Defining Nature and Extent of Contamination for the Waste Management Area C RCRA Corrective Action Process at the Hanford Site in Southeast Washington – 17403

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ABSTRACT

Determination of the nature and extent of contamination is a critical task in any *Resource Conservation and Recovery Act of 1976* (RCRA) Facility Investigation. Nature and extent are typically defined through field investigation results. In some cases, however, physical and/or programmatic limitations on field work can impede efforts to define nature and extent based on field work alone. Both physical and programmatic restrictions affected efforts to characterize soil contamination at Waste Management Area C, on the U.S. Department of Energy's Hanford Site. As a result, fate and transport modeling was undertaken to enhance the definition of the nature and extent of soil contamination at Waste Management Area C.

INTRODUCTION

Waste Management Area C (WMA C) is located within the ~1500 km^2 U.S. Department of Energy's (DOE's) Hanford Site in southeastern Washington State. The WMA C includes the 241-C Tank Farm (C Farm), which is comprised of 16 aging single-shell tanks and associated support structures and equipment that stored and treated chemically and radioactively contaminated waste (mixed waste) from Hanford Site nuclear operations. The DOE is retrieving waste from the tanks to prepare C Farm for closure under the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA). During the more than 70 years that C Farm equipment was used for the storage and treatment of mixed waste, waste escaped to the environment.

Soil contamination at WMA C is being addressed through the RCRA corrective action process. The RCRA corrective action process at WMA C is a multi-step process for evaluating the nature and extent of releases to the environment, determining whether corrective action is necessary, and implementing a corrective action. The process requirements are defined by RCRA and the *Hanford Federal Facility Agreement and Consent Order of 1989*, as well as other federal and state requirements. To meet the various regulatory requirements associated with the WMA C corrective action process, and to define the nature and extent of contamination at WMA C, it was necessary to generate and integrate information from numerous documents. The most consequential of these, relative to the WMA C corrective action, describe the soil contamination inventory, the RCRA facility investigation (RFI), and the performance assessment (PA), as described below.

Millions of gallons of nuclear waste were stored in the C Farm single-shell tanks, and some of the tanks are known to have leaked. Spills and pipeline leaks during transfers and storage and intentional discharges to French drains also resulted in waste releases to the environment. Liquid waste that could be removed by pumping has been removed from the majority of the C Farm single-shell tanks to reduce the potential for future leaks. The soil contamination inventory report presents information on the estimated leaks and the release volumes and dates, along with the associated waste compositions, including estimates of the inventory of individual contaminants in the releases [1].

The purpose of an RFI is to obtain information to characterize the nature, extent, and rate of migration of releases to the environment and to interpret this information to determine whether corrective measures and/or a corrective measures study (CMS) may be necessary. As envisioned in the *Hanford Federal Facility Agreement and Consent Order* Action Plan Appendix I, an RFI may be conducted in multiple phases.

The WMA C field investigation was conducted over 20 years in two main phases, supplemented by additional field work. The WMA C Phase 1 RFI was conducted to identify and confirm locations where significant releases to WMA C soils occurred. While the Phase 1 RFI report was being finalized, and prior to the completion of the Phase 2 planning documentation, characterization work in WMA C continued. This transitional characterization effort focused on the deployment of hydraulically driven direct push technology to push boreholes for geophysical logging, placement of deep electrodes, and collection of soil samples. The Phase 2 RFI focused on collecting information to support both risk analyses and the evaluation of alternatives in a planned CMS. The Phase 2 RFI also used direct push technology (for sampling and logging), geophysical logging of surrounding drywells and groundwater wells, and surface geophysical exploration (SGE) (i.e., electrical resistivity). Ultimately, however, physical and programmatic restrictions on the characterization work (e.g., prioritization of tank waste retrieval work, difficulties working in a physically congested location, risks of radiological exposure to investigators during drilling and sampling) limited characterization of the full horizontal and vertical extent of WMA C. As a result, the draft Phase 2 RFI identifies the difficulties of fully defining the nature and extent of WMA C soil contamination based on the results of field work alone [2].

Fig. 1 shows the WMA C field investigation locations along with the RFI/CMS study boundary. The area within the study boundary is approximately 60,000 m^2. The volume of soil within study boundary, from the ground surface to the water table is approximately 4,681,500 m^3. The ground surface in WMA C around Tank 241-C-105 is approximately 198 m above mean sea level (amsl). The groundwater around Tank 241-C-105 is approximately 77 m below ground surface, while the average elevation of groundwater at WMA C is approximately 121 m amsl.

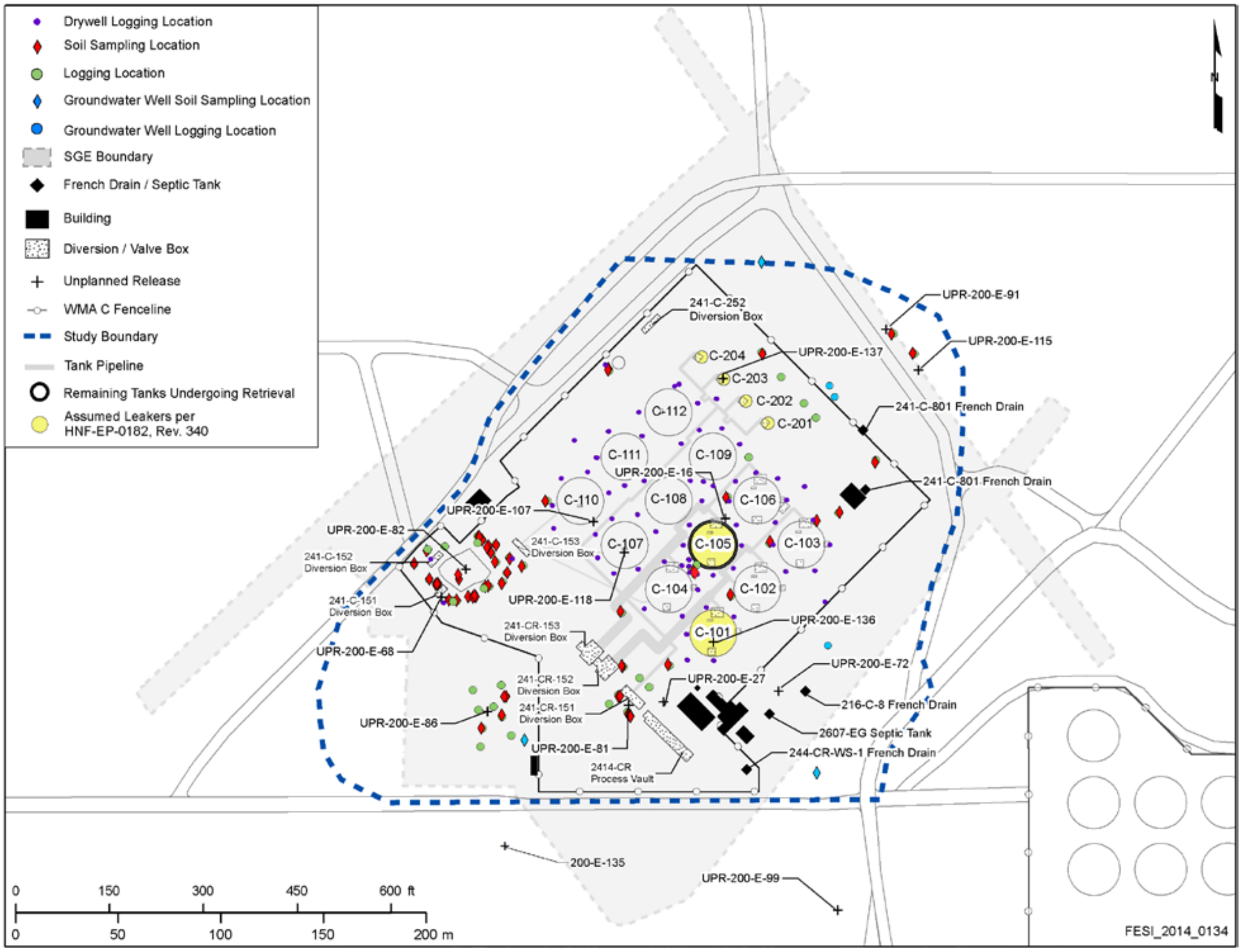

Fig. 1. Waste Management Area C Phase 2 RCRA Facility Investigation Map.

Concurrent with the preparation of the revised Phase 2 RFI report [3], the DOE Order 435.1 radiological PA was being developed to support single-shell tank closure decision-making. In recognition of parallel risk assessment requirements of RCRA, *The Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA), and DOE Order 435.1, DOE and state and federal regulators agreed to develop a single PA for evaluating whether WMA C closure conditions will be protective of human health and the environment for all WMA C contaminants of potential concern (COPCs), both radiological and nonradiological. This agreement is documented in the *Hanford Federal Facility Agreement and Consent Order* Action Plan Appendix I. Thus, the WMA C Appendix I PA addresses the requirements of RCRA, the Washington State *Hazardous Waste Management Act* (HWMA), *Federal Water Pollution Control Act* (Clean Water Act), *Atomic Energy Act of 1954*, *Safety of Public Water Systems* (Safe Drinking Water Act of 1974), and any other performance requirements that might be applicable or relevant and appropriate requirements under CERCLA.

One of the pivotal products of the WMA C Appendix I PA was numerical model scenarios that can be used to predict the movement of soil contaminants in the

WMA C subsurface. The model scenarios developed for the Appendix I PA can also be used to predict where contamination may have migrated in the past and where it currently resides. The Appendix I PA modeling incorporated geological information and field investigation data derived from the WMA C RFI, as well as soil contamination inventory estimates, which by themselves do not fully define the nature and extent of soil contamination at WMA C. However, the results of the Appendix I PA modeling, having used historical information about planned and unplanned contaminant releases, provide significant insight about contamination in the WMA C vadose zone. Therefore, the Appendix I PA modeling results have been used in conjunction with field characterization work to enhance the determination of the nature and extent of soil contamination at WMA C.

DETERMINING NATURE AND EXTENT FOR SOIL CONTAMINATION

Determination of the nature and extent of soil contamination at WMA C relied on outputs of site-specific contaminant fate and transport modeling conducted as part of the WMA C Appendix I PA. This modeling employed the Subsurface Transport Over Multiple Phases (STOMP)©[a] code to generate both three-dimensional depictions of current soil contamination and estimates of the released contaminant inventory that remains in the vadose zone and that has reached groundwater.

The largest documented releases to the environment at WMA C were associated with leaks from pipelines and diversion boxes, with the inlets or outlets of the tanks, or with leaks from the tanks themselves. The leaks and releases carried nonradiological and radiological contaminants into the soil. Soil contamination inventories have been determined for 80 contaminants. To model the fate and transport of these contaminants, model inputs were provided for the timing of the releases, the volume of the releases, and the inventory of contaminants in the releases.

The technical basis for the inventory estimates for, and timing of, past leaks and releases to the soil at WMA C is presented in the *Assessment of WMA C Tank Farm Leaks* [4] and *Hanford Waste Management Area C Soil Contamination Inventory Estimates* [1]. The process to estimate tank leak inventories is described in *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning* [5]. Information for WMA C single-shell tanks, catch tanks, pits, diversion boxes, and pipelines was reviewed to assess evidence of waste releases to the environment.

For the WMA C Appendix I PA, a screening analysis (using the STOMP© code) was performed to identify which of the 80 contaminants associated with WMA C leaks and releases are not sufficiently mobile to impact groundwater within 10,000 years. These contaminants, along with others that are present in relatively small amounts or that have a short radiological half-life (i.e., those not expected to impact groundwater) were excluded from further fate and transport analysis.
The remaining nonradiological and radiological contaminants considered for fate

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[a] *Subsurface Transport Over Multiple Phases (STOMP)© is copyrighted by Battelle Memorial Institute, 1996.*

and transport modeling were Tc-99, H-3, Co-60, Se-79, I-129, Sn-126, U-238, nitrate, sulfate, chromium, and total uranium. TABLE I provides the soil contamination inventories for each contaminant and each WMA C release or leak evaluated in the screening analysis.

The WMA C fate and transport analysis used a site-specific model described in detail in the *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington* [6]. The overall approach to developing the site-specific fate and transport model was to develop a “base case” scenario, representing features of the hydrogeological system reasonably expected (or demonstrated by the field investigation) to exist, and then explore the sensitivities to variations on the base case conceptual model by simulating fate and transport under a range of permutations of scenarios. These various model scenarios are referred to as “scoping analysis cases.” The model scoping analysis case that produced results that were both reasonably consistent with observed groundwater data, and that was most consistent with the model described in other WMA C Appendix I PA documents, was selected to represent contaminant fate and transport at WMA C.

TABLE I: Waste Management Area C Soil Contamination Inventory Information used in Predictive Fate and Transport Modeling

Leak Site	Tank C-101	Tank C-104	Tank C-105	Tank C-108	Tank C-110	Tank C-112	UPR-81	UPR-82	UPR-86	Surface Contamination	French Drain 216-C-8
Estimated Leak Time	**Late 1965 through 1969**	**~1965**	**Multiple releases between 1963 and 1967**	**~1965**	**Between 1971 and 1972**	**between 1946 and 1974**	**October, 1969**	**December, 1969**	**December, 1969 (discovered)**	**Unknown (Assumed to be 1965)**	**January 1960 through March 1965**
Modeled Leak Beginning Time	**1965**	**1965**	**1963**	**1965**	**1971**	**1965**	**1969**	**1969**	**1971**	**1965**	**1960**
Leak Volume (gal)*	37,000	28,000	20,500	18,000	2,000	7,000	36,000	2,600	17,000	1,000	32,000
Tc-99 (Bq)	9.21E+09	1.11E+09	3.64E+11	7.18E+08	1.24E+11	2.79E+08	4.07E+09	4.63E+10	9.92E+10	4.00E+07	0.00E+00
I-129 (Bq)	1.42E+09	1.10E+09	2.19E+07	7.07E+08	7.36E+07	2.75E+08	3.53E+09	2.77E+06	5.96E+06	3.92E+07	0.00E+00
Co-60 (Bq)	7.25E+12	5.48E+12	7.62E+12	3.52E+12	1.08E+12	1.37E+12	2.81E+13	4.40E+11	7.25E+11	1.96E+11	0.00E+00
H-3 (Bq)	6.44E+12	4.96E+12	2.15E+11	3.19E+12	9.25E+10	1.24E+12	2.05E+13	1.95E+10	3.74E+10	1.77E+11	0.00E+00
U-238 (Bq)	5.37E+07	4.07E+07	2.22E+07	2.61E+07	8.95E+06	1.01E+07	2.09E+08	2.82E+06	6.07E+06	1.45E+06	7.40E+05
Se-79 (Bq)	2.81E+07	2.56E+06	1.17E+09	1.64E+06	3.89E+08	6.40E+05	9.77E+06	1.48E+08	3.18E+08	9.14E+04	0.00E+00
Sn-126 (Bq)	1.16E+08	1.05E+07	4.85E+09	6.77E+06	1.62E+09	2.63E+06	4.03E+07	6.18E+08	1.32E+09	3.77E+05	0.00E+00
Nitrate (kg)	5.90E+03	4.53E+03	4.32E+02	2.91E+03	1.82E+03	1.13E+03	2.32E+04	5.48E+01	1.18E+02	1.62E+02	1.46E-01
Sulfate (kg)	1.29E+02	9.03E+01	6.91E+02	5.81E+01	2.12E+02	2.26E+01	3.53E+02	8.76E+01	1.88E+02	3.23E+00	1.37E-01
Chromium (kg)	2.32E+01	1.70E+01	2.46E+01	1.09E+01	3.86E+01	4.25E+00	8.68E+01	3.12E+00	6.70E+00	6.07E-01	0
Total Uranium (kg)	4.34E+00	3.29E+00	1.80E+00	2.11E+00	7.27E-01	8.21E-01	1.69E+01	2.28E-01	4.90E-01	1.17E-01	6.00E-05

Sources: [1] and [6]
Note: The inventory estimates have been radioactive decay corrected to the beginning of the leak or unplanned release modeled year.
*Conversion 1 gal = 3.78541 L

The primary COPCs in the vadose zone were identified in the *Baseline Risk Assessment for Waste Management Area C* [7] and include: nitrate, Cs-137, Tc-99, and Sn-126. The COPCs for the groundwater beneath WMA C were identified in the

Remedial Investigation Report for the 200-BP-5 Groundwater Operable Unit Remedial Investigation [8] and include: cyanide, nitrate, sulfate, I-129, and Tc-99.

Predictive modeling, using the selected model scenario, was performed with the release inventory information listed in TABLE I to estimate the current location of contamination in the vadose zone. STOMP© outputs from the predictive modeling were used to estimate both volumes and masses of soil contamination.

The approach used to quantify areas of vadose zone contamination likely exaggerates the extent of contamination because for each modeled contaminant, one tenth of the analytical detection limit or soil background limit (if available) was used to define the current distribution of soil contamination. Three-dimensional depictions of current soil contamination volumes are represented by grid cells within the STOMP© model. Grid cells vary from 3 m by 3 m to as large as 20 m by 20 m.

Planar views of the three-dimensional depictions, shown in relation to the RFI/CMS study boundary, were generated to show the greatest extent of contamination by depth. Planar views also show sampling and analysis information to support integration of both field and modeling information. Graphs from the predictive modeling were also generated to show how the volume of soil contamination changes over time.

The current mass of contamination in the vadose zone and groundwater were also predicted from STOMP© outputs along with the flux rates (i.e., the rate at which contamination is reaching the water table). The changes in mass over time were graphically presented in the *Analysis of Past Tank Waste Leaks and Losses in the Vicinity of Waste Management Area C at the Hanford Site, Southeast Washington* [6].

NITRATE SOIL CONTAMINATION

The following is an example of the information generated to depict soil contamination for nitrate, one of the WMA C soil and groundwater COPCs.

Nitrate is considered to be a major risk contributor and COPC from the WMA C vadose zone. Approximately 40,300 kg of nitrate were released from WMA C tanks and equipment from 1965 to 1974, accounting for 23% of the overall chemical inventory released. The mass of nitrate released from various WMA C sources ranged from 0.146 kg at the 216-C-8 French drain to 23,000 kg from the unplanned release (UPR) at UPR-200-E-81 (TABLE I).

During Phase 2 of the WMA C RFI, more than 150 soil samples were collected. Nitrate was reported at concentrations greater than its background level of 52,000 µg/kg [9] in only eight soil samples. The maximum concentration (198,000 µg/kg) was reported between the 241-C-801 Load Out Facility and Tank 241-C-103 at 38 m (below ground surface (Fig. 2).

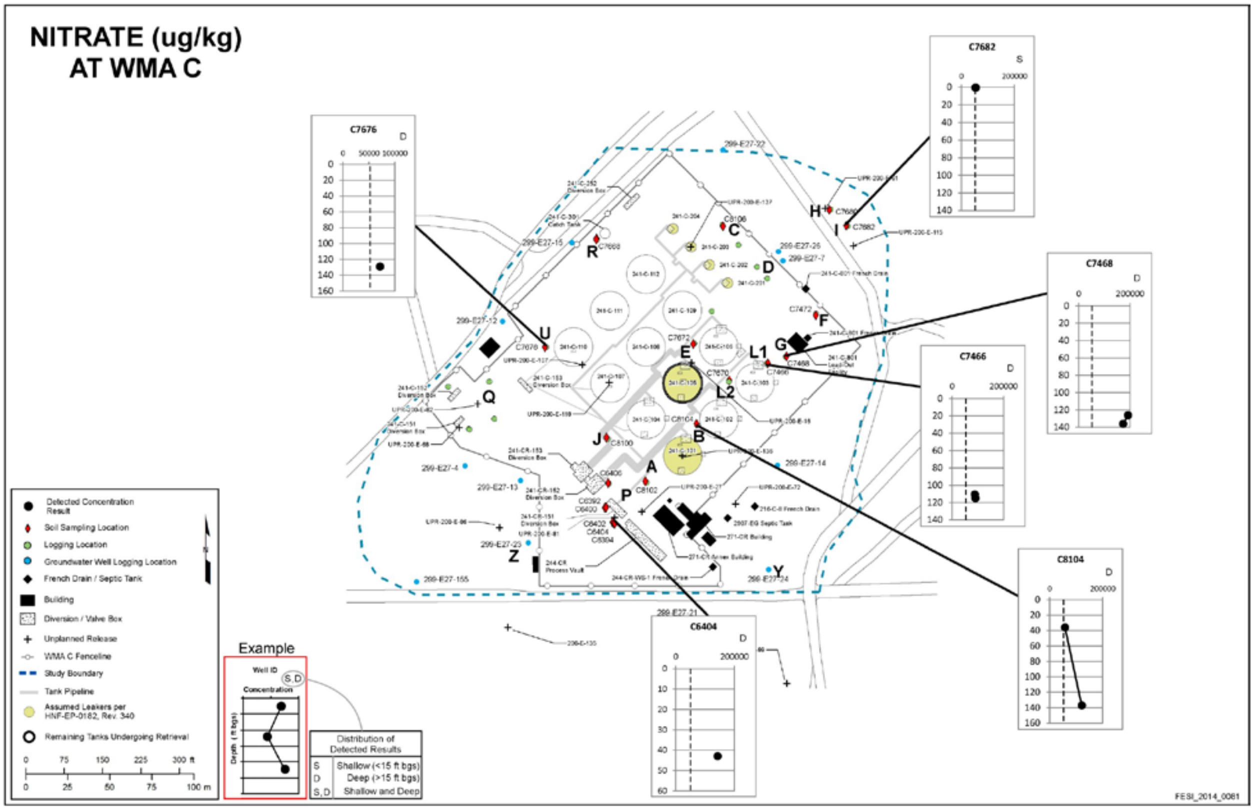

Fig. 2. Phase 2 Nitrate Results at Waste Management Area C.

Model results predicted that nitrate released from WMA C would first reach groundwater in 1988. The current flux rate for nitrate is anticipated to be 767 kg/yr, with 31,565 kg of nitrate remaining in the vadose zone and 8,745 kg having reached groundwater.

The model results indicate that the current volume of nitrate-contaminated soil at WMA C is approximately 59,185 m^3. Fig. 3 and Fig. 4 provide three-dimensional depictions of where nitrate-contaminated soil is located. Fig. 5 presents a planar view of soil contamination depicting the maximum extent of contamination for each modeled release area by elevation. Fig. 6 shows how the volume of contaminated soil is anticipated to change over time.

Both modeling and field work provide results that inform the determination of the nature and extent of soil contamination. Modeled soil contamination inventories provide more complete depictions of where nitrate contamination is likely to reside. Actual field results provide information for areas where there is no documented release inventory available to use in modeling. For instance, Fig. 2 and Fig. 5 show that nitrate was detected above background in field samples collected from Investigation Site I, which is associated with UPR-200-E-115. TABLE I does not include a release inventory for UPR-200-E-115 because no documented release volume or contaminant mass information was available for this unplanned release site; therefore, the site was not included in the predictive modeling effort.

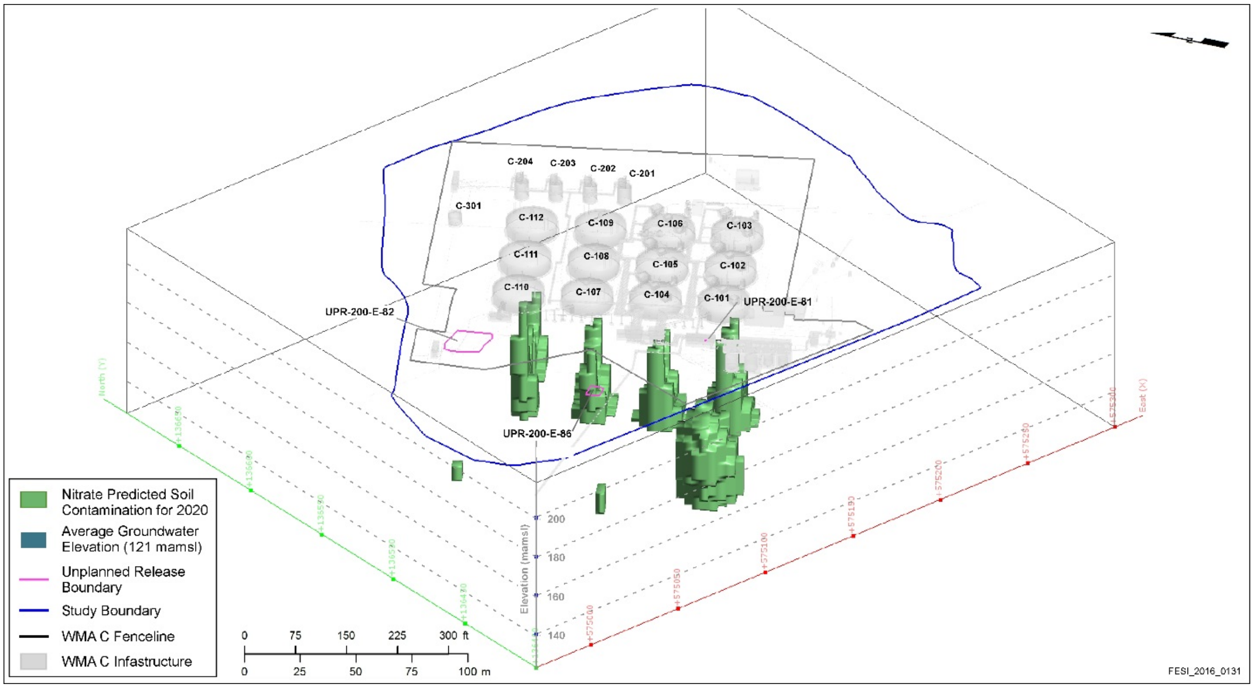

Fig. 3. Three Dimensional Views of Nitrate Soil Contamination.

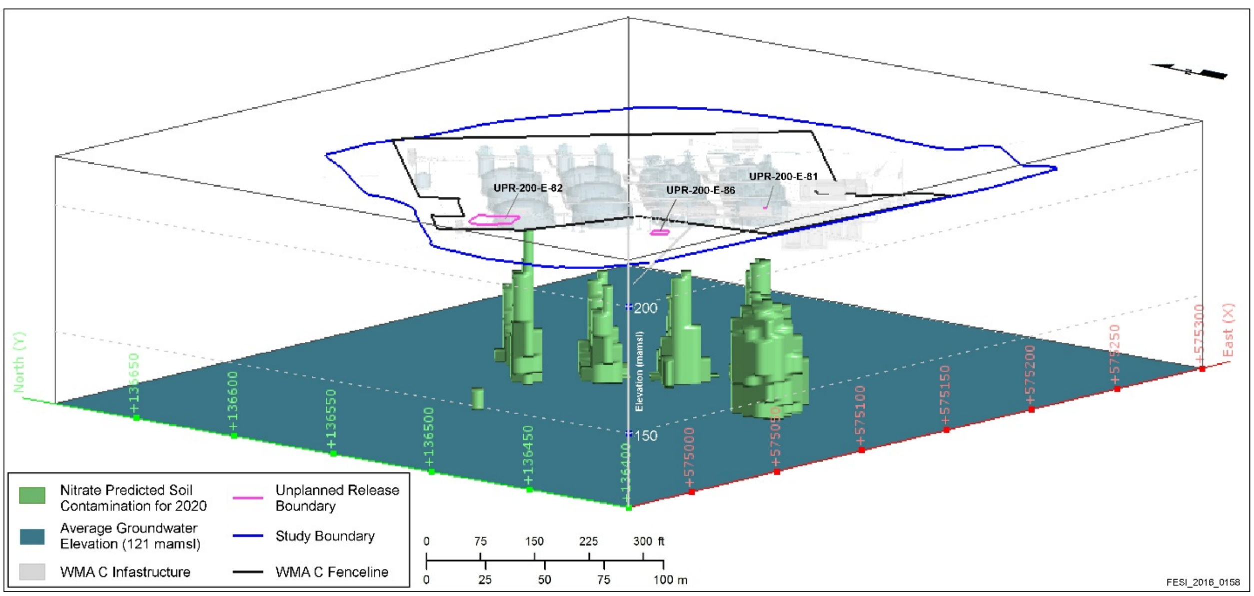

Fig. 4. Three Dimensional Views of Nitrate Soil Contamination.

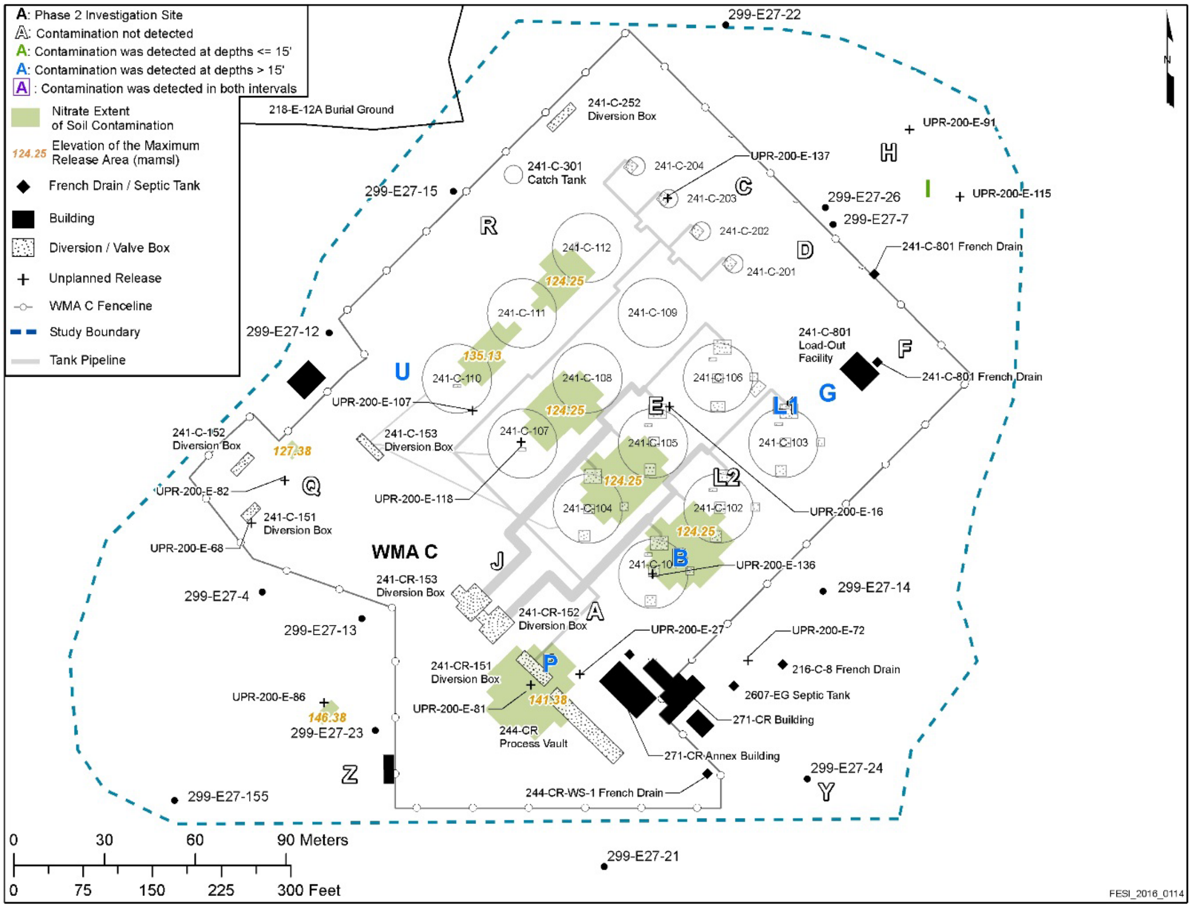

Fig. 5. Nitrate Soil Contamination - Maximum Extent by Elevation.

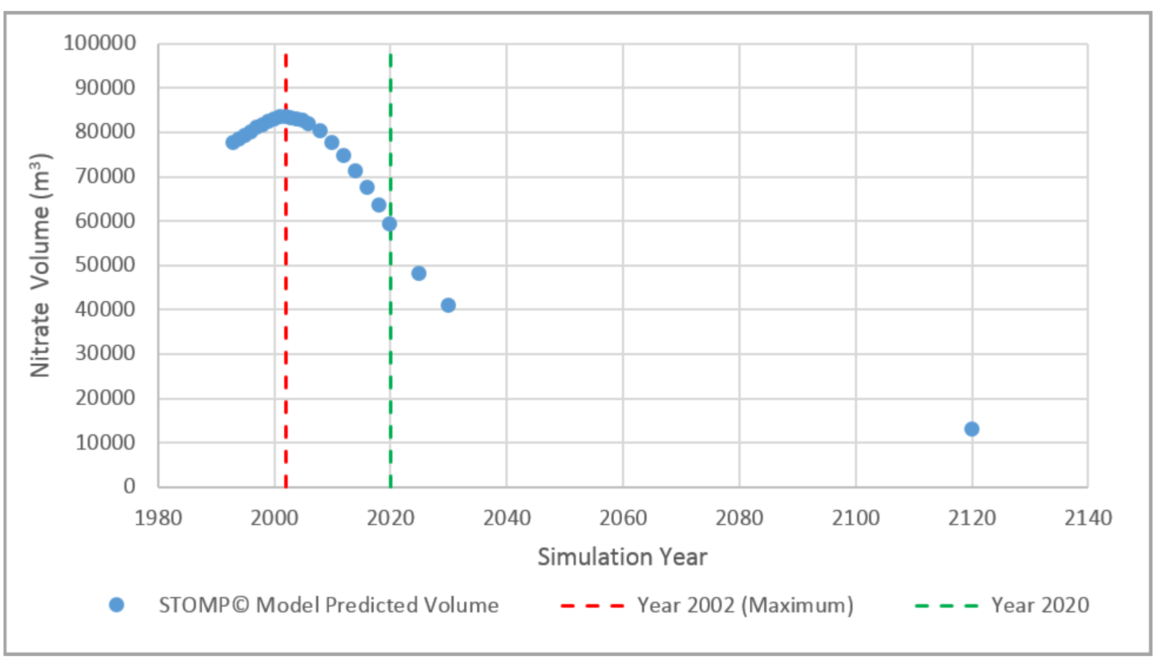

Fig. 6. Predicted Volumes for Nitrate Soil Contamination.

In summary, modeling results, used in conjunction with field information, indicate that nitrate soil contamination is continuous from the locations of the releases/leaks to the water table. Individual modeled nitrate releases from the C Farm single-shell tanks have spread and combined to impact the majority of the vadose zone beneath the 12 largest C Farm single-shell tanks. The maximum lateral extent of nitrate soil contamination is at an elevation near groundwater for most of the releases/leaks.

Evaluation of the relative volumes of contaminated soil associated with the various WMA C soil COPCs indicates that that nitrate impacts a larger volume of WMA C soil than any other COPC: approximately 59,190 m^3. The volume of nitrate-contaminated soil represents approximately 1.3% of the RFI/CMS study area.

CONCLUSIONS

The draft Phase 2 RFI report defines the nature and extent of WMA C soil contamination primarily using the results of field investigations. The field investigations provided evidence of widespread shallow and deep contamination, a discontinuity between soil constituents and groundwater contamination, and a limited understanding of the linkage between sources and vadose zone contamination at WMA C. The field results also indicated that contamination, in general, was found from the surface to approximately 73 m below ground surface, and specific correlations to sources was difficult due to the number and nature of the waste releases that occurred within the 60,000 m^2 study area. While these conclusions are highly valuable to the RFI process, the field results alone do not provide sufficient information to fully define the nature and extent of WMA C soil contamination. As a result, no quantitative estimates were provided in the draft RFI report for soil contamination masses or volumes.

Use of the results of field investigations in conjunction with modeling results improved the definition of the nature and extent of soil contamination at WMA C. When contaminant inventories associated with specific WMA C releases were modeled, the nature and extent of contamination could be determined for locations that could not be accessed during field investigations. Quantitative estimates of the current volumes and masses of contaminated soil were determined through predictive modeling and STOMP© outputs. Analytical data from field efforts was reviewed to determine if locations for which no documented release inventory was available had also impacted the vadose zone. In summary, integration of both field and modeling information provided a more comprehensive picture of soil contamination at WMA C than was possible using only field information.

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