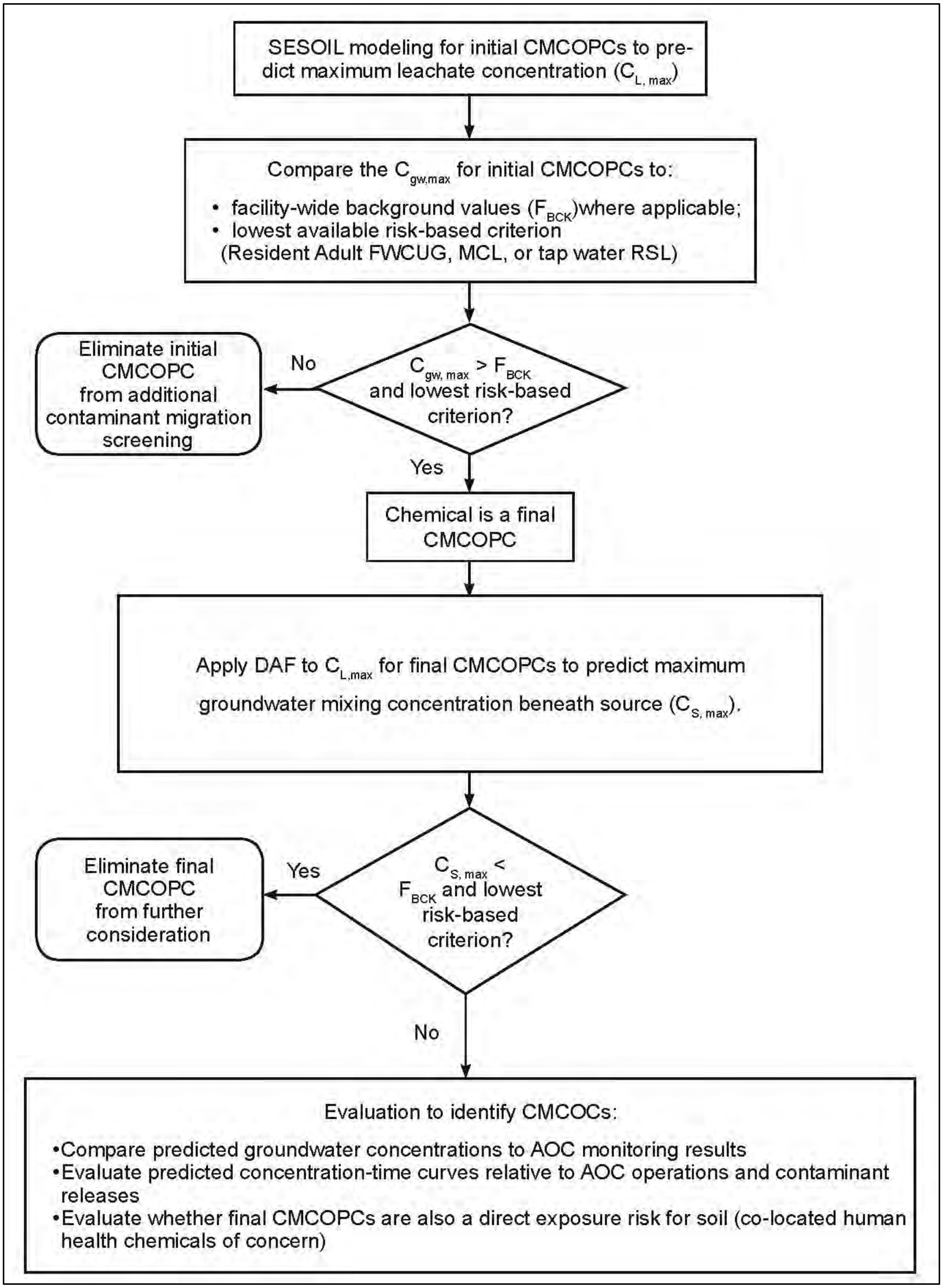
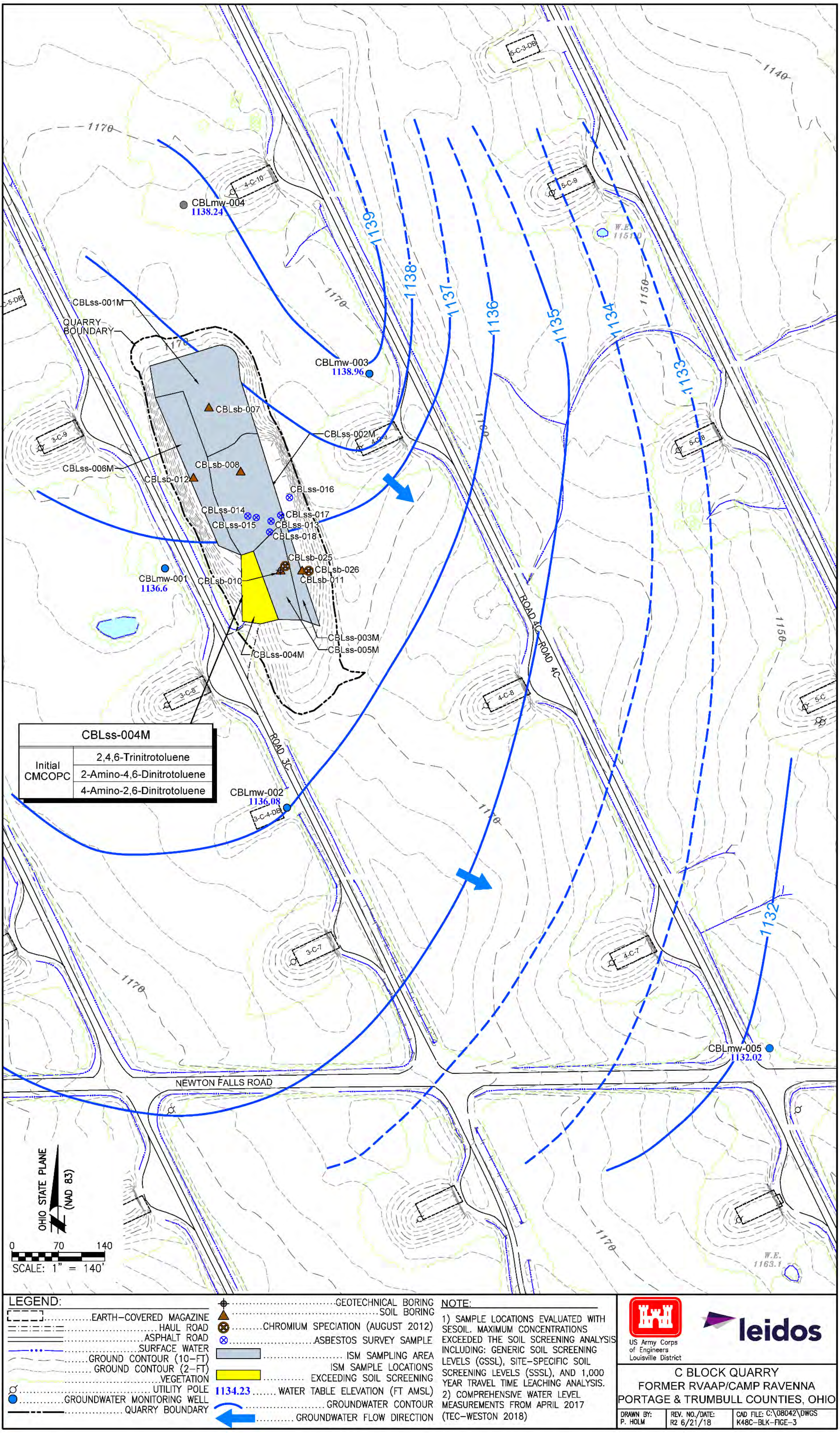


Figure E–2. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation (continued)

THIS PAGE INTENTIONALLY LEFT BLANK.



CBLss-004M	
Initial CMCOPC	2,4,6-Trinitrotoluene
	2-Amino-4,6-Dinitrotoluene
	4-Amino-2,6-Dinitrotoluene

NOTE:

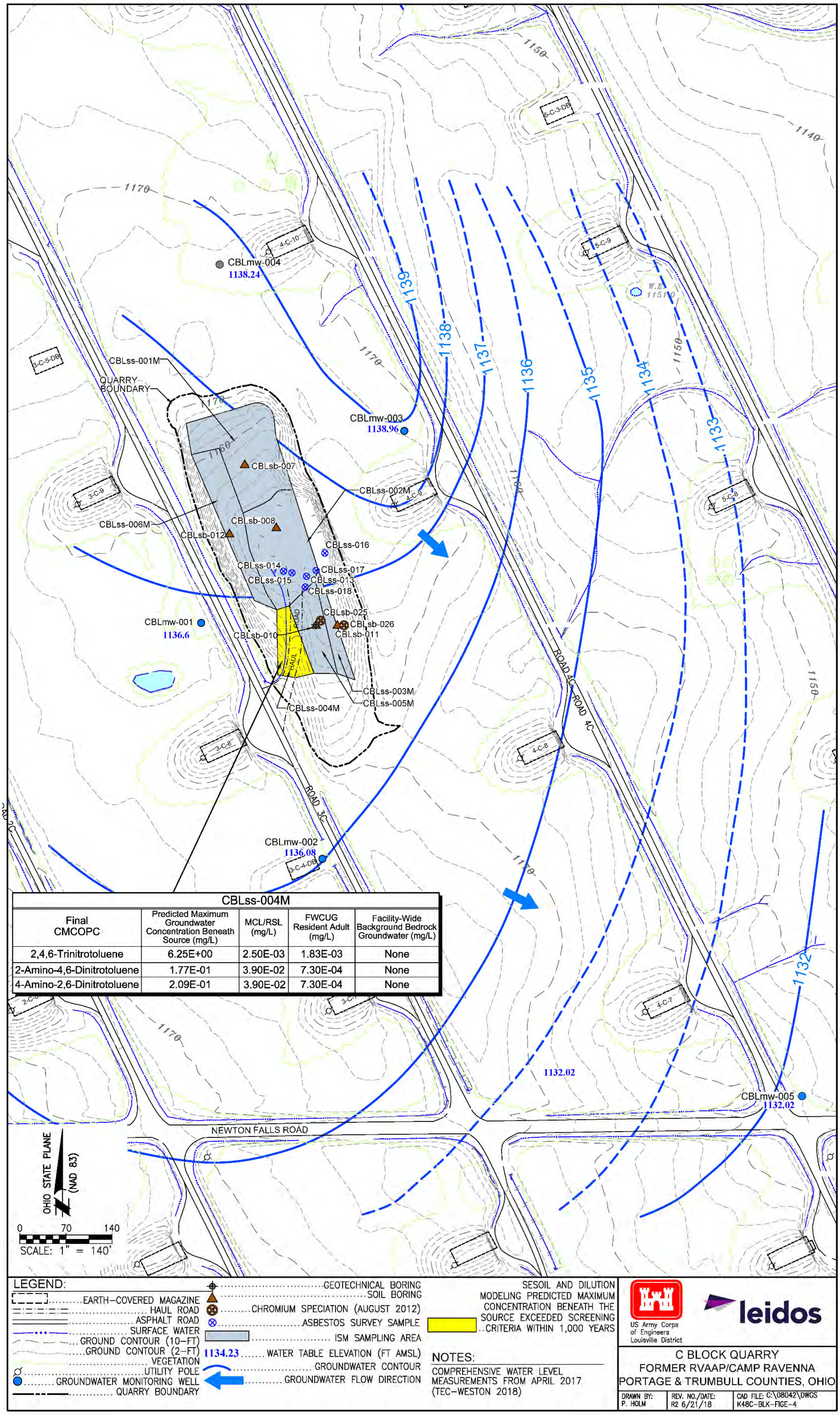
1) SAMPLE LOCATIONS EVALUATED WITH SESOIL. MAXIMUM CONCENTRATIONS EXCEEDED THE SOIL SCREENING ANALYSIS INCLUDING: GENERIC SOIL SCREENING LEVELS (GSSL), SITE-SPECIFIC SOIL SCREENING LEVELS (SSSL), AND 1,000 YEAR TRAVEL TIME LEACHING ANALYSIS.

2) COMPREHENSIVE WATER LEVEL MEASUREMENTS FROM APRIL 2017 (TEC-WESTON 2018)

C BLOCK QUARRY
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	R2 6/21/18	K48C-BLK-FIGE-3

Figure E–3. Initial CMCOPCs Identified in Soil Screening Analysis for SESOIL Evaluation



CBLss-004M

Final CMCOPC	Predicted Maximum Groundwater Concentration Beneath Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)	Facility-Wide Background Bedrock Groundwater (mg/L)
2,4,6-Trinitrotoluene	6.25E+00	2.50E-03	1.83E-03	None
2-Amino-4,6-Dinitrotoluene	1.77E-01	3.90E-02	7.30E-04	None
4-Amino-2,6-Dinitrotoluene	2.09E-01	3.90E-02	7.30E-04	None

NOTES:

COMPREHENSIVE WATER LEVEL MEASUREMENTS FROM APRIL 2017 (TEC–WESTON 2018)

C BLOCK QUARRY
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\08042\DWGS
P. HOLM	R2 6/21/18	K48C–BLK–FIGE–4

Figure E–4. Final CMCOPCs Identified for Further Weight-of-Evidence Evaluation Based on SESOIL and Dilution Modeling

REFERENCES

Cockerham, Lorris, G. and Barbara S. Shane 1994. *Basic Environmental Toxicology*. CRC Press, 29 Boca Raton, Florida. 1994.

Dragun, James 1988. *The Soil Chemistry of Hazardous Materials*. Hazardous Materials Control Research Institute, Silver Spring, MD. 1988.

EQM (Environmental Quality Management, Inc.) 2010. *Facility-wide Groundwater Monitoring Program Annual Report for 2009, Ravenna Army Ammunition Plant, Ravenna, Ohio*. March 2010.

EQM 2015. *Final Facility-wide Groundwater Monitoring Program Annual Report for 2014, Former Ravenna Army Ammunition Plant, Portage and Trumbull Counties, Ohio*. March 2015.

ERDC (U.S. Army Engineer Research and Development Center) 2007. *Development of Environmental Data for Navy, Air Force, and Marine Munitions*. Cold Regions Research and Engineering Laboratory, Arlington, Virginia. June 2007.

Funk, S.B., et al. 1993. *Initial-Phase Optimization for Bioremediation of Munition Compound-Contaminated Soils*. Applied and Environmental Microbiology, Volume 59, No. 7. July 1993.

GSC (General Sciences Corporation) 1998. *SESOIL for Windows*, Version 3.0, Laurel, MD. 1998.

Hetrick, D.M., et al. 1986. *Model Predictions of Watershed Hydrologic Components: Comparison and Verification*. Journal of the American Water Resources Association. October 1986.

Hetrick, D.M. and S.J. Scott 1993. *The New SESOIL User's Guide*, Wisconsin Department of Natural Resources, PUBL-SW-200, Madison, WI. 1993.

Jacobs (Jacobs Engineering Group, Inc.) 1989. *RCRA Facility Assessment, Preliminary Review/ Visual Site Inspection Ravenna Army Ammunition Plant, Ravenna, Ohio*. October 1989.

Lyman, Warren J., et al. 1990. *Handbook of Chemical Property Estimation Methods*. American Chemical Society, Washington, D.C. 1990.

MKM (MKM Engineers, Inc.) 2007. *Final Characterization of 14 AOCs at Ravenna Army Ammunition Plant.* March 2007.

OGE (O'Brien and Gere Engineers, Inc.) 1988. *Hazardous Waste Site Remediation, the Engineer's Perspective*. 1988.

TEC-WESTON Joint Venture 2018. *Draft Facility-wide Groundwater Monitoring Program RVAAP-66 Annual Report for 2017, Former Ravenna Army Ammunition Plant, Portage and Trumbull Counties, Ohio*. February 2018.

USACE (U.S. Army Corps of Engineers) 2003. *Phase II Remedial Investigation Report for the Load Line 1 at the Ravenna Army Ammunition Plant, Ravenna, Ohio*. June 2003.

USACE 2006. *Environmental Transport and Fate Process Descriptors for Propellant Compounds*. June 2006.

USACHPPM (U.S. Army Center for Health Promotion and Preventative Medicine) 2000. *Wildlife Toxicity Assessment for 2,4,6-Trinitrotoluene*. November 2000.

USEPA (U.S. Environmental Protection Agency) 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water, Revised 1985 Parts 1 and 2, EPA/600/6-85/002*. Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. September 1985.

USEPA 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3*. EPA/600/R-94/168b, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC. September 1994.

USEPA 1996. *Soil Screening Guidance: Technical Background Document*. Office of Solid Waste and Emergency Response, Washington, D.C. May 1996.

USEPA 2015. Risk-Based Screening Table-Generic Tables. Website: http://www.epa.gov/risk/risk-based-screening-table-generic-tables. June 2015.

ATTACHMENT E.1

Supporting Information for Fate and Transport Modeling Results

TABLES

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK.

Tables

Table E.1-1. Physical and Chemical Properties of Inorganic SRCs in Surface and Subsurface Soil at C Block Quarry

Analyte	K_d (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	C_w (mg/L)	SSL Type	Generic SSL (mg/kg)	Reference	SSL Type
Metals									
Arsenic	2.90E+01	a	NA	-	1.00E-02	MCL	2.90E-01	a	MCL
Cadmium	7.50E+01	a	NA	-	5.00E-03	MCL	3.80E-01	a	MCL
Chromium	1.80E+06	a	NA	-	1.00E-01	MCL	1.80E+05	a	MCL
Chromium, hexavalent	1.90E+01	a	NA	-	3.50E-05	RSL	6.70E-04	a	Risk
Copper	3.50E+01	a	NA	-	1.30E+00	MCL	4.60E+01	a	MCL
Lead	9.00E+02	a	NA	-	1.50E-02	MCL	1.40E+01	a	MCL
Mercury	5.20E+01	a	1.14E-02	a	2.00E-03	MCL	1.00E-01	a	MCL
Thallium	7.10E+01	a	NA	-	2.00E-03	MCL	1.40E-01	a	MCL

[a] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.
atm-m^3/mol = atmospheres-Cubic meters per Mole.
C_w = Target groundwater concentration (either MCL or RSL).
HLC = Henry's Law Constant.
K_d = Distribution coefficient.
L/kg = Liters per kilogram.
MCL = Clean Water Act drinking water maximum contaminant level.
mg/L = Milligrams per liter.
mg/kg = Milligrams per kilogram
NA = Not applicable.
RSL = USEPA regional screening level (USEPA 2015).
SRC = Site-related contaminant.
SSL = Soil screening level.

Table E.1-2. Physical and Chemical Properties of Organic SRCs in Surface and Subsurface Soil at C Block Quarry

Analyte	K_{oc} (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	C_w (mg/L)	SSL Type	Generic SSL (mg/kg)	Reference	SSL Type
Explosives									
2,4,6-Trinitrotoluene	2.81E+03	a	2.08E-08	a	2.50E-03	RSL	1.50E-02	a	Risk
2-Amino-4,6-dinitrotoluene	2.83E+02	a	1.62E-10	a	3.90E-02	RSL	3.00E-02	a	Risk
4-Amino-2,6-dinitrotoluene	2.83E+02	a	1.62E-10	a	3.90E-02	RSL	3.00E-02	a	Risk
Nitrocellulose	1.00E+01	a	3.29E-23	a	6.00E+04	RSL	1.30E+04	a	Risk
Semi-volatile Organic Compounds									
Anthracene	1.64E+04	a	5.56E-05	a	1.80E+00	RSL	5.80E+01	a	Risk
Benz(*a*)anthracene	1.77E+05	a	1.20E-05	a	1.20E-05	RSL	4.25E-03	a	Risk
Benzo(*a*)pyrene	5.87E+05	a	4.57E-07	a	2.00E-04	MCL	2.40E-01	a	MCL
Benzo(*b*)fluoranthene	5.99E+05	a	6.57E-07	a	3.40E-05	RSL	4.10E-02	a	Risk
Benzo(*ghi*)perylene[c]	1.07E+07	b	1.40E-07	b	1.20E-01	RSL	1.30E+01	a	Risk
Benzo(*k*)fluoranthene	5.87E+05	a	5.84E-07	a	3.40E-04	RSL	4.00E-01	a	Risk
Bis(2-ethylhexyl)phthalate	1.20E+05	a	2.70E-07	a	6.00E-03	MCL	1.40E+00	a	MCL
Chrysene	1.81E+05	a	5.23E-06	a	3.40E-03	RSL	1.20E+00	a	Risk
Fluoranthene	5.55E+04	a	8.86E-06	a	8.00E-01	RSL	8.90E+01	a	Risk
Fluorene	9.16E+03	a	9.62E-05	a	2.90E-01	RSL	5.40E+00	a	Risk
Indeno(1,2,3-*cd*)pyrene	1.95E+06	a	3.48E-07	a	3.40E-05	RSL	1.30E-01	a	Risk
Phenanthrene[c]	1.82E+04	b	3.93E-05	b	1.20E-01	RSL	1.30E+01	a	Risk
Pyrene	5.43E+04	a	1.19E-05	a	1.20E-01	RSL	1.30E+01	a	Risk

[a] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

[b] USEPA 1994. Risk Reduction Engineering Laboratory Treatability Database, Version 5.0, Office of Research and Development, Cincinnati, Ohio.

[c] Pyrene C_w and Generic SSL used as a surrogate for benzo(ghi)perylene and phenanthrene.

atm-m^3/mol = Atmospheres-Cubic Meters per Mole.
C_w = Target groundwater concentration (either MCL or RSL).
HLC = Henry's Law Constant.
K_{oc} = Organic carbon partition coefficient.
L/kg = Liters per kilogram.
MCL = Clean Water Act drinking water maximum contaminant level.
mg/L = Milligrams per liter.
mg/kg = Milligrams per kilogram
RSL = USEPA regional screening level (USEPA 2015).
SRC = Site-related contaminant.
SSL = Soil screening level.

Table E.1-3. HELP Model Parameters for Developing Water Balance Estimates

Layer	Layer Type	Thickness (inch)	Effective K (cm/sec)
1	1--Vertical Percolation Layer	60	2.50E-05
2	3--Barrier Soil Liner	84	8.20E-06

Evapotranspiration and Weather Data	
Station Latitude =	41.24
Maximum Leaf Area Index =	3.5
Start of Growing Season (Julian Date) =	120
End of Growing Season (Julian Date) =	290
Evaporative Zone Depth (inch) =	20 (Fair)

General Design and Evaporative Zone Data	
Fraction of Area Allowing Runoff (%) =	100
Default Soil Database Texture =	Silty Clay
Vegetative Cover =	Poor Stand of Grass
Surface Slope (%) =	4
Slope Length (ft) =	500
SCS Runoff Curve Number =	93

Precipitation Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

Temperature Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

Solar Radiation Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

cm/sec = Centimeters per second.
ft = Feet.
HELP = Hydrologic evaluation of landfill performance.
K = Hydraulic conductivity.
SCS = Soil Conservation Service.

Table E.1-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for C Block Quarry

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type (mg/kg)	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL / Total Samples	Sample ID at Maximum Concentration	Date Collected
Metals									
Arsenic	**7440-38-2**	**1.90E+01**	**2.90E-01**	**MCL**	**Yes**	**Exceeds SSL**	**13/ 13**	**CBLss-001M-SO**	**11/04/04**
Cadmium	7440-43-9	1.10E-01	3.80E-01	MCL	No	Below SSL	0/ 13	CBLsb-011-5263-SO	03/23/10
Chromium	7440-47-3	1.00E+03	1.80E+05	MCL	No	Below SSL	0/ 17	CBLss-005M-5877-SO	08/10/12
Chromium, hexavalent	**18540-29-9**	**3.90E+01**	**6.70E-04**	**Risk**	**Yes**	**Exceeds SSL**	**5/ 9**	**CBLsb-025-5879-SO**	**08/10/12**
Copper	**7440-50-8**	**2.18E+02**	**4.60E+01**	**MCL**	**Yes**	**Exceeds SSL**	**2/ 13**	**CBLsb-010-5258-SO**	**03/22/10**
Lead	**7439-92-1**	**4.30E+01**	**1.40E+01**	**MCL**	**Yes**	**Exceeds SSL**	**9/ 13**	**CBLss-002M-SO**	**11/04/04**
Mercury	7439-97-6	7.00E-02	1.00E-01	MCL	No	Below SSL	0/ 13	CBLss-006M-SO	11/04/04
Thallium	**7440-28-0**	**3.60E-01**	**1.40E-01**	**MCL**	**Yes**	**Exceeds SSL**	**5/ 13**	**CBLss-002M-SO**	**11/04/04**
Explosives									
2,4,6-Trinitrotoluene	**118-96-7**	**2.20E+01**	**1.50E-02**	**Risk**	**Yes**	**Exceeds SSL**	**3/ 13**	**CBLss-004M-SO**	**11/04/04**
2-Amino-4,6-dinitrotoluene	**35572-78-2**	**5.40E-01**	**3.00E-02**	**Risk**	**Yes**	**Exceeds SSL**	**3/ 13**	**CBLss-004M-SO**	**11/04/04**
4-Amino-2,6-dinitrotoluene	**19406-51-0**	**6.40E-01**	**3.00E-02**	**Risk**	**Yes**	**Exceeds SSL**	**3/ 13**	**CBLss-004M-SO**	**11/04/04**
Nitrocellulose	9004-70-0	1.30E+00	1.30E+04	Risk	No	Below SSL	0/ 3	CBLss-005M-SO	11/04/04
Semi-volatile Organic Compounds									
Anthracene	120-12-7	2.10E-02	5.80E+01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Benz(*a*)anthracene	**56-55-3**	**4.80E-02**	**4.25E-03**	**Risk**	**Yes**	**Exceeds SSL**	**2/ 3**	**CBLsb-011-5262-SO**	**03/23/10**
Benzo(*a*)pyrene	50-32-8	4.90E-02	2.40E-01	MCL	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Benzo(*b*)fluoranthene	**205-99-2**	**6.20E-02**	**4.10E-02**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 3**	**CBLsb-011-5262-SO**	**03/23/10**
Benzo(*ghi*)perylene[a]	191-24-2	3.70E-02	1.30E+01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Benzo(*k*)fluoranthene	207-08-9	2.80E-02	4.00E-01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Bis(2-ethylhexyl)phthalate	117-81-7	5.40E-02	1.40E+00	MCL	No	Below SSL	0/ 3	CBLss-005M-SO	11/04/04
Chrysene	218-01-9	5.00E-02	1.20E+00	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Fluoranthene	206-44-0	1.30E-01	8.90E+01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Fluorene	86-73-7	9.40E-03	5.40E+00	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Indeno(1,2,3-*cd*)pyrene	193-39-5	3.00E-02	1.30E-01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10

Table E.1-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for C Block Quarry (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type (mg/kg)	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL / Total Samples	Sample ID at Maximum Concentration	Date Collected
Phenanthrene[a]	85-01-8	8.70E-02	1.30E+01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10
Pyrene	129-00-0	9.70E-02	1.30E+01	Risk	No	Below SSL	0/ 3	CBLsb-011-5262-SO	03/23/10

[a] Pyrene generic SSL was used as a surrogate for benzo(*ghi*)perylene and phenanthrene.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
GSSL = Generic soil screening level.
ID = Identification.
MCL = Maximum contaminant level.
mg/kg = Milligrams per kilogram.
SRC = Site-related contaminant.
SSL = Soil screening level.
Bold = SRCs that exceed the GSSL.

Table E.1-5. DAF Calculation for C Block Quarry

$$\boxed{\mathrm{DAF} = 1 + \frac{\left(\mathrm{K} \times i \times \mathrm{d}\right)}{\left(\mathrm{q} \times \mathrm{L}\right)}}$$

$$\boxed{\mathrm{d} = \sqrt{0.0112 \times \mathrm{L}^2} + \mathrm{d_a} \times \left[1 - \exp\left(\frac{-\mathrm{L} \times \mathrm{q}}{\mathrm{K} \times i \times \mathrm{d_a}}\right)\right]}$$

Parameter	Symbol	Value	Unit	Note
DAF	DAF	1.85	unitless	Calculated from DAF equation shown above
Aquifer hydraulic conductivity	K	1.20E+02	m/year	Average of slug test results from MKM (2007)
Horizontal hydraulic gradient	i	2.82E-03	m/m	Determined from Figure 3-1
Percolation rate	q	9.40E-02	m/year	Developed from HELP model from Cleveland, Ohio, weather data
Source length parallel to groundwater flow	L	25.5	m	Based on average area for all ISM areas for C Block Quarry
Mixing zone depth	d	6	m	Determined from the lower value between above equation for “d” (d = 6.86 m) and d_a
Aquifer thickness	d_a	6	m	Facility-wide assumption for the aquifer presented in the Load Line 1 investigation (USACE 2003)

MKM (MKM Engineers, Inc.) 2007. *Final Characterization of 14 Areas of Concern at Ravenna Army Ammunition Plant: Characterization of C-Block Quarry*. March 2007.

USACE (U.S. Army Corps of Engineers) 2003. *Phase II Remedial Investigation Report for the Load Line 1 at the Ravenna Army Ammunition Plant, Ravenna, Ohio*. June 2003.

DAF = Dilution attenuation factor.

HELP = Hydrologic evaluation of landfill performance.

ISM = Incremental sampling methodology.

m = Meter.

Table E.1-6. Initial CMCOPCs Based on Comparison of the SRC's Maximum Concentration at C Block Quarry with a DAF of 1.85

Analyte	CAS Number	Maximum Concentration (mg/kg)	SSSL (mg/kg)	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Sample ID at Maximum Concentration	Date Collected
Metals							
Arsenic	**7440-38-2**	**1.90E+01**	**5.37E-01**	**Yes**	**Exceeds SSSL**	**CBLss-001M-SO**	**11/04/04**
Chromium, hexavalent	**18540-29-9**	**3.90E+01**	**1.24E-03**	**Yes**	**Exceeds SSSL**	**CBLsb-025-5879-SO**	**08/10/12**
Copper	**7440-50-8**	**2.18E+02**	**8.51E+01**	**Yes**	**Exceeds SSSL**	**CBLsb-010-5258-SO**	**03/22/10**
Lead	**7439-92-1**	**4.30E+01**	**2.59E+01**	**Yes**	**Exceeds SSSL**	**CBLss-002M-SO**	**11/04/04**
Thallium	**7440-28-0**	**3.60E-01**	**2.59E-01**	**Yes**	**Exceeds SSSL**	**CBLss-002M-SO**	**11/04/04**
Explosives							
2,4,6-Trinitrotoluene	**118-96-7**	**2.20E+01**	**2.78E-02**	**Yes**	**Exceeds SSSL**	**CBLss-004M-SO**	**11/04/04**
2-Amino-4,6-dinitrotoluene	**35572-78-2**	**5.40E-01**	**5.55E-02**	**Yes**	**Exceeds SSSL**	**CBLss-004M-SO**	**11/04/04**
4-Amino-2,6-dinitrotoluene	**19406-51-0**	**6.40E-01**	**5.55E-02**	**Yes**	**Exceeds SSSL**	**CBLss-004M-SO**	**11/04/04**
Semi-volatile Organic Compounds							
Benz(*a*)anthracene	**56-55-3**	**4.80E-02**	**7.86E-03**	**Yes**	**Exceeds SSSL**	**CBLsb-011-5262-SO**	**03/23/10**
Benzo(*b*)fluoranthene	205-99-2	6.20E-02	7.59E-02	No	Below SSSL	CBLsb-011-5262-SO	03/23/10

CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
DAF = Dilution attenuation factor.
ID = Identification.
mg/kg = Milligrams per kilogram.
SRC = Site-related contaminant.
SSSL = Site-specific soil screening level (generic soil screening level multiplied by the DAF of 1.85).
Bold = SRCs that exceed the SSSL.

THIS PAGE INTENTIONALLY LEFT BLANK.

Table E.1-7. Initial CMCOPCs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years at C Block Quarry

$$R = 1 + \frac{\rho_b K_d}{\theta_w}$$

$$T = L_z \theta_w R / q$$

Parameter	Symbol	Value	Unit	Note
Percolation rate	q	0.31	ft/year	Developed from HELP model from Cleveland, Ohio, weather data
Soil-water distribution coefficient	K_d	chemical-specific	L/kg	See footnotes below for references
Organic carbon distribution coefficient	K_{oc}	chemical-specific	L/kg	See footnotes below for references
Fraction organic carbon	f_{oc}	0.00067	unitless	PBA08 RI geotechnical sample CBLSB-010-5269-SO
Water-filled soil porosity	θ_w	0.237	unitless	
Bulk density (dry)	ρ_b	1.74	gm/cm^3	
Leaching zone	Lz	sample-specific	ft	Distance from last layer of soil contamination greater than background concentration to top of water table
Retardation factor	R	chemical-specific	unitless	Calculated by equation shown above
Arrival time	T	chemical-specific	year	Calculated by equation shown above

Analyte	Initial CMCOPC Sample ID	Sample Depth[a] (ft)	Lz[b] (ft)	K_{oc} (L/kg)	Reference	K_d (L/kg)	Reference	R	T (year)	T <1,000? from Sample Depth to Groundwater Table (Yes/No)
Metals										
Arsenic	CBLss-001M-SO	0–1	20	NA	-	2.90E+01	c	2.14E+02	3,270	No
Chromium, hexavalent	CBLsb-025-5879-SO	1–2	16.5	NA	-	1.90E+01	c	1.41E+02	1,770	No
Copper	CBLsb-010-5258-SO	1–4	17.5	NA	-	3.50E+01	c	2.58E+02	3,450	No
Lead	CBLsb-011-5263-SO	4–4.5	15	NA	-	9.00E+02	c	6.62E+03	75,800	No
Thallium	CBLss-002M-SO	0–1	14	NA	-	7.10E+01	c	5.23E+02	5,590	No
Explosives										
2,4,6-Trinitrotoluene	**CBLss-004M-SO**	**0–0.5**	**25**	**2.81E+03**	**c**	**1.88E+00**	**d**	**1.49E+01**	**283**	**Yes**
2-Amino-4,6-dinitrotoluene	**CBLsb-010-5258-SO**	**1–4**	**17.5**	**2.83E+02**	**c**	**1.90E-01**	**d**	**2.39E+00**	**32**	**Yes**
4-Amino-2,6-dinitrotoluene	**CBLss-004M-SO**	**0–0.5**	**25**	**2.83E+02**	**c**	**1.90E-01**	**d**	**2.39E+00**	**46**	**Yes**
Semi-volatile Organic Compounds										
Benz(*a*)anthracene	CBLsb-011-5262-SO	1–4	15.5	1.77E+05	c	1.19E+02	d	8.73E+02	10,300	No

[a] The maximum depth of an initial CMCOPC (based on the maximum depth that an analyte is detected above facility-wide background).

[b] Based on each specific sample ID location and depth to water table shown in Figure 3-1.

[c] U.S. Environmental Protection Agency regional screening levels generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

[d] K_d value for organic chemicals calculated by multiplying K_{oc} by fraction organic carbon (f_{oc}) of 0.00067 (from PBA08 RI geotechnical sample CBLSB-010-5269-SO).

CMCOPC = Contaminant migration chemical of potential concern.
ft = Feet.
gm/cm^3 = Grams per cubic centimeter.
HELP = Hydrologic evaluation of landfill performance.
ID = Identification.
K_d = Distribution coefficient.
K_{oc} = Organic carbon partition coefficient.
L/kg = Liters per kilogram.
Lz = Leaching zone.
NA = not applicable.
PBA08 RI = Performance-based Acquisition 2008 Remedial Investigation.
Bold = Initial CMCOPCs that exceed the 1,000-year travel time screen.
< = Less than.

Table E.1-8. Climatic Data from SESOIL for C Block Quarry

Month	Air Temp (°C)	Cloud Cover	Humidity	Albedo	Evapotranspiration[a] (cm/day)	Precipitation (cm)	Duration (days)	Storms per Month	Model Days in Month
October	12	0.60	0.70	0.17	0.00	6.46	0.42	5.33	30.4
November	5.22	0.70	0.75	0.24	0.00	7.4	0.53	6.67	30.4
December	-1.06	0.80	0.75	0.31	0.00	7.06	0.57	6.14	30.4
January	-2.94	0.80	0.80	0.3	0.00	7.06	0.61	5.69	30.4
February	-2.33	0.70	0.75	0.32	0.00	5.76	0.53	5.09	30.4
March	2.33	0.70	0.70	0.29	0.00	8.26	0.55	7.14	30.4
April	9.11	0.70	0.70	0.19	0.00	8.83	0.48	7.4	30.4
May	14.61	0.60	0.70	0.16	0.00	8.46	0.45	7.15	30.4
June	19.89	0.60	0.70	0.16	0.00	9.07	0.36	6.57	30.4
July	21.89	0.50	0.70	0.16	0.00	9.8	0.3	6.06	30.4
August	21.11	0.55	0.70	0.16	0.00	8.14	0.3	6.06	30.4
September	17.67	0.55	0.70	0.16	0.00	7.85	0.4	5.44	30.4

[a] Data calculated in SESOIL model. 0.00 indicates evapotranspiration is calculated from other climatic data. 1996 data from Youngstown, Ohio, Weather Service Office - Airport Station.

cm = Centimeter.

SESOIL = Seasonal soil compartment model.

Table E.1-9. Physical and Chemical Properties of Initial CMCOPCs Selected for SESOIL Modeling for C Block Quarry

Initial CMCOPC	Molecular Weight	Solubility (mg/L)	Reference	K_{oc} (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	Diffusion Coefficient in Air (cm^2/sec)	Reference	Biodegradation Rate (1/day)	Sample Location	Application Area (cm^2)
Explosives												
2,4,6-Trinitrotoluene	227.1	1.15E+02	a	2.81E+03	a	2.08E-08	a	2.95E-02	a	NA	CBLss-004M-SO	4.04E+06
2-Amino-4,6-dinitrotoluene	197.2	3.19E+02	a	2.83E+02	a	1.62E-10	a	5.61E-02	a	NA	CBLss-004M-SO	4.04E+06
4-Amino-2,6-dinitrotoluene	197.2	3.19E+02	a	2.83E+02	a	1.62E-10	a	5.61E-02	a	NA	CBLss-004M-SO	4.04E+06

[a] U.S. Environmental Protection Agency regional screening level generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

cm^2/sec = Square centimeters per second.

CMCOPC = Contaminant migration chemical of potential concern.

HELP = Hydrologic evaluation of landfill performance.

K_{oc} = Organic carbon partition coefficient.

L/kg = Liters per kilogram.

mg/L = Milligrams per liter.

NA = Not applicable.

SESOIL = Seasonal soil compartment model.

Table E.1-10. Load Application Data for SESOIL Model at C Block Quarry

25-ft-Thick Vadose Zone

Analyte	Layer Number	Layer Thickness (ft)	Number of Sublayers	Sublayer Number	Concentration (mg/kg)	Purpose
2,4,6-Trinitrotoluene	1	1.5	3	1	22.0	Contaminant Loading
				2	0.0	Leaching
				3	0.0	
	2	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	3	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	4	0.5	1	1	0.0	
2-Amino-4,6-dinitrotoluene	1	1.5	3	1	0.54	Contaminant Loading
				2	0.0	Leaching
				3	0.0	
	2	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	3	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	4	0.5	1	1	0.0	
4-Amino-2,6-dinitrotoluene	1	1.5	3	1	0.64	Contaminant Loading
				2	0.0	Leaching
				3	0.0	
	2	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	3	11.5	4	1	0.0	
				2	0.0	
				3	0.0	
				4	0.0	
	4	0.5	1	1	0.0	

ft = Feet.
mg/kg = Milligrams per kilogram.
SESOIL = Seasonal soil compartment model.

THIS PAGE INTENTIONALLY LEFT BLANK.

Figures

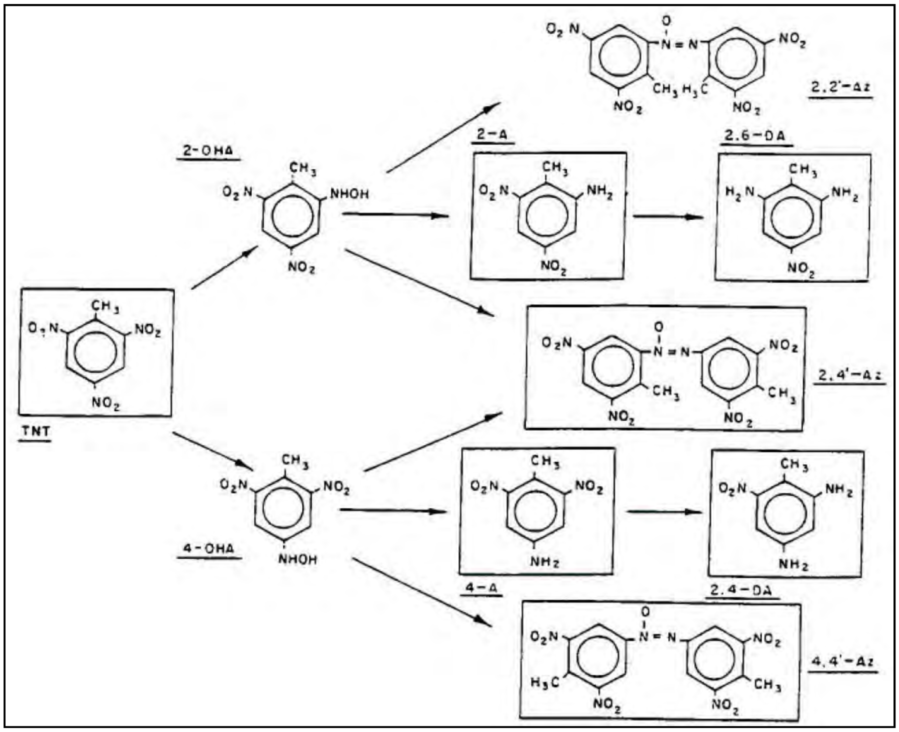


Figure E.1-1. TNT Biotransformation Pathway

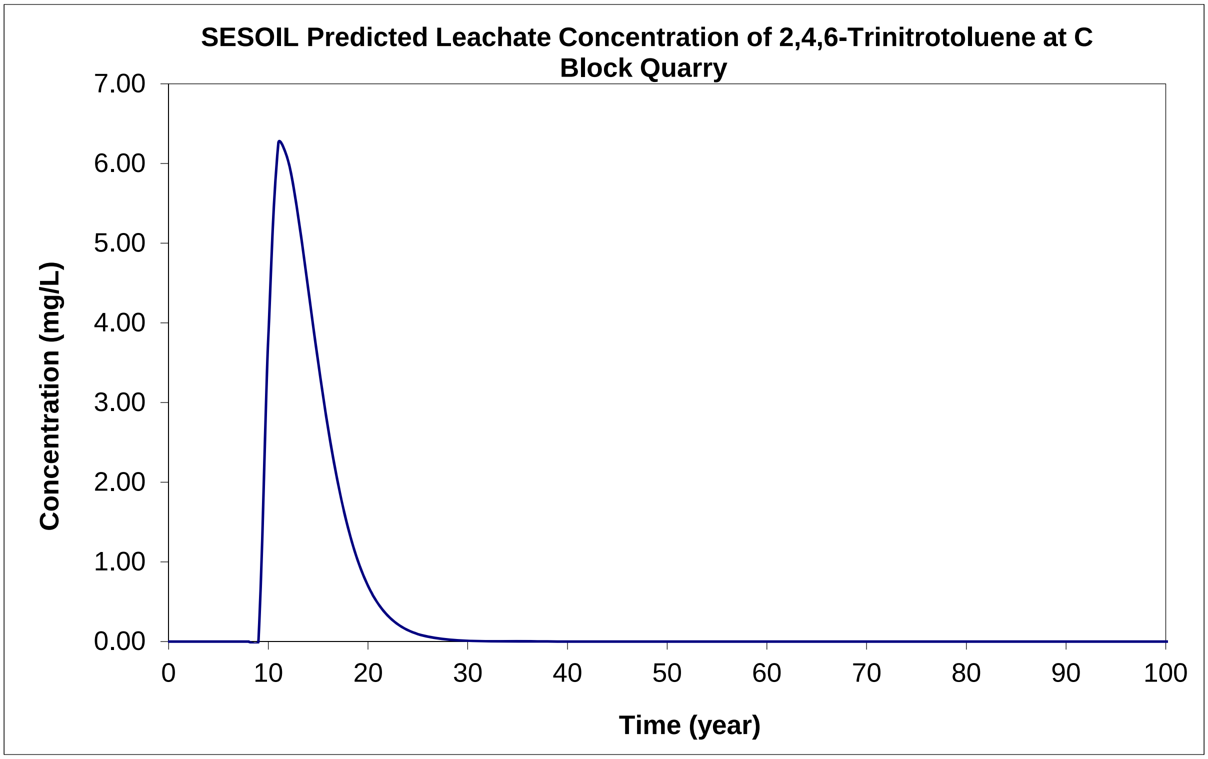


Figure E.1-2. SESOIL Predicted Leachate Concentration at C Block Quarry – TNT

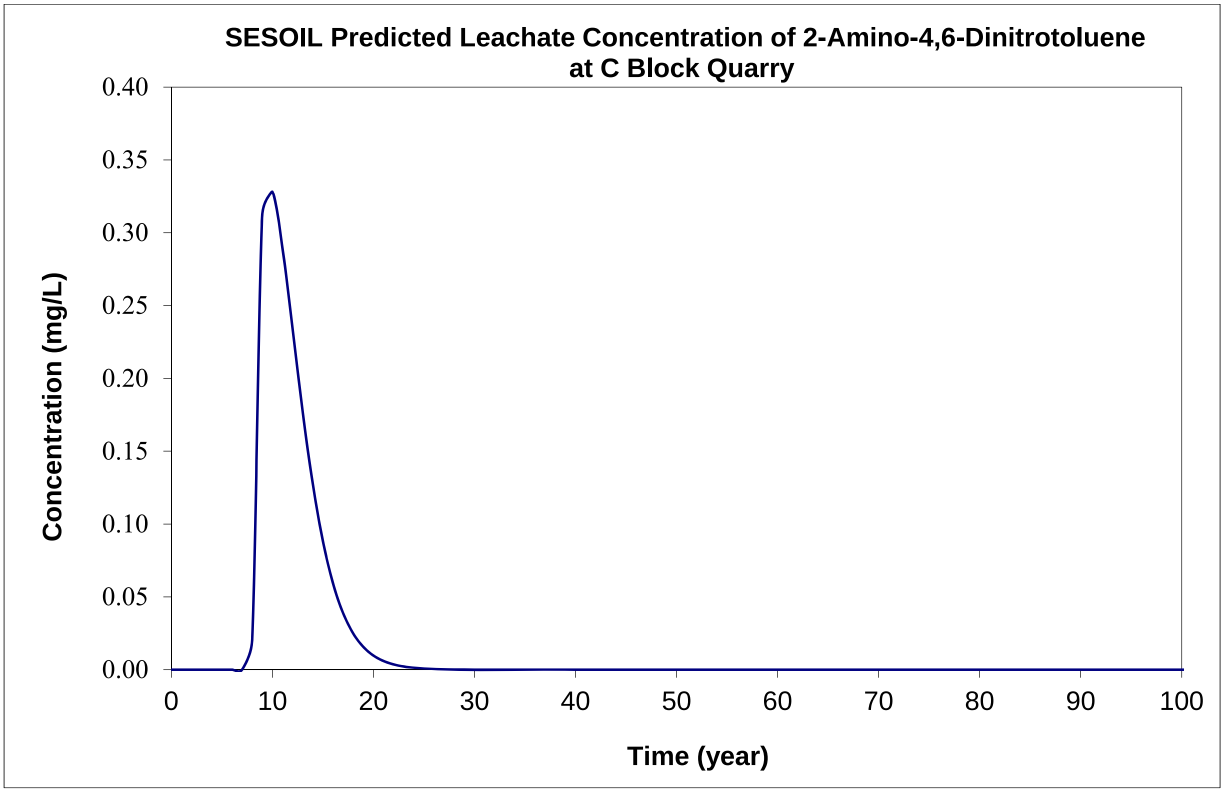


Figure E.1-3. SESOIL Predicted Leachate Concentration at C Block Quarry – 2-Amino-4,6-Dinitrotoluene

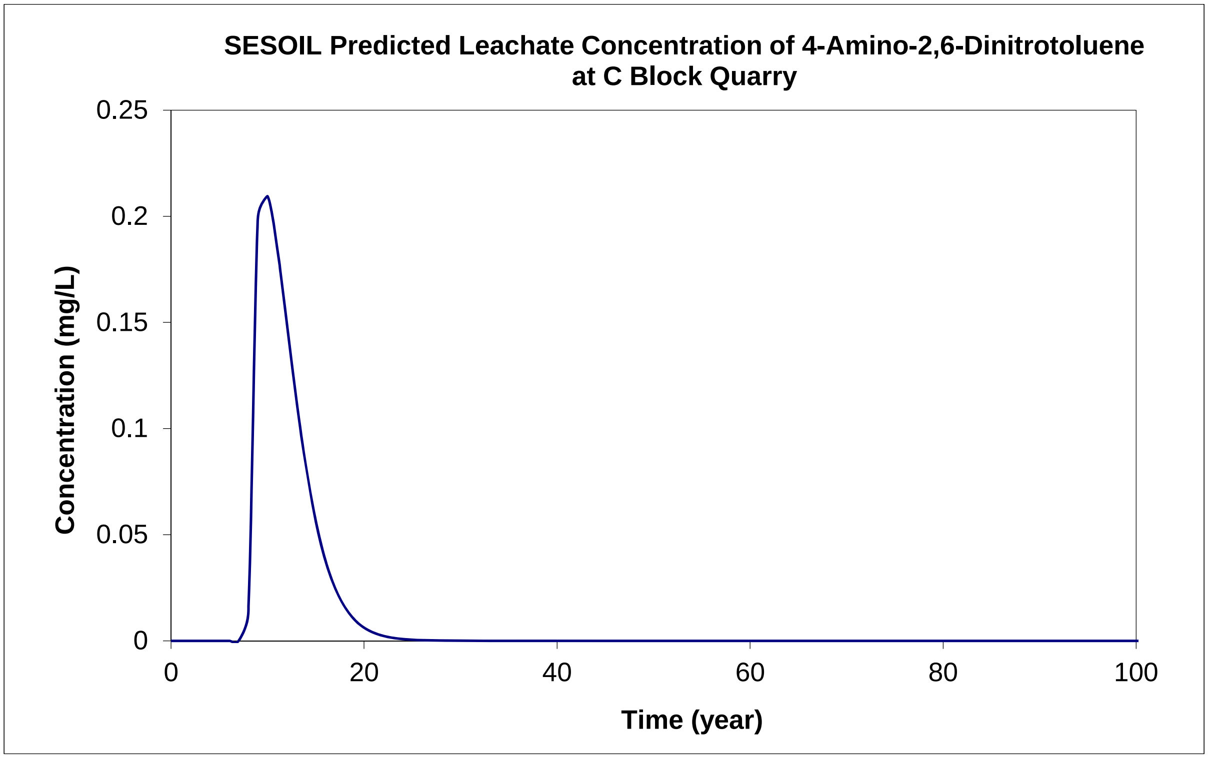


Figure E.1-4. SESOIL Predicted Leachate Concentration at C Block Quarry – 4-Amino-2,6-Dinitrotoluene

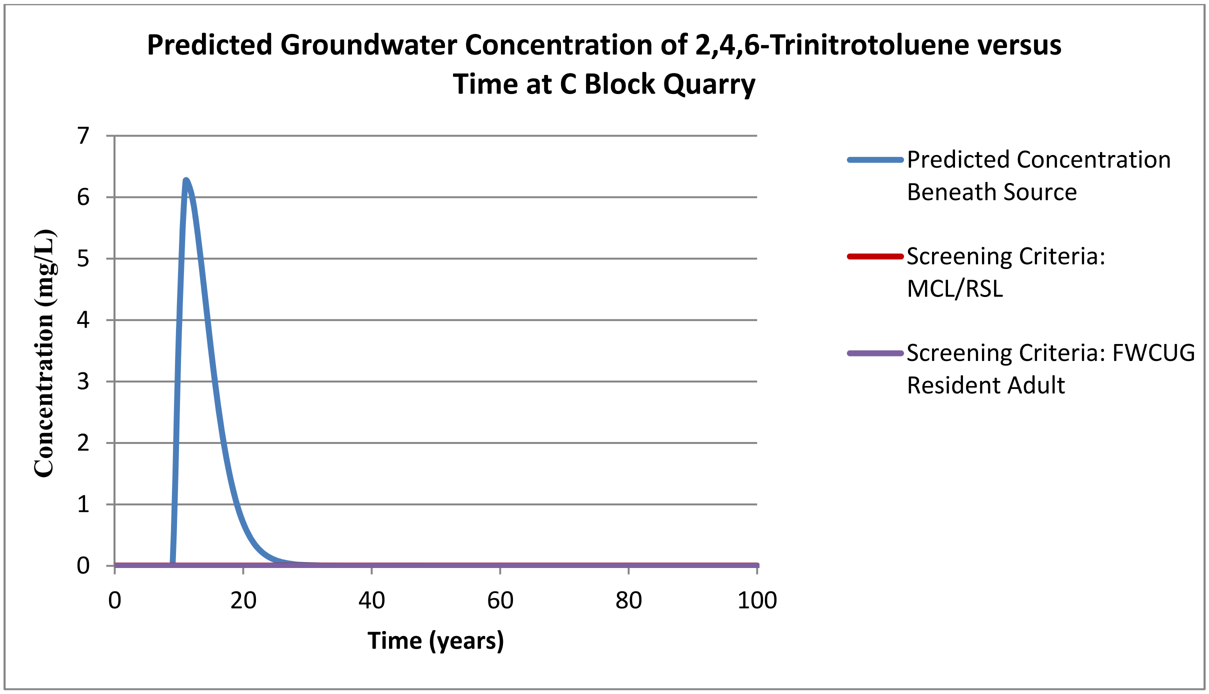


Figure E.1-5. Predicted Concentration of TNT in Groundwater Based on SESOIL and Dilution Modeling at C Block Quarry

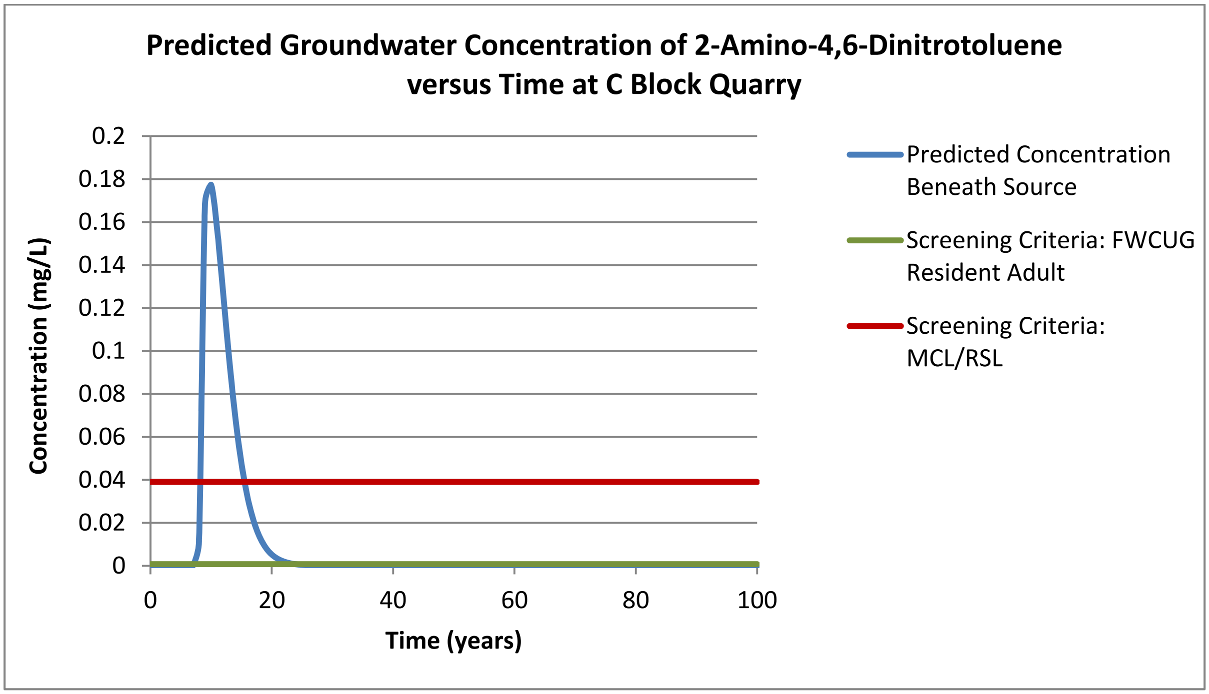


Figure E.1-6. Predicted Concentration of 2-Amino-4,6-Dinitrotoluene in Groundwater Based on Dilution Modeling at C Block Quarry

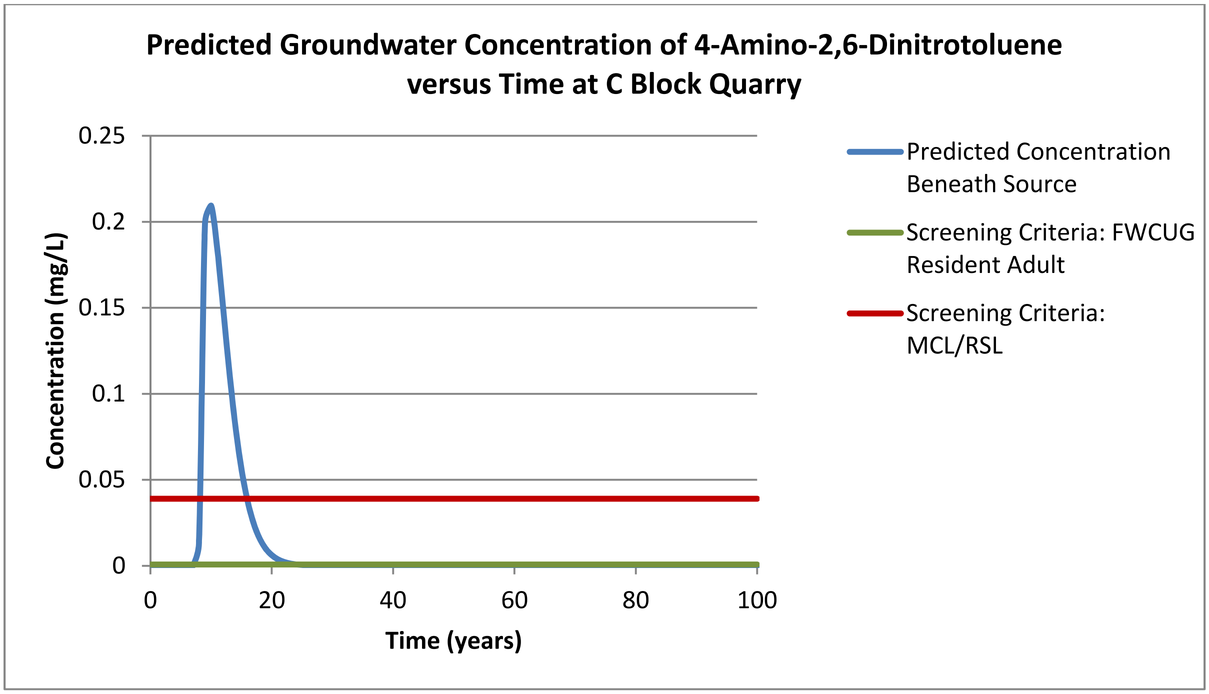


Figure E.1-7. Predicted Concentration of 4-Amino-2,6-Dinitrotoluene in Groundwater Based on SESOIL and Dilution Modeling at C Block Quarry

ATTACHMENT C.

C Block Quarry RI/FS Report – Revised Figure 3-1

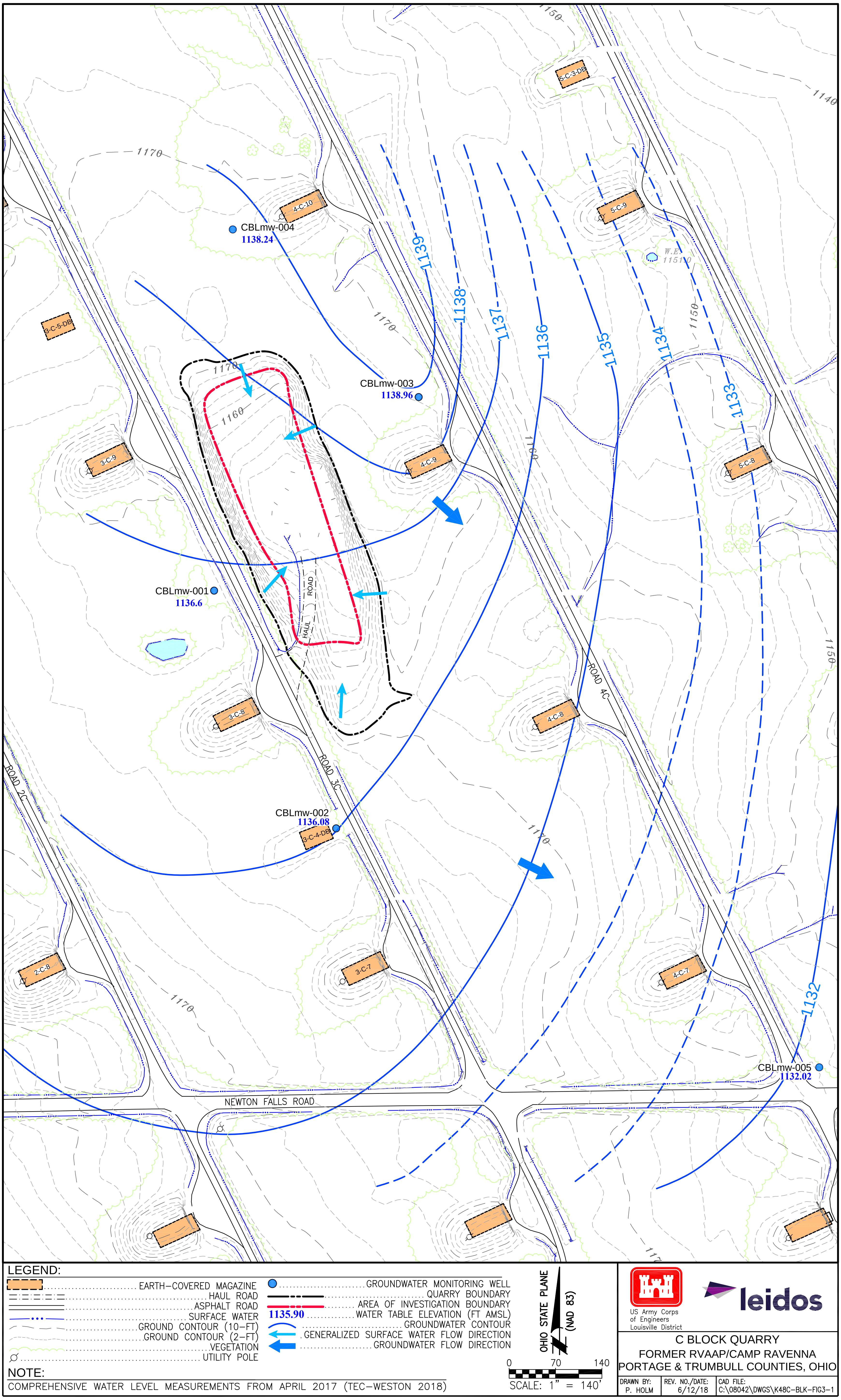


Figure 3-1. Topography, Groundwater Flow, and Surface Water Flow at C Block Quarry.

Ohio Environmental
Protection Agency

John R. Kasich, Governor
Mary Taylor, Lt. Governor
Craig W. Butler, Director

May 18, 2018

LTC James Crowley, ARNG-IED
National Guard Bureau
111 South George Mason Drive
Arlington, VA 22204

Re: US Army Ammunition PLT RVAAP
Remediation Response
Project Records
Remedial Response
Portage County
267000859095

Subject: **Ravenna Army Ammunition Plant, Portage/Trumbull Counties. "Responses to Comments on the Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry"**

Dear Lieutenant Colonel Crowley:

The Ohio Environmental Protection Agency (Ohio EPA) has received and reviewed the "Response to Comments on the Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry" for the Ravenna Army Ammunition Plant (RVAAP), Portage/Trumbull Counties. This document is dated and was received at Ohio EPA, Northeast District Office (NEDO) on March 8, 2018. Please find below Ohio EPA's comments on the Army's responses.

General Comments

Ohio EPA General Comment 1: Adequately addressed.

Ohio EPA General Comment 2: Adequately addressed.

Ohio EPA General Comment 3: Adequately addressed.

Ohio EPA General Comment 4: Adequately addressed.

Ohio EPA General Comment 5: Revise the text to incorporate the information provided in this comment response.

Ohio EPA General Comment 6: Adequately addressed.

Ohio EPA General Comment 7: Adequately addressed.

Ohio EPA General Comment 8: Ohio EPA concurs with the Army's response for the RI/FS. However, an updated asbestos inspection will need to be conducted during the Remedial Design (RD) phase prior to implementation of the Remedial Action (RA). The condition and location of the observed ACM, as noted in the 2011 asbestos survey, needs to be reassessed, as eight years of weathering has most likely changed the condition, the location and ability to locate the material.

Ohio EPA General Comment 9: Ohio EPA concurs with the Army's response for the RI/FS. However, an updated asbestos inspection will need to be conducted during the Remedial Design (RD) phase prior to implementation of the Remedial Action (RA). Ohio EPA recommends that additional Seibert stakes be incorporated into the RD/RA phase to ensure high visibility of the barrier for site receptors.

Ohio EPA General Comment 10: Adequately addressed.

Ohio EPA General Comment 11: Adequately addressed.

Ohio EPA General Comment 10: Adequately addressed.

Fate and Transport Model/Groundwater Comments

Ohio EPA reviewed the responses to the seven fate and transport model/ground water comments (FTGW Comments) and determined that the responses to three of the FTGW Comments (FTGW Comments 4, 5, and 7) are adequate. However, the comment responses to the remaining four FTGW Comments (FTGW Comments 1, 2, 3, and 6) are inadequate and remain a concern. Ohio EPA concurs that the SESOIL™/AT123D™ models utilized in the Draft RI/FS do not accurately predict contaminant migration, even for screening purposes beneath C Block Quarry given the hydrogeology. The use of the models for C-Block Quarry need to be resolved. The following are Ohio EPA comments on the FTGW are as follows:

1. The Army has not adequately responded to Ohio EPA's FTGW Comments 1, 2, and 3 dated November 28, 2017, regarding the appropriateness of the SESOIL™/AT123D™ fate and transport model used in the *RVAAP-06 C Block Quarry RI/FS Report* given the hydrogeology beneath C Block Quarry. Considering that the response to Ohio EPA's FTGW Comment 4 dated November 28, 2017, acknowledges that the SESOIL™/AT123D™ does not accurately predict contaminant migration through a highly heterogenous hydrogeologic system such as exists beneath C Block Quarry, the responses to Ohio EPA's, FTGW Comments 1, 2, and 3 dated November 28, 2017, are not adequate. Revise this section accordingly. Also, refer to Comment 2 below.

2. Ohio EPA concurs with the Army's response to FTGW Comment 4 and agrees that the SESOIL™/ AT123D™ model does not accurately predict contaminant migration through a highly heterogenous hydrogeologic system, such as exists beneath C Block Quarry. The geology beneath C Block Quarry consists of a thin layer of

soil/unconsolidated material over fractured and weathered Homewood Sandstone. While part of the vadose zone consists of unconsolidated material/soil, most of the vadose zone is in the fractured and weathered Homewood Sandstone. According to Pfingston (2002), this area was also likely subject to blasting during quarrying. SESOIL™/AT123D™ are not appropriate screening tools to model fate and transport in bedrock (New Jersey DEP, 2014) or in non-homogenous or fractured geologic media (Kauffman and McLane, 2015).

The Army can demonstrate potential for impact to ground water in evaluating ground water to surface water pathway by sampling the four RI wells (CBLmw-001, CBLmw-002, CBLmw-003, and CBL-004). The four aforementioned wells have not been sampled since 2013, and according to the 2016 *RI Work Plan for Ground Water* will need to be sampled to support the Facility-Wide Ground Water (FWGW) RI. Ohio EPA recommends that these four wells be sampled for the parameters specified in the 2016 *RI Work Plan for Ground Water* for C Block Quarry wells including: SVOCs, metals including hexavalent chromium, and PCBs. Considering the history, disposal practices and pH issues in the C Block, Ohio EPA recommends that these four wells also be sampled for: explosives, nitrate/nitrite, sulfate/sulfide, and pH. Further, Ohio EPA recommends that the four C Block Quarry RI wells be sampled for a minimum of two consecutive sampling events and be added to the list of wells to be sampled in 2018 in the *Facility-Wide Ground Water Monitoring Addendum*.

3. Ohio EPA concurs with the response to FTGW Comment 5. In the response, the Army acknowledges the fact that the SESOIL™/AT123D™ model does not take into account the direct disposal of wastes onto the weathered and fractured bedrock, as was reported to have been historically practiced in the 1950's and 1960's in C Block Quarry. Therefore, Ohio EPA recommends that the four C Block RI wells be added to the list of wells to be sampled in 2018 in the Facility Wide Ground Water Monitoring Addendum, as recommended in Comment 2 above.

4. The Army's response to Ohio EPA's FTGW Comment 6 dated November 28, 2017, is inadequate. The ground water flow interpretations in Figures 3, 3-1, 4, and 4-1 are incorrect. Ground water flow on the knob of the Homewood Sandstone was re-interpreted a number of years ago to be radial, and not as shown on the figures. Attached is the most recent April 2017 Potentiometric Map, which shows radial flow in that hydrostratigraphic unit in the vicinity of C Block Quarry. While the aforementioned flow map only shows one flow arrow, the potentiometric map shows an arced potentiometric line, which follows the contour of the Homewood Knob in the vicinity C Block Quarry, where ground water flow in the Homewood is radial. Ground water flow interpretations in the RI report need to be modified to accurately show ground water flow in the vicinity of C Block Quarry.

5. The Army has adequately responded to Ohio EPA's Comment 7, dated November 28, 2017. The response indicates that the Geologic Bedrock Map (Figure 3-3) will be corrected to show the correct geologic units.

REFERENCES

New Jersey DEP, 2014, *Guidance Document, Using the Combined SESOIL/AT123D Models to Develop Site-Specific Impact to Ground Water Soil Remediation Standards for Mobile Contaminants*, New Jersey DEP, Trenton, New Jersey, 35 p.

Kaufmann, Mark and McLane, Charles, 2015, *Using SESOIL to Evaluate Contaminant Release Timeframes in an Environmental Litigation Context*, 67th Annual American Academy of Forensic Sciences Meeting in Orlando Florida, McLane Environmental, Princeton, New Jersey 23 p.

Pfingsten, Ralph A., 2002*, A History of the Ravenna Arsenal*, The Northern Ohio Railway Museum, Chippewa, Ohio., 341 p

ATTACHMENTS

Potentiometric Surface Map, Homewood Sandstone Aquifer, April 2017
Surface Geology Map

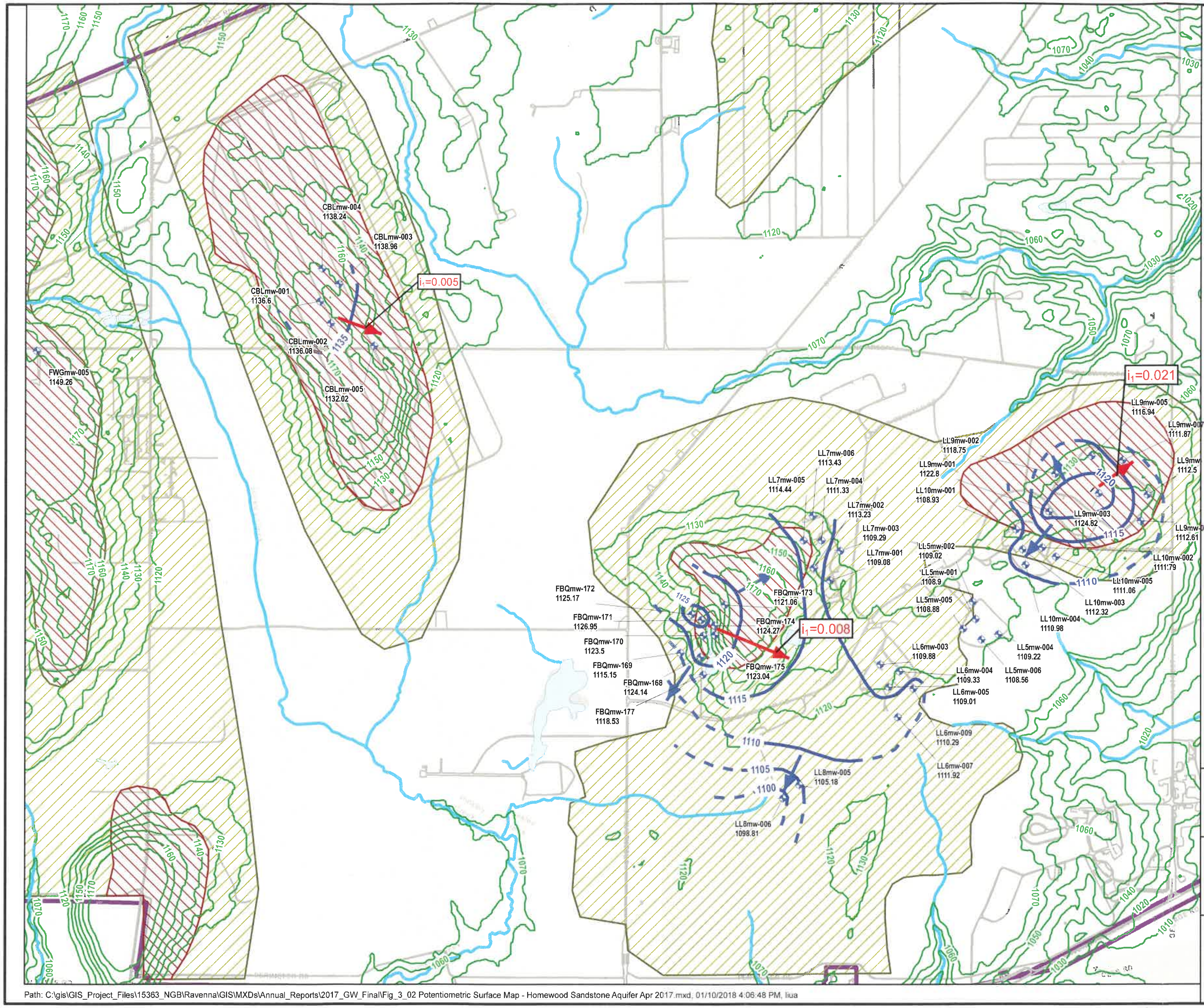
Ohio EPA will be coordinating a meeting with the Army to discuss Ohio EPA's comments and the comment responses. Please contact me at (330) 963-1219 or vanessa.steigerwald-dick@epa.ohio.gov, if there are any issues or concerns.

Sincerely,

Vanessa Steigerwald Dick, Ph.D. - Environmental Scientist
Division of Environmental Response and Revitalization

VS-D/nvp

ec: Katie Tait/Kevin Sedlak OHARNG RTLS
Craig Coombs, USACE
Rebecca Shreffler/Gail Harris, VISTA Sciences Corp.
Josh Koch, ODH
Brian Ng, ARAQMD
James Crowley, ARNG-IED
Nat Peters, USACE
Bob Princic, Ohio EPA, NEDO, DERR
Mark Johnson, Ohio EPA, NEDO, DERR
Tom Schneider, Ohio EPA, SWDO, DERR
Vicki Deppisch, Ohio EPA, NEDO, DERR
Tim Christman, Ohio EPA, CO, DERR
Al Muller, Ohio EPA, NEDO, DDAGW
Kevin Palumbo, NEDO, DERR
Frederick Jones, Ohio EPA, CO, DAPC
Chris Williams, Ohio EPA, NEDO, DAPC



Legend

- ⊕ Upper Bedrock Aquifer Well
- ➤ Direction Of Flow
- ➤ i1 = Hydraulic Gradient (ft/ft)
- — Roads
- — Creeks and Streams
- — Elevation Contours (Feet)
- ▭ Camp Ravenna Property Line

Geology

- ▨ Homewood Sandstone Member
- ▨ Mercer Member

Notes:
1. Potentiometric Surfaces were prepared based on data collected in April 2017.
2. All wells presented are installed within the upper contact saturated zone of the initial bedrock formation, reported in previously prepared documents as the Homewood Sandstone.
3. Groundwater elevations measured in April 2017 at BKGmw-022 (not present in map view), BKGmw-023 (not present in map view) and FWGmw-005 were not used in preparation of potentiometric surface contours based on their distance (i.e., greater than 4,500 feet) from current AOCs/MRSs being monitored for groundwater contamination and from the next closest wells installed in the Homewood formation.

- NM = Not Measured

- Basemap Sources: ESRI Map Services - Canvas/World_Light_Gray_Base and World_Street_Map
- Surface Elevation Contours - USDA

N

0 1,600 3,200 Feet
1:19,500
NAD83 UTM Zone 17N

Cardno TEC
WESTON
TEC-Weston Joint Venture

POTENTIOMETRIC SURFACE MAP
HOMEWOOD SANDSTONE AQUIFER

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-wide Groundwater
Former Ravenna Army Ammunition Plant
Ravenna, Ohio

Figure: 3-2

FINAL

Path: C:\gis\GIS_Project_Files\15363_NGB\Ravenna\GIS\MXDs\Annual_Reports\2017_GW_Final\Fig_3_02 Potentiometric Surface Map - Homewood Sandstone Aquifer Apr 2017.mxd, 01/10/2018 4:06:48 PM, liua

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

NATIONAL GUARD BUREAU
111 SOUTH GEORGE MASON DRIVE
ARLINGTON VA 22204-1373

March 8, 2018

Ohio Environmental Protection Agency
DERR-NEDO
Attn: Mr. Bob Princic
2110 East Aurora Road
Twinsburg, OH 44087-1924

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry, Responses to Comments on the Remedial Investigation/Feasibility Study Report (Work Activity No. 267-000-859-095)

Dear Mr. Princic:

The Army appreciates your time and comments (dated November 28, 2017, received December 5, 2017) on the *Revised Draft Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry*. Enclosed for your review are responses to your comments. The Army anticipates a resolution meeting will be conducted to coincide with this letter and requests dates in which appropriate staff from Ohio EPA are available to meet.

Please contact the undersigned at (703) 607-7955 or mark.s.leeper.civ@mail.mil if there are issues or concerns with this submission.

Sincerely,

Mark Leeper
RVAAP Restoration Program Manager
Army National Guard Directorate

cc: Rod Beals, Ohio EPA, NEDO
Tom Schneider, Ohio EPA, SWDO
Tim Christman, Ohio EPA, CO
Al Mueller, Ohio EPA, NEDO
Frederick Jones, Ohio EPA, DAPC CO
Chris Williams, Ohio EPA, DAPC NEDO
Josh Koch, Ohio Department of Health
Brian Ng, ARAQMD
Kevin Sedlak, ARNG, Camp Ravenna
Katie Tait, OHARNG, Camp Ravenna
Craig Coombs, USACE Louisville
Nathaniel Peters, II, USACE Louisville
Jed Thomas, Leidos
Gail Harris, Vista Sciences Corporation

Subject: Ravenna Army Ammunition Plant (RVAAP) Restoration Program, Portage/Trumbull Counties, RVAAP-06 C Block Quarry (Work Activity No. 267-000-859-095)

General Comments

Ohio EPA General Comment 1:
Executive Summary, page ES-1, lines 36 and 37: The report states "Triton N.E. and Naccronal N.R." were included for possible disposal at C Block Quarry. Please verify and discuss what these are.

Army Response: Agree. Triton N.E. (also X-100) and Naccronal N.R (also Santomerse No. 3) are non-ionic surfactants used for wetting, spreading, penetrating, and emulsifying agents and detergents. The only known documentation of these chemicals occurs in an Army letter dated March 24, 1950, where these wastes were listed as satisfactory for disposal at C-Block Quarry. Unlike documentation of annealing process liquids, there is no documented evidence to confirm if disposal of these chemicals, commonly identified as detergents, ever occurred.

The referenced paragraph has been revised as follows:

> *"In a letter, dated March 24, 1950, a conference was conducted to assess waste disposal for the former RVAAP. The conference concluded that C Block Quarry was the most satisfactory location to dispose sulfuric acid, nitric acid, mercury, chromic acid, phosphoric acid plus accelerator, alkali compound stripper. Triton N.E. (or X-100), and Naccronal N.R (or Santomerse No.3), surfactants commonly used in detergents, were also listed**.** The summary report (U.S. Government 1950) …"*

Ohio EPA General Comment 2:
Figures 5-2 and 5-2, Hexavalent Chromium: Sample CBLsb-025 indicates an increase in hexavalent chromium at depth from 16 mg/kg from 0-1' to 39 mg/kg from 1-2'. Although the 39 mg/kg is below the commercial/industrial concentration of 63 mg/kg, it was not demonstrated that the concentration decreased or increased below the 1-2' depth.

Army Response: Clarification and agree. The CBLsb-025 boring intervals from 0-1' and 1-2' bgs were composed of sand and course angular sandstone fragments. At 2' bgs, the CBLsb-025 boring was terminated due to auger refusal in sandstone. In addition, the CBLsb-026 boring had concentration (6.4J mg/kg) exceeding the Resident RSL in the 1-1.8' bgs interval. CBLsb-026 was terminated at 1.8' bgs due to refusal. Accordingly, Figures 5-2 and 5-4 will be revised to provide a footnote in the CBLsb-025 and CBLsb-026 boxes to indicate the depths in which borings refusal was encountered.

Ohio EPA General Comment 3:
Section 7.2.7, Identification of COCs for potential remediation: Please add in a discussion regarding the commercial/industrial receptor of 63 mg/kg referencing the RSL at 1E-05. This is important as the recommended alternative #2 is for a LUC for the commercial/industrial applicable standard.

Army Response: Clarification and agree. Table 7-6 and Section 7.2.5.1 Selection of Appropriate FWCUGs (Chromium Speciation) present the hexavalent chromium FWCUGs and RSLs. The last sentence of Section 7.2.5.1 has been revised to clearly identify 63 mg/kg as the RSL for the Industrial Receptor at a TR of 1E-05.

The last sentence of Section 7.2.7 notes that there are no exceedances of the Industrial RSL and no COCs are identified for Commercial/Industrial Land Use, therefore the section focuses on COCs that trigger potential remediation (including land use controls). For added clarity, the last paragraph in Section 7.2.7 will be revised as follows:

> *"All hexavalent chromium concentrations are less than the Industrial RSL of 63 mg/kg at a target risk of 1E-05; thus, no COCs are identified for Commercial/Industrial Land Use."*

Ohio EPA General Comment 4:
Section 9.3, Remedial Action cleanup goals, Table 9-1: The Army has only provided the unrestricted, residential use cleanup goal in this table, but Alternative 2 is proposing commercial/industrial cleanup goals. Please add to the table the commercial/industrial land use receptor cleanup goal for hexavalent chromium (RSL at 63 mg/kg) and asbestos (specify concentration, if any).

Army Response: Clarification. Hexavalent chromium is not a COC for the Industrial Receptor, as the hexavalent chromium concentrations are below the Industrial RSL of 63 mg/kg. Accordingly, there is no remedial cleanup goal for hexavalent chromium per the Industrial Receptor in Table 9-1. To clarify, the table title has been revised to: "*Remedial Cleanup Goals at C Block Quarry*" and the following note will be added to the table:

> *"The hexavalent chromium cleanup goal of 3 mg/kg is applicable to the Resident Receptor. Hexavalent chromium is not a COC for the Industrial Receptor, as there were no exceedances of the Industrial RSL of 63 mg/kg."*

Also, for clarification, Alternative 2 does not propose soil cleanup for hexavalent chromium in soil. The removal included in Alternative 2 is limited to surficial ACM to achieve the RAO to prevent Industrial Receptor exposure to friable ACM. Further, Land Use Controls (LUCs) are a part of the alternative because hexavalent chromium at concentrations above the Resident Receptor remedial cleanup goal will remain in place and to prevent receptor exposure to any potential subsurface ACM (no digging). This is discussed further in response to Ohio EPA's General Comment 10.

Ohio EPA General Comment 5:
Executive Summary, page ES-8, Table ES-1, page 9-2, Section 9.3, Table 9-1, Cleanup goals: Please specify the analytical method that will be used for asbestos for both unrestricted and commercial/industrial use in all appropriate text areas and tables.

Army Response: Clarification. Detail on sampling protocol and analytical methods will be developed during the Remedial Design (including the QAPP and work plans) phase of the CERCLA process to ensure the most current requirements are met. The Remedial Design will be provided to Ohio EPA for review prior to implementation. No change to the document is proposed.

Ohio EPA General Comment 6:
LUC/Groundwater: Historical information regarding disposal practices, COCs, proposed LUCs, etc. at C Block Quarry should be forward and evaluated under the FWGWMP for possible ground water contamination and ground water use restriction.

Army Response: Comment noted. This report will be available for review for future groundwater evaluations. No change to the document is proposed.

Ohio EPA General Comment 7:
Solid Waste Issues: This area is covered under the site-wide Solid Waste Management Plan. Ohio EPA and USACE have determined that areas containing solid waste and construction demolition and debris (CD&D) waste will be addressed in a case-by-case basis, if the potential for development or reuse of these areas were to occur in the future. However, Ohio EPA noted the report stated previous investigations identified materials that appear to be CD&D debris, which may fall under the solid waste regulations. Regulation of CD&D, as defined by OAC 3745-400-01(F), for closure obligations began on September 30, 1996. According to historical information, please provide a time frame of when this debris may have been dumped.

Army Response: Clarification. As cited in the RI-FS Report, the 1982 Installation Reassessment indicates that waste was placed at C Block Quarry during the 1950s and 1960s. The 1989 Resource Conservation and Recovery Act (RCRA) Facility Assessment observed two empty 55-gal drums, glass fragments, cinder blocks, and several empty 5-gal buckets at the AOC (Jacobs 1989). In addition, a recently identified *USEPA 1988 Inventory of Federal Hazardous Waste Activities* stated the following: "Site (C Block Quarry) only utilized for disposal of annealing waste during one period in the 1960's. Site has been inactive since that time." No change to the document is proposed.

Ohio EPA General Comment 8:
Asbestos Issues: On October 5, 2017, Ohio EPA representatives, accompanied by an Akron Regional Air Quality Management District (ARAQMD) asbestos inspector, along with RVAAP representatives, inspected the C Block Quarry site. The area was found to be heavily overgrown with vegetation, including ground cover, which made access by foot difficult. The sides of the quarry were irregular, steep and strewn with rocks, wood and other natural debris. Because of the wet ground conditions, our observations were limited to the exterior edge of the quarry along the road. Seibert stakes, which serve as warning signs in lieu of an actual fence, were visible from the road. There was no visible surficial ACM in the areas observed, nor was there any bare soil visible.

Regulatory applicability: Based on our inspection and discussions, the following comments are provided for consideration in moving forward in selecting a remedial alternative. Both the Ohio Department of Health (ODH) and Ohio EPA, DAPC asbestos programs have determined that the activities at the quarry which have resulted in ACM being deposited were not abatement or renovation activities subject to the sections of the rule related to inspection and applicability (OAC 3745-20-02), notification prior to demolition or renovation (OAC 3745-20-03), and the ODH regulation that delineates the requirements for an asbestos survey (OAC 3701-34-02). There are sections of the asbestos regulation that could potentially be applicable, depending upon the remedial alternative selected.

Based on that determination, the 2011 asbestos survey would not be sufficient for determining the nature, extent and condition of ACM in the quarry. Depending upon the remedial alternative selected, additional inspection and sampling (both surficial and subsurficial) activities could be necessary.

Army Response:

Regarding the rules, comment noted regarding the previous activities not being under OAC 3745-20-02 (Asbestos Emission Control), 3745-03 (Standard for notification prior to demolition or renovation), and 3701-34-02 (Prohibitions, now cited as 3745-22-02). Please note that Section 10 of the RI-FS Report presents potential action specific ARARs, including standards for asbestos waste handling (OAC Section 3745-20-05) and standards for inactive asbestos waste disposal sites (OAC Section 3745-20-07).

Regarding the nature and extent of ACM, the Army believes that additional inspections or sampling are not warranted to complete the RI/FS phase. As discussed in Section 4.3 and Appendix J of the RI-FS Report, an Asbestos Hazard Evaluation Specialist, certified by the State of Ohio Department of Health, conducted a reconnaissance of the entire C Block Quarry. Four suspect ACM were identified and six samples were collected of the bulk material. Ten soil samples were analyzed for asbestos content.

In review of the 5 soil borings collected in the 0.96 acre site, none of the borings identified any debris. Regardless, the Army conservatively accounts for potential ACM in the subsurface in Alternatives 2 and 3, as summarized below:

- Alternative 2 includes a land use control (LUC) to “Prevent intrusive and digging activities, as friable ACM potentially exists in the subsurface soil.”

- Alternative 3 includes “excavating test trenches throughout the quarry bottom to identify any possible subsurface ACM. Additional areas in which ACM is present in soil will be removed and disposed accordingly.”

No change to the document is proposed.

Ohio EPA General Comment 9:
Alternative 1: No Action. – OAC 3745-20-07, Standard for inactive asbestos waste disposal sites, refers to “….any disposal site or portion thereof, which contains asbestos-containing materials, but where such material has not been deposited within the past year.”

In the event that there is no remedial activity planned or conducted, the potential for human exposure to ACM must be investigated. There also exists a potential concern for airborne ACM in the absence of an engineered soil cover. Depending upon the type of cover selected, either six inches of vegetated cover or two feet of non-vegetated, non-asbestos-containing material would need to be utilized as cover. While the inspectors did not observe any visible ACM at the surface, or visible soil, it is unclear without a thorough inspection of the entire area if this condition applies to the entire surface of the quarry.

An inspection would also be necessary to determine if the current condition of the surface cover fulfills the requirement of this section (OAC 3745-20-07(A)), and to identify any areas where additional ground cover may need to be added. During the removal of the surficial ACM, these disturbed areas and any other areas without surface cover would be required to have additional ground cover, using one of the options described above.

The property is not accessible by the public, with the entire facility surrounded by fencing, and entry areas manned by guards. The quarry boundary is delineated with Seibert stakes, which serve as a warning of restricted access to on-site personnel and visitors. Ohio EPA's DAPC asbestos program has made a determination that the installation security and Seibert stakes designed to restrict access at the quarry meet the requirements of OAC 3745-20-07 (C).

Army Response: Clarification. Alternative 1: Consistent with the CERCLA process, the "No Action" alternative is presented to provide the "baseline to which other remedial alternatives are compared. This alternative assumes all current actions (e.g., access restrictions and environmental monitoring) will be discontinued and no future actions will take place to protect human receptors or the environment. Contaminants in soil will not be removed or treated."

Generally, the No Action alternative does not meet the Threshold Criteria requirement to be protective of Human Health and the Environment. Alternative 1, No Action does not quality for selection as the remedial alternative at C Block Quarry.

Regarding the ACM at the surface, as discussed in Section 4.3 and Appendix J of the RI-FS Report, an Asbestos Hazard Evaluation Specialist, certified by the State of Ohio Department of Health, conducted a reconnaissance of the entire C Block Quarry. The Army believes that additional inspections or sampling are not warranted to complete the RI/FS phase. The development of Alternatives 2 and 3 took information from this inspection into account with respect to remedial actions necessary to address the identified ACM. In addition, these alternatives include OAC 3745-20-07(A) as an ARAR. No change to the document is proposed.

Ohio EPA General Comment 10:
Alternative 2: Surficial ACM removal and Land Use Controls (LUCs). All regulatory requirements potentially applicable to Alternative 1 would also apply here. In the event that more than 50 linear or square feet of ACM were disturbed or removed, work practices described in the applicable sections of OAC 3745-20-04, demolition and renovation procedures for asbestos emission control, and the applicable sections of OAC 3745-20-05, standard for asbestos waste handling, would proscribe requirements for collecting, packaging and placarding of waste material, along with recordkeeping and disposal. This alternative describes that workers would manually remove visible ACM found at the surface, but not any buried material.

Army Response: Comment noted. Section 10 of the RI-FS Report presents potential action specific ARARs, including standards for asbestos waste handling (OAC Section 3745-20-05) and standards for inactive asbestos waste disposal sites (OAC Section 3745-20-07). The applicability of OAC 3745-20-04 references to OAC 3745-20-05 within the code, therefore, OAC 3745-20-04 was not included in the ARARs.

Workers performing these activities would be required to be ODH-certified and under the direction of an ODH-certified asbestos contractor in the event that the regulatory threshold for ACM (i.e., 50 linear or square feet) were to be disturbed or removed. The ODH asbestos program has determined that if less than that amount of ACM is involved, the regulatory requirements cited above are not applicable.

Army Response: Comment noted. Work practices and procedures as well as applicable regulations and certifications associated with ACM removal activities will be developed and detailed in the Remedial Design.

Page 2-2 describes the AOC as currently heavily forested with brush and trees at least one foot in diameter. Alternative 2, the recommended alternative, does not provide enough detail on the surficial removal process, including removal around the brush and trees which may be difficult during the growing season.

Army Response: Comment noted. Procedures associated with identification of ACM and subsequent removal of vegetative growth will be detailed in the Remedial Design phase of the CERCLA process.

The report states “An estimated 10 cubic yards of exposed ACM (e.g., transite/shingle and steel panels with block insulation and paper) were observed to be in surface soil at C Block Quarry.” The removal does not include soil removal although asbestos was detected in the one sampling collected during the asbestos survey.

Army Response: Clarification regarding the asbestos soil sampling: one soil sample was collected and analyzed for asbestos in soil during the visual survey. This soil sample has less than 1% chrysotile. In addition, the nine soil samples were submitted for asbestos analysis from four of the soil borings advanced during the PBA08 RI (CBLsb-007, CBLsb-008, CBLsb-010, and CBLsb-012). Results are presented in Tables 4-9 and 4-10. None of the nine soil samples exhibited detectable asbestos content.

In Alternative 2, the Army is eliminating the Industrial Receptor’s potential exposure to asbestos in soil by implementing a LUC to not allow digging at the site. This LUC is in addition to removing exposed ACM (e.g., transite/shingle and steel panels with block insulation and paper).

Although cleanup goals for hexavalent chromium and asbestos are provided in the report for unrestricted use, commercial/industrial cleanup goals were not. These should be discussed and presented in Alternative 2.

Army Response: Clarification. There are no exceedances of the hexavalent chromium Industrial RSL, and therefore hexavalent chromium is not a COC for the Industrial Receptor and does not have a remedial cleanup goal for the Industrial Receptor. Also, as indicated in the prior response, only the surficial ACM will be removed in Alternative 2. Soil will not undergo removal for asbestos content in Alternative 2, consequently, there is no applicable remedial cleanup goal.

The Army will revise the sentence in Section 9.3, as below:

> “In addition, for any remedial action taking place to remove subsurface friable ACM, soil samples will be collected and analyzed for asbestos content.”

Alternative 2 does not propose to meet the unrestricted land use goal, but instead implement Land Use Controls (LUC). Leaving the asbestos in the soil would require a demonstration that the asbestos-containing soil would not become airborne due to wind erosion, and travel beyond the LUC boundary. It would also require demonstrations that the surface water entering the quarry on all sides and slopes, will not erode the side slope or bottom soils and further expose asbestos-contaminated soil to potential wind erosion.

Response: Agree. The following new Section 12.2.1.2 will be added to the text.

> *12.2.1.2 Asbestos-Contaminated Soil Assessment*
>
> *Ten soil samples within C Block Quarry were analyzed for asbestos. Nine of the samples had no detections and one of the samples had a detection at less than 1% chrysotile. Although asbestos content in soil is considered nonfriable, this section further evaluates the potential of asbestos travelling beyond the LUC Boundary.*
>
> *Wind and sediment erosion at the C Block Quarry AOC is negligible. As presented in Figure 2-1, soil within the C Block Quarry AOC boundary is predominantly surrounded by approximately 25 ft high walls created during the quarry operations. These high walls will reduce the likelihood of wind erosion. The AOC is heavily vegetated, as further confirmed in a site walk with Ohio EPA conducted in 2017, which will deter soil erosion. In addition, surface water is not a permanent feature of the site, and rain events generally do not create ponds or surficial flow.*
>
> *As presented in Figure 5-5, the one sample location that had asbestos in soil is in flat terrain, very near the approximately 25 ft high quarry wall, thus unlikely to result in the limited asbestos in soil traveling beyond the LUC boundary.*

The report states that Alternative 2 consists of removing the surficial ACM through use of non-intrusive, no-digging methods to prevent industrial receptor exposure to ACM in surface soil. In additional to the above comments that asbestos in surface soil may not have been adequately characterized, the soils beneath the proposed material removal require confirmatory sampling to demonstrate that the surface meets RAOs. Refer to the above comment regarding adding the commercial/industrial cleanup goals (RAOs) to Table 9-1. Note, the confirmatory samples should be discreet samples and not ISM samples.

Army Response: Clarification requested. Previous guidance from Ohio EPA NESHAPs indicated that removal of ACM per non-intrusive/non-digging methods did not require subsequent soil sampling. The approach was documented in the approved Ramsdell Quarry Remedial Design, dated April 9, 2014.

The Army believes asbestos in soil is adequately characterized for purposes of Alternative 2, as discussed in Ohio EPA General Comment 8. Although the exposed ACM will be removed as part of Alternative 2, the Army does not propose removing soil based on asbestos content. Rather, the Army is eliminating the Industrial Receptor's potential exposure to asbestos in soil by implementing an LUC to not allow digging at the site. As such, confirmatory samples are not required as part of this remedy. No change to the document is proposed.

Ohio EPA General Comment 11:
Alternative 3: Excavation and off-site disposal. This alternative would require additional surface and subsurface sampling to delineate the extent of ACM contamination, in preparation for removal down to 13 feet below ground surface (bgs), in order to demonstrate that the point of compliance for unrestricted (residential) land use has been met.

Army Response: Comment noted. As indicated in Sections 12.3.1 and 12.3.2, implementation of Alternative 3 will include excavating test trenches throughout the quarry to identify any possible subsurface ACM and pre-excavation sampling. No change to the document is proposed.

In the event this alternative is chosen, the regulatory requirements of OAC 3745-20-07 would not be required. In addition, the Army would not be required to institute an LUC or record a deed restriction on the quarry.

However, contractor activities involving ACM collection, on-site storage, packaging, transport, documentation and disposal could be subject to the applicable OSHA regulations. Perimeter air sampling and standard work practices could potentially be required to ensure that unpermitted air releases of ACM were not occurring during removal activities.

Certified asbestos workers under the direction of an ODH-certified asbestos contractor would be necessary to perform this work in the event that the regulatory threshold of amount of ACM were to be removed or disturbed. Also, this activity would require formal prior 10-day notification. If there is less than 50 linear or square feet to be disturbed or removed, the requirements listed above, including notification, would not apply. The Army should be aware that although state asbestos regulations may not apply to these activities, OSHA requirements may be applicable.

Army Response: Comment noted. As noted in Section 12.3.3, “The Remedial Design will contain an Asbestos Soil Abatement Plan to outline requirements specific to the removal of ACM, including identifying key personnel and PPE, specifying air monitoring requirements, and stating the site control measures.” No change to the document is proposed.

Ohio EPA General Comment 12:
Appendix K, Detailed Cost Estimate: Please discuss the rationale for why only six five-year reviews were budgeted.

Army Response: Per CERCLA guidance, cost estimates for Feasibility Studies are prepared to estimate 30 years into the future when the actual timeframe to achieve RAOs is unknown, thus six five-year reviews would occur over a 30-year period of time. No change to the document is proposed.

Fate and Transport Model/Groundwater Comments

Ohio EPA F&T Comment 1:
The site conceptual model appears to consist of a contaminated layer of unconsolidated soil over bedrock (Figure 6-1). That model is not supported by the borings. For example, the drilling log for CBLsb-026 shows that bedrock is about two feet down. Thus, most of the vadose zone is rock rather than soil which is not what Figure 6-1 portrays. It would be helpful to Ohio EPA if all logs for all of the borings shown in Figure 5-4 were included in the report. With that information, we could better define the site stratigraphy, especially the quarry. In addition, it would also be helpful to include some cross-sections through the quarry area showing the various layers and their thicknesses.

Army Response: Clarification. Figure 6-1 is a contaminant migration conceptual model which is not to scale, and the purpose is to show how the models (SESOIL and AT123D) are used for contaminant fate and transport analysis. On Figure 6-1, there is no separation between the bedrock zone and the unconsolidated overburden. Instead, it just shows that once the contaminant leachate percolates through the unsaturated zone and reaches the water table (i.e., water carrying the contaminants first, moves downward through the overburden and then into the bedrock zone that is modeled by SESOIL), it migrates with the local groundwater and discharges at the downgradient receptors (that is modeled by AT123D). Additional cross-sections are not required to evaluate fate and transport. For reference, the soil borings that went to depths greater than 1 ft bgs (CBLsb-007, 008, 010, 011, 012, 025, and 026) were included in Appendix A of the RI-FS Report. No change to the document is proposed.

Ohio EPA F&T Comment 2:
The SESOIL model is unclear as to the properties of the various layers. Table E-10 of the Fate and Transport Section (Appendix E) presents four layers that constitute the vadose zone. While the top 1.5 ft. thick layer is probably accurately represented by the surface soil, the lower layers would be fractured bedrock. It is unclear if the model used appropriate properties for the bedrock. Table 6-2 of the report only appears to give properties for the unconsolidated soil layer, not the bedrock. Given the lack of standing water in the quarry, the permeability of the bedrock is probably high and needs to be properly considered in the modeling.

Army Response: Clarification. In SESOIL, the four separate layers are for input of soil/rock contamination data (based on analytical data available), and the hydrogeologic properties for the unsaturated zone representing both unconsolidated soil and the bedrock above the water table (e.g., intrinsic permeability and disconnectedness index) were calibrated using the percolation rate as the calibration target. While average soil properties (e.g., bulk density, porosity, moisture content, etc., used by SESOIL) represented site data, these parameters do not have any significant impact on the flow calibration of the SESOIL model. The fraction organic carbon (foc) is an important soil property for SESOIL modeling with respect to contaminant partitioning, but it does not impact the flow calibration of the model. In addition, the average foc for soil was very low and is likely a very conservative value for bedrock. No change to the document is proposed.

Ohio EPA F&T Comment 3:
In a similar manner, it is unclear if the transport calculations presented in Table E-7 considered the properties of fractured bedrock rather than the overburden soil. Note that the high chromium borings, like

CBLsb-026, hit rock at about two feet. Thus, most of the transport to the water table is through bedrock rather than soil. The properties in that table appear to represent the sandy soil rather than the bedrock. In particular, the following equation for travel time to the water table:

$$T = \frac{L_z \Theta_w R}{q}$$

needs input values for the fractured bedrock as well as the overburden.

Army Response: Clarification. The leachate travel time (T) is defined as the time it takes for a contaminant to reach the water table from the bottom of the contaminated soil/rock (i.e., unsaturated zone/vadose zone). This is based on the percolation rate (q), the volumetric moisture content of the unsaturated zone material (Θ_w), the chemical-specific soil/water partitioning coefficient (Kd) used to calculate the retardation factor (R), and the leaching zone thickness (Lz) which was based on site-specific data. The percolation rate is the primary hydrogeologic parameter affecting the seepage velocity and associated travel time and is essentially the recharge to the water table through both the unconsolidated and bedrock zones. The presence of bedrock does not impact the percolation rate. A discussion on how the percolation rate was obtained is in Section 6.2.4. The limitations of flow and transport in the vadose zone are discussed in Section 6.4.6. No change to the document is proposed.

Ohio EPA F&T Comment 4:

It is not clear how the SESOIL™/ACT123D™ software accurately models contaminant fate and transport in weathered fractured Homewood Sandstone in which fracture flow may be a significant or dominant component of ground water flow. SESOIL™ models contaminant leaching in the vadose zone, and ACT123D advection, dispersion, adsorption/retardation, and decay.

Available drilling logs (attached) for the four (CBL-mw-001, CBL-mw-002, CBL-mw-003, CBL-mw-004) of the five (Note: A drilling log for CBL-mw-005 could not be found) indicate that the Homewood Sandstone encountered in these wells is weathered. Based on Ohio EPA experience of examining rock cores from wells installed at Camp Ravenna, the Homewood Sandstone beneath Camp Ravenna is typically both weathered and fractured. Based on historical records, it is likely that the Homewood Sandstone was quarried using explosives which would have created additional fracturing in the already weathered and fractured rock. According to Pfingsten (2002), because there was a shortage of trenching and digging equipment when Camp Ravenna was being Constructed, dynamite was used for activities such as quarrying and trenching.

It needs to be explained how the SESOIL™ accurately models ground water flow with significance of dominant fracture flow.

Army Response: Clarification. SESOIL is the leaching model from soil to groundwater and is not used to model lateral groundwater flow. AT123D is the model used for lateral groundwater flow and transport. The primary hydrogeologic parameters used in AT123D are the hydraulic conductivity and hydraulic gradient. At C Block Quarry, the average hydraulic conductivity determined during slug testing from site-specific bedrock wells (CBLMW-01 through CBLMW-004) was used in the AT123D model. This slug test data accounts for the lateral groundwater flow in the fractured bedrock zone. Figure 3-1 was used to determine the hydraulic gradient at the site. It should be noted here that both SESOIL and

AT123D models are screening level models and do not "accurately" predict contaminant migration through highly heterogenous hydrogeologic system. The text under Section 6.4.6 Limitation/Assumptions, will be revised to add, "the effects of heterogeneity, anisotropy, and spatial distribution of fractures are not addressed in these simulations. The present modeling study using SESOIL and AT123D does not address the effects of flow and contaminant transport across interfaces in rapidly varying heterogeneous media."

Ohio EPA F&T Comment 5:
SESOIL ™/ ACT123D™ modeling only considers the leaching of CMCOCs from soil to ground water, and does not account for the direct disposal of wastes onto the weathered and fractured bedrock, as has been reported to have been historically practiced during the 1950's and 1960s at C Block Quarry. Because this source of ground water contamination has not been considered in the SESOIL ™/ ACT123D™ model, it is unclear how well the model has predicted all of the impacts to ground water discharges at Hinkley Creek from past disposal practices at C-Block Quarry. It is understood that the purpose of the submitted report was to evaluate the potential for soil leaching to evaluate alternatives for soil, and is not a complete evaluation of impacts to ground water in the vicinity of C Block Quarry. Therefore, the modeled concentrations of CMCOCs in ground water discharging to Hinkley Creek are not considered representative for the purposes of evaluating ground water impacts.

Due to previous waste disposal practices at C Block Quarry, the following should be forwarded and considered for evaluation under the FWGWMP:

- Evaluate ground water horizontal/vertical gradients and permeability measurements of the Homewood, Mercer, and Sharon Aquifers, and surface topography in the area to determine the effect on contaminant transport.
- Evaluate the potential for discharge of chemicals of potential concern (COPCs) to surface water to the east.
- Confirm that historically characterized COPC concentrations indicate that site related contaminant mass presents limited potential for significant horizontal or vertical migration.
- Evaluate the potential for COPCs historically detected in the Homewood Aquifer to have migrated down-gradient after the collection of RI samples.
- Evaluate the effect of Sharon Shale on vertical contaminant migration.

Note: November 2016 pH measurements, in the five monitoring wells located in the vicinity of C Block Quarry, are all relatively low (e.g., 4.45 [well CBL-mw-001] to 5.59 [CBL-mw-003]), i.e., either below or near the bottom of the naturally-occurring range of 5 to 9 typically found in uncontaminated ground water. These low pH measurements are consistent with impacts that would be expected from the direct disposal of sulfuric acid and pickle liquor onto the weathered fractured bedrock surface.

Army Response: Clarification. C Block Quarry was used for disposal nearly 60 years ago (1950s to 1960s). With the exception of ACM on the ground surface, source material was not identified or encountered during the remedial investigation. Although past source materials are not used as input into the SESOIL model, the secondary sources (i.e., the contaminated soils based on releases from the primary source) are used by SESOIL model as the source terms. Therefore, the fate and transport analysis have indirectly included the impact of primary source materials using samples collected in 2004, 2010, and 2012. Regarding evaluation under the FWGWMP, the information noted above will be available to the executing contractor.

Ohio EPA F&T Comment 6:
The ground water flow direction shown Figures 3, 3-1, 4, and 4-1 is over-generalized. Ground water flow on the knob of Homewood Sandstone is controlled in part by the geometry and topography of isolated sub-crop of Homewood Sandstone, and is more radial than shown in the aforementioned figures. There is also variation in flow and the elevation of the potentiometric surface. Refer to the attached July 2015 and September 2016 Potentiometric Maps.

Army Response: Clarification. Figures 3-1 and 4-1 are based on the site-specific well data available in 2010, near the time of the final stages of the remedial investigation, and are over-generalized due to the limited number of monitoring wells at C-Block Quarry (there were only four wells in 2010). The groundwater flow direction was similar to the regional bedrock flow direction that was available in 2011. The potentiometric surface for the Homewood Sandstone in the *Final Facility-Wide Groundwater Monitoring Program, RVAAP-66 Facility-Wide Groundwater Annual Report for 2015* and the *Draft Facility-Wide Groundwater Monitoring Program, RVAAP-66 Facility-Wide Groundwater Annual Report for 2016* both show a similar predominant groundwater flow direction. No change to the potentiometric surface is proposed.

Ohio EPA F&T Comment 7:
The Geologic Bedrock Map (Figure 3-3) is not accurate. The map inaccurately shows that the Devonian-aged Berea Sandstone and Mississippian-aged Cuyahoga Group are the uppermost bedrock units in portions of the eastern part of Camp Ravenna. The uppermost bedrock units beneath Camp Ravenna all belong to the Pottsville Group and are Pennsylvanian in age. An accurate version of the Geologic Bedrock Map is attached. For more information regarding the bedrock geology beneath Camp Ravenna refer to Geology and Ground Water Resources of Portage County (Winslow and White, 1966).

Army Response: Clarification and agree. A figure was not attached to the Ohio EPA comment letter. Plate 3 of the Geology and Ground Water Resources of Portage County (Winslow and White, 1966) shows the Berea Sandstone at the same location as C Block Quarry RI-FS, Figure 3-3. Regardless, the Berea Sandstone and Mississippian-aged Cuyahoga Group on Figure 3-3 are now identified as the Sharon Member - Shale Unit in the recent Groundwater RI Work Plan (dated 12/21/16). Figure 3-3 of the C Block Quarry RI-FS will be revised accordingly.

Ohio Environmental Protection Agency

John R. Kasich, Governor
Mary Taylor, Lt. Governor
Craig W. Butler, Director

RECEIVED 12/5/2017

November 28, 2017

Mr. Mark Leeper
Team Lead
Cleanup/Restoration Branch
Army National Guard Directorate
111 South George Mason Drive
Arlington, VA 22204

Re: US Army Ammunition PLT RVAAP
Remediation Response
Project Records
Remedial Response
Portage County
267000859095

Subject: Ravenna Army Ammunition Plant, Portage/Trumbull Counties. "Revised Draft, Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06, C Block Quarry," Dated August 4, 2017

Dear Mr. Leeper:

The Ohio Environmental Protection Agency (Ohio EPA) has received and reviewed the "Revised Draft, Remedial Investigation/Feasibility Study Report for Soil, Sediment, and Surface Water at RVAAP-06 C Block Quarry" for the Ravenna Army Ammunition Plant (RVAAP), Portage/Trumbull Counties. This report is dated and was received at Ohio EPA, Northeast District Office (NEDO) on August 4, 2017. The report was reviewed by Ohio EPA personnel in NEDO and Central Office (CO).

C Block Quarry is 0.96 acre in size and was used during the 1940s and 1950s to mine the Homewood Sandstone. This sandstone was quarried for road and construction base material. C Block Quarry currently has a maximum depth of 25 feet below the surrounding grade and does not hold ponding surface water.

During the 1950s and 1960s, C Block Quarry was used as a disposal area for annealing process waste. Liquid waste was dumped on the ground surface in the bottom of the abandoned, unlined borrow pit. The liquid waste reported included annealing process liquids (chromic acid) from Building 802 at LL-2 and spent pickle liquor containing lead, mercury, chromium and sulfuric acid from brass finishing operations, and possibly nitric acid, phosphoric acid plus accelerator, alkali compound stripper and others. The volume of liquid waste disposed at C Block Quarry is unknown.

Northeast District Office • 2110 East Aurora Road • Twinsburg, OH 44087-1924
epa.ohio.gov • (330) 963-1200 • (330) 487-0769 (fax)

Friable asbestos and hexavalent chromium have been identified as Contaminants of Concern (COCs) for evaluation in the FS portion of the report. Alternative 2, Surficial Asbestos-Containing Material (ACM) Removal and Land Use Controls (LUC) is the recommended remedial alternative (Alternative #2). This alternative will remove approximately 10 cubic yards of exposed ACM identified during a 2011 asbestos survey. The ACM included transite/shingle and steel panels with block insulation and paper. No soil is proposed for removal. As proposed, the soil will meet commercial/industrial standards for hexavalent chrome (63 mg/kg) and, as stated in the report, this alternative would exclude intrusive activities and contact with asbestos.

The following are Ohio EPA comments:

Executive Summary, page ES-1, lines 36 and 37: The report states "Triton N.E. and Naccronal N.R." were included for possible disposal at C Block Quarry. Please verify and discuss what these are.

Figures 5-2 and 5-2, Hexavalent Chromium: Sample CBLsb-025 indicates an increase in hexavalent chromium at depth from 16 mg/kg from 0-1' to 39 mg/kg from 1-2'. Although the 39 mg/kg is below the commercial/industrial concentration of 63 mg/kg, it was not demonstrated that the concentration decreased or increased below the 1-2' depth.

Section 7.2.7, Identification of COCs for potential remediation: Please add in a discussion regarding the commercial/industrial receptor of 63 mg/kg referencing the RSL at 1E-05. This is important as the recommended alternative #2 is for a LUC for the commercial/industrial applicable standard.

Section 9.3, Remedial Action cleanup goals, Table 9-1: The Army has only provided the unrestricted, residential use cleanup goal in this table, but Alternative 2 is proposing commercial/industrial cleanup goals. Please add to the table the commercial/industrial land use receptor cleanup goal for hexavalent chromium (RSL at 63 mg/kg) and asbestos (specify concentration, if any).

Executive Summary, page ES-8, Table ES-1, page 9-2, Section 9.3, Table 9-1, Cleanup goals: Please specify the analytical method that will be used for asbestos for both unrestricted and commercial/industrial use in all appropriate text areas and tables.

LUC/Groundwater: Historical information regarding disposal practices, COCs, proposed LUCs, etc. at C Block Quarry should be forward and evaluated under the FWGWMP for possible ground water contamination and ground water use restriction.

Solid Waste Issues: This area is covered under the site-wide Solid Waste Management Plan. Ohio EPA and USACE have determined that areas containing solid waste and construction demolition and debris (CD&D) waste will be addressed in a case-by-case basis, if the potential for development or reuse of these areas were to occur in the future. However, Ohio EPA noted the report stated previous investigations identified materials that appear to be CD&D debris, which may fall under the solid waste regulations. Regulation of CD&D, as defined by OAC 3745-400-01(F), for closure obligations began on September 30, 1996. According to historical information, please provide a time frame of when this debris may have been dumped.

Asbestos Issues: On October 5, 2017, Ohio EPA representatives, accompanied by an Akron Regional Air Quality Management District (ARAQMD) asbestos inspector, along with RVAAP representatives, inspected the C Block Quarry site. The area was found to be heavily overgrown with vegetation, including ground cover, which made access by foot difficult. The sides of the quarry were irregular, steep and strewn with rocks, wood and other natural debris. Because of the wet ground conditions, our observations were limited to the exterior edge of the quarry along the road. Seibert stakes, which serve as warning signs in lieu of an actual fence, were visible from the road. There was no visible surficial ACM in the areas observed, nor was there any bare soil visible.

Regulatory applicability: Based on our inspection and discussions, the following comments are provided for consideration in moving forward in selecting a remedial alternative. Both the Ohio Department of Health (ODH) and Ohio EPA, DAPC asbestos programs have determined that the activities at the quarry which have resulted in ACM being deposited were not abatement or renovation activities subject to the sections of the rule related to inspection and applicability (OAC 3745-20-02), notification prior to demolition or renovation (OAC 3745-20-03), and the ODH regulation that delineates the requirements for an asbestos survey (OAC 3701-34-02). There are sections of the asbestos regulation that could potentially be applicable, depending upon the remedial alternative selected.

Based on that determination, the 2011 asbestos survey would not be sufficient for determining the nature, extent and condition of ACM in the quarry. Depending upon the remedial alternative selected, additional inspection and sampling (both surficial and subsurficial) activities could be necessary.

Alternative 1: No Action. – OAC 3745-20-07, Standard for inactive asbestos waste disposal sites, refers to "....any disposal site or portion thereof, which contains asbestos-containing materials, but where such material has not been deposited within the past year."

In the event that there is no remedial activity planned or conducted, the potential for human exposure to ACM must be investigated. There also exists a potential concern for airborne ACM in the absence of an engineered soil cover. Depending upon the type of cover selected, either six inches of vegetated cover or two feet of non-vegetated, non-asbestos-containing material would need to be utilized as cover. While the inspectors did not observe any visible ACM at the surface, or visible soil, it is unclear without a thorough inspection of the entire area if this condition applies to the entire surface of the quarry.

An inspection would also be necessary to determine if the current condition of the surface cover fulfills the requirement of this section (OAC 3745-20-07(A)), and to identify any areas where additional ground cover may need to be added. During the removal of the surficial ACM, these disturbed areas and any other areas without surface cover would be required to have additional ground cover, using one of the options described above.

The property is not accessible by the public, with the entire facility surrounded by fencing, and entry areas manned by guards. The quarry boundary is delineated with Seibert stakes, which serve as a warning of restricted access to on-site personnel and visitors. Ohio EPA's DAPC asbestos program has made a determination that the installation security and Seibert stakes designed to restrict access at the quarry meet the requirements of OAC 3745-20-07 (C).

Alternative 2: Surficial ACM removal and Land Use Controls (LUCs). All regulatory requirements potentially applicable to Alternative 1 would also apply here. In the event that more than 50 linear or square feet of ACM were disturbed or removed, work practices described in the applicable sections of OAC 3745-20-04, demolition and renovation procedures for asbestos emission control, and the applicable sections of OAC 3745-20-05, standard for asbestos waste handling, would proscribe requirements for collecting, packaging and placarding of waste material, along with recordkeeping and disposal. This alternative describes that workers would manually remove visible ACM found at the surface, but not any buried material.

Workers performing these activities would be required to be ODH-certified and under the direction of an ODH-certified asbestos contractor in the event that the regulatory threshold for ACM (i.e., 50 linear or square feet) were to be disturbed or removed. The ODH asbestos program has determined that if less than that amount of ACM is involved, the regulatory requirements cited above are not applicable.

Page 2-2 describes the AOC as currently heavily forested with brush and trees at least one foot in diameter. Alternative 2, the recommended alternative, does not provide enough detail on the surficial removal process, including removal around the brush and trees which may be difficult during the growing season.

The report states "An estimated 10 cubic yards of exposed ACM (e.g., transite/shingle and steel panels with block insulation and paper) were observed to be in surface soil at C Block Quarry." The removal does not include soil removal although asbestos was detected in the one sampling collected during the asbestos survey.

Although cleanup goals for hexavalent chromium and asbestos are provided in the report for unrestricted use, commercial/industrial cleanup goals were not. These should be discussed and presented in Alternative 2.

Alternative 2 does not propose to meet the unrestricted land use goal, but instead implement Land Use Controls (LUC). Leaving the asbestos in the soil would require a demonstration that the asbestos-containing soil would not become airborne due to wind erosion, and travel beyond the LUC boundary. It would also require demonstrations that the surface water entering the quarry on all sides and slopes, will not erode the side slope or bottom soils and further expose asbestos-contaminated soil to potential wind erosion. The report states that Alternative 2 consists of removing the surficial ACM through use of non-intrusive, no-digging methods to prevent industrial receptor exposure to ACM in surface soil. In additional to the above comments that asbestos in surface soil may not have been adequately characterized, the soils beneath the proposed material removal require confirmatory sampling to demonstrate that the surface meets RAOs. Refer to the above comment regarding adding the commercial/industrial cleanup goals (RAOs) to Table 9-1. Note, the confirmatory samples should be discreet samples and not ISM samples.

Alternative 3: Excavation and off-site disposal. This alternative would require additional surface and subsurface sampling to delineate the extent of ACM contamination, in preparation for removal down to 13 below ground surface (bgs), in order to demonstrate that the point of compliance for unrestricted (residential) land use has been met.

In the event this alternative is chosen, the regulatory requirements of OAC 3745-20-07 would not be required. In addition, the Army would not be required to institute an LUC or record a deed restriction on the quarry.

However, contractor activities involving ACM collection, on-site storage, packaging, transport, documentation and disposal could be subject to the applicable OSHA regulations. Perimeter air sampling and standard work practices could potentially be required to ensure that unpermitted air releases of ACM were not occurring during removal activities.

Certified asbestos workers under the direction of an ODH-certified asbestos contractor would be necessary to perform this work in the event that the regulatory threshold of amount of ACM were to be removed or disturbed. Also, this activity would require formal prior 10-day notification. If there is less than 50 linear or square feet to be disturbed or removed, the requirements listed above, including notification, would not apply. The Army should be aware that although state asbestos regulations may not apply to these activities, OSHA requirements may be applicable.

Appendix K, Detailed Cost Estimate: Please discuss the rationale for why only six five-year reviews were budgeted.

Fate and Transport Model/Groundwater

1. The site conceptual model appears to consist of a contaminated layer of unconsolidated soil over bedrock (Figure 6-1). That model is not supported by the borings. For example, the drilling log for CBLsb-026 shows that bedrock is about two feet down. Thus, most of the vadose zone is rock rather than soil which is not what Figure 6-1 portrays. It would be helpful to Ohio EPA if all logs for all of the borings shown in Figure 5-4 were included in the report. With that information, we could better define the site stratigraphy, especially the quarry. In addition, it would also be helpful to include some cross-sections through the quarry area showing the various layers and their thicknesses.

2. The SESOIL model is unclear as to the properties of the various layers. Table E-10 of the Fate and Transport Section (Appendix E) presents four layers that constitute the vadose zone. While the top 1.5 ft. thick layer is probably accurately represented by the surface soil, the lower layers would be fractured bedrock. It is unclear if the model used appropriate properties for the bedrock. Table 6-2 of the report only appears to give properties for the unconsolidated soil layer, not the bedrock. Given the lack of standing water in the quarry, the permeability of the bedrock is probably high and needs to be properly considered in the modeling.

3. In a similar manner, it is unclear if the transport calculations presented in Table E-7 considered the properties of fractured bedrock rather than the overburden soil. Note that the high chromium borings, like CBLsb-026, hit rock at about two

feet. Thus, most of the transport to the water table is through bedrock rather than soil. The properties in that table appear to represent the sandy soil rather than the bedrock. In particular, the following equation for travel time to the water table:

$$T = \frac{L_z \Theta_w R}{q}$$

needs input values for the fractured bedrock as well as the overburden.

4. It is not clear how the SESOIL™/ACT123D™ software accurately models contaminant fate and transport in weathered fractured Homewood Sandstone in which fracture flow may be a significant or dominant component of ground water flow. SESOIL™ models contaminant leaching in the vadose zone, and ACT123D advection, dispersion, adsorption/retardation, and decay.

   Available drilling logs (attached) for the four (CBL-mw-001, CBL-mw-002, CBL-mw-003, CBL-mw-004) of the five (Note: A drilling log for CBL-mw-005 could not be found) indicate that the Homewood Sandstone encountered in these wells is weathered. Based on Ohio EPA experience of examining rock cores from wells installed at Camp Ravenna, the Homewood Sandstone beneath Camp Ravenna is typically both weathered and fractured. Based on historical records, it is likely that the Homewood Sandstone was quarried using explosives which would have created additional fracturing in the already weathered and fractured rock. According to Pfingsten (2002), because there was a shortage of trenching and digging equipment when Camp Ravenna was being Constructed, dynamite was used for activities such as quarrying and trenching.

   It needs to be explained how the SESOIL™ accurately models ground water flow with significance of dominant fracture flow.

5. SESOIL ™/ ACT123D™ modeling only considers the leaching of CMCOCs from soil to ground water, and does not account for the direct disposal of wastes onto the weathered and fractured bedrock, as has been reported to have been historically practiced during the 1950's and 1960s at C Block Quarry. Because this source of ground water contamination has not been considered in the SESOIL ™/ ACT123D™ model, it is unclear how well the model has predicted all of the impacts to ground water discharges at Hinkley Creek from past disposal practices at C-Block Quarry. It is understood that the purpose of the submitted report was to evaluate the potential for soil leaching to evaluate alternatives for

soil, and is not a complete evaluation of impacts to ground water in the vicinity of C Block Quarry. Therefore, the modeled concentrations of CMCOCs in ground water discharging to Hinkley Creek are not considered representative for the purposes of evaluating ground water impacts.

Due to previous waste disposal practices at C Block Quarry, the following should be forwarded and considered for evaluation under the FWGWMP:

- Evaluate ground water horizontal/vertical gradients and permeability measurements of the Homewood, Mercer, and Sharon Aquifers, and surface topography in the area to determine the effect on contaminant transport.
- Evaluate the potential for discharge of chemicals of potential concern (COPCs) to surface water to the east.
- Confirm that historically characterized COPC concentrations indicate that site related contaminant mass presents limited potential for significant horizontal or vertical migration.
- Evaluate the potential for COPCs historically detected in the Homewood Aquifer to have migrated down-gradient after the collection of RI samples.
- Evaluate the effect of Sharon Shale on vertical contaminant migration.

Note: November 2016 pH measurements, in the five monitoring wells located in the vicinity of C Block Quarry, are all relatively low (e.g., 4.45 [well CBL-mw-001] to 5.59 [CBL-mw-003]), i.e., either below or near the bottom of the naturally-occurring range of 5 to 9 typically found in uncontaminated ground water. These low pH measurements are consistent with impacts that would be expected from the direct disposal of sulfuric acid and pickle liquor onto the weathered fractured bedrock surface.

6. The ground water flow direction shown Figures 3, 3-1, 4, and 4-1 is over-generalized. Ground water flow on the knob of Homewood Sandstone is controlled in part by the geometry and topography of isolated sub-crop of Homewood Sandstone, and is more radial than shown in the aforementioned figures. There is also variation in flow and the elevation of the potentiometric surface. Refer to the attached July 2015 and September 2016 Potentiometric Maps.

7. The Geologic Bedrock Map (Figure 3-3) is not accurate. The map inaccurately shows that the Devonian-aged Berea Sandstone and Mississippian-aged Cuyahoga Group are the uppermost bedrock units in portions of the eastern part of Camp Ravenna. The uppermost bedrock units beneath Camp Ravenna all belong to the Pottsville Group and are Pennsylvanian in age. An accurate version of the Geologic Bedrock Map is attached. For more information regarding the bedrock geology beneath Camp Ravenna refer to *Geology and Ground Water Resources of Portage County* (Winslow and White, 1966).

The above comments need to be adequately addressed before moving forward with the C Block Quarry RI/FS report.

If you have any questions, please call me at (330) 963-1207.

Sincerely,

Vicki Deppisch

Vicki Deppisch
Hydrogeologist/Project Coordinator
Division of Environmental Response and Revitalization

VD/nvp

cc: Katie Tait/Kevin Sedlak OHARNG RTLS
Craig Coombs, USACE
Rebecca Shreffler/Gail Harris, VISTA Sciences Corp.
Josh Koch, ODH
Brian Ng, ARAQMD

ec: Mark Leeper, ARNG
Nat Peters, USACE
Bob Princic, Ohio EPA, NEDO DERR
Rodney Beals, Ohio EPA NEDO DERR
Tom Schneider, Ohio EPA, SWDO DERR
Tim Christman, Ohio EPA, CO DERR
Al Mueller, Ohio EPA, NEDO DDAGW
Frederick Jones, Ohio EPA, DAPC CO
Chris Williams, Ohio EPA DAPC NEDO

THIS PAGE INTENTIONALLY LEFT BLANK.