DRAFT
FINAL PERIODIC REVIEW REPORT FOR
BUILDING T-91
FORT DRUM, NEW YORK

Prepared for:

UNITED STATES ARMY ENVIRONMENTAL COMMAND
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Contract No. W91ZLK-05-D-0011
Delivery Order No. 004

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ACRONYMS

AEC	Army Environmental Command
AOC	area of concern
AST	above ground storage tanks
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CDM	Camp, Dresser, and McKee
DER	Divisions of Environmental Remediation
EPA	Environmental Protection Agency
HHRA	human health risk assessment
HQ	hazard quotient
M-K	Mann-Kendall
MNA	monitored natural attenuation
N:P:K	nitrogen: phosphorous: potassium
NYSDEC	New York State Department of Environmental Conservation
Plexus	Plexus Scientific Corporation
POL	petroleum, oil, and lubricant
SCG	standards, criteria and guidance
USAEHA	United States Army Environmental Hygiene Agency
UST	underground storage tank
µg/L	micrograms per liter

EXECUTIVE SUMMARY

Plexus Scientific Corporation (Plexus), under the United States Army Environmental Command (AEC) Contract No. W91ZLK-05-D-0011 Delivery Order 0004, has provided this comprehensive review of the environmental data collected at Building T-91 from 1984 to 2011. This report is comprised of five elements that evaluate the environmental program at Building T-91:

- A historical review of the remedial program to date;
- A comparison of the initial and current contaminant concentrations, and extent of contamination at Building T-91;
- Time series and statistical evaluation of contaminant data trends;
- An evaluation of monitored natural attenuation (MNA); and,
- A human health risk assessment (HHRA) of the present condition of the site.

Review of these elements provides a comprehensive assessment of the program's progress and current conditions at the site. In addition, this review presents the required lines of evidence that are needed to achieve regulatory closure of the site, as outlined in the New York State Department of Environmental Conservation (NYSDEC) Divisions of Environmental Remediation (DER)-10 Technical Guidance for Site Investigation and Remediation for Building T-91. More specifically, data have been evaluated relative to subsection 6.4(c) of the DER-10 which outlines the closure requirements. Based upon this evaluation, the Army has determined that MNA has remediated the site in a manner that is fully protective of all identified sensitive receptors and that monitoring can be terminated.

Historical Review

Sections 2 and 3 provide a historical review of the remedial and monitoring activities to date. The primary source of the contamination at Building T-91 was determined to be rinse water from a parts-cleaning sink drain that was discharged onto the ground outside the north portion of Building T-91. Suspected leaks at various underground storage tanks (USTs) and above ground storage tanks (ASTs) were also identified as potential contaminant sources. These tanks were removed in 1990. In 1992, a Phase II investigation determined the nature and extent of site-related contaminants. In 1994, a remedial recommendation study was performed; the report recommended that all impacted surficial soils should be removed and that the site be placed into a MNA program. The results of a risk assessment performed in 2002 concluded that no risk remained at the site, as long as the shallow aquifer was not used as a potable water source. From 1994 to August 2011, the site was been monitored under the basewide sampling program that successfully evaluated MNA and the trend of groundwater contaminants.

Initial and Current Extent of Groundwater Contamination

Sections 4 and 5 outline the initial and current characterization of the groundwater contaminant plume at Building T-91. The contaminants of concern (COCs) at Building T-91 were determined to be benzene, toluene, ethylbenzene, total xylenes (BTEX), and naphthalene. The concentrations of all five of these compounds have exceeded NYSDEC screening criteria in site groundwater monitoring wells over the monitored history. The maximum recorded total BTEX concentration of 280 micrograms per liter (µg/L) was recorded at the site in July 1992. Benzene and toluene have not exceeded NYSDEC screening criteria since July 1992; ethylbenzene and total xylenes have not exceeded NYSDEC screening criteria since October 2009; and naphthalene has not exceeded NYSDEC screening criteria since October 2010. Analytical results from the Fall 2011 groundwater samples indicate that all COCs are currently below their respective NYSDEC screening criteria.

Contaminant Data Trends

Section 5 outlines the contaminant data trends over the course of the site's monitored history. Analytical data time series plots and Mann-Kendall (M-K) statistical analyses were used to evaluate contaminant concentration trends. MNA has been the only mechanism for contaminant degradation in groundwater. Time series and M-K tests show that site-related COCs continue to decrease over time. Due to the Army's cumulative efforts, the total BTEX concentrations in the area of concern (AOC) monitoring well T-91-001 have decreased from 280 µg/L to 5.43 µg/L over a time period of 18 years.

Evaluation of MNA

Section 5 outlines the evidence that MNA continues to occur at the site and has proven to be an effective remedial approach for reducing site-related contaminants. A constant supply of oxygenated groundwater continues to facilitate aerobic biodegradation of the contaminant plume. MNA data show that the microbial population within the contaminant plume continues to consume the available oxygen, demonstrating that the natural biodegradation mechanisms are still in place despite the absence of active remediation. To enhance future MNA at the site an application of a nitrogen: phosphorous: potassium (N:P:K) solution was administered from January to March 2011 (Plexus, 2010a). The results of the post-nutrient application sampling event show that the application was successful in promoting biodegradation.

Updated HHRA

Section 6 summarizes the updated HHRA, which reconfirms the findings of the 2002 and 2009 HHRAs that were performed to evaluate conditions at Building T-91. The updated HHRA concludes there is no risk to receptors under industrial worker or residential scenarios. In addition, future land use plans do not include residential zoning.

Conclusion and Recommendation

This Final Periodic Review Report (PRR) for Building T-91 provides the lines of evidence (as outlined in Section 7) which clearly demonstrate that the remedial program at Building T-91 has satisfied the DER-10 requirements of no further monitoring under the DER-10 Section 6.4(c)3, outlining remedial process closure requirements.

In accordance with the DER-10, site closeout is recommended as outlined in the Section 6.5(a) as the conditions of Section 6.4 have been met as outlined in this PRR.

1.0 Introduction

Fort Drum, encompassing approximately 168 square miles, is located in upstate New York, approximately 10 miles northeast of Watertown and 80 miles north of Syracuse (**Figure 1-1**). Building T-91 is located at the intersection of First Street West and Warehouse Road (**Figure 1-2**). The site, a former vehicle maintenance facility, is currently being used as a wheeled vehicle maintenance shop. In the past, solvent- and petroleum-contaminated wastewater was discharged onto the ground via a drainage pipe. In addition, several USTs and ASTs around the building could have contributed to site contamination. The current remedy at this site is MNA. Groundwater sampling and well gauging were performed until August 2011, in accordance with AEC Contract No. W91ZLK-05-D-0011 Delivery Order 0004.

2.0 Site Background

Building T-91 is a one-story, approximately 270-feet-by-76-feet structure, located northwest of the intersection of Railroad Street and Quartermaster Road, along the western portion of Gasoline Alley, within the Cantonment area of Fort Drum, NY. Building T-91 lies near the groundwater divide that parallels the Black River; groundwater at the site flows toward the Black River. **Figure 2-1** illustrates the site boundary for Building T-91.

Building T-91 was a truck maintenance facility, in operation for at least 22 years prior to 1990. At a minimum, between 1990 and 1994, the building was used for storage. Currently, the building is being used as a wheeled vehicle maintenance shop.

During the vehicle maintenance operations, T-91 was divided into two workspaces: a radiator shop and an electric and fuel shop. In the radiator shop, radiators were soaked in a hydroxide bath that was replaced approximately every two months, when the bath no longer had caustic properties. In the electric and fuel shop, rinse water from a parts-cleaning sink drain discharged onto the ground outside of the north portion of Building T-91, until the drain was connected to the sanitary sewer in 1989 (Camp, Dresser, and McKee [CDM], 1994). One of the carburetor-cleaning solutions used in the cleaning sink was P&D Metaclene, which contains naphtha, methylene chloride, cresol, phenol, and bichromate solution.

In addition to the maintenance shop operations potential contamination sources, several tanks were located in the site area. A 600-gallon waste petroleum, oil, and lubricant (POL) UST was located near the south corner of Building T-93, which is just north of Building T-91. A heating oil UST, located east of Building T-91was used to fuel the building's heating system. Two 500-gallon waste-oil USTs located along the south side of Building T-91 were removed in 1990. Two diesel fuel ASTs located near the southeast corner of Building T-9l were removed in 1990.

Environmental investigations at Building T-91 began in 1989. Historically, there were nine permanent monitoring wells around Building T-91. One well, T-91-003, was damaged and subsequently removed from the sampling program in 1990.

CDM completed a risk assessment of T-91 in 1994. Malcolm Pirnie conducted another risk assessment in 2002. Plexus conducted an HHRA in January 2010, which has been updated as part of this report to reflect data collected in 2011. Most recently, the site was in an MNA program which required semi-annual groundwater sampling of monitoring wells T-91-001 and T-91-002. The last sampling event at Site T-91 was in August 2011.

3.0 Investigations and Remedial Program to Date

January 1984. The United States Army Environmental Hygiene Agency (USAEHA) collected samples from the dip-and-rinse tanks at Building T-91. Based on the analytical results for these samples, USAEHA suggested various engineering/process modifications and recommended that the area contaminated from the parts-cleaning sink drain discharge be remediated (Malcolm Pirnie, 2002).

November 1989. CDM conducted a Phase I investigation of the area northwest of Building T-91, in the vicinity of the former parts-cleaning sink drain discharge (CDM, 1990). Investigation activities included surface and subsurface soil sampling in addition to the installation and sampling of two groundwater monitoring wells (identified as T-91-001 and T-91-002). Laboratory data for the surface and subsurface soil samples collected during the Phase I investigation indicated that soil contamination was generally limited to depths of less than three feet below ground surface (bgs) in the area between Buildings T-91 and T-93. A railroad formerly ran through this area; the soil contamination was attributed to former rail traffic.

A free-floating product layer was observed on the water table in the shallow monitoring well T-91-001. Analysis of the product indicated a diesel source. Reported concentrations of BTEX and naphthalene in samples collected from the deep monitoring well T-91-002 exceeded NYSDEC screening criteria.

July 1992. CDM completed a Phase II investigation to further characterize the nature and extent of soil and groundwater contamination at Building T-91. The Phase II investigation included collecting surface and subsurface soil samples from 12 soil borings and the installation and sampling of four groundwater monitoring wells (identified as wells T-91-003 through T-91-006). In a draft Phase II Site Investigation Report (CDM, 1993), CDM presented Phase II sample results and provided a comparison to preliminary remediation goals calculated for the Building T-91.

August 1994. McLaren and Hart completed a Remedial Recommendation Report for Building T-91. The study was conducted to evaluate potential remedial alternatives for soil and groundwater contamination at Building T-91. The recommendations included the excavation of surface and shallow soils and MNA of groundwater.

February 1995. McLaren and Heart conducted a Pre-Engineering Field Investigation Report for Building T-91. The field investigation showed that soil was impacted at the smear zone in the area of monitoring well T-91-001 and that groundwater contamination exceedances for BTEX and naphthalene were confined to the area of monitoring wells T-91-001 and T-91-002.

September 2002. Malcolm Pirnie completed a Risk Assessment for Building T-91. The findings of the 2002 Risk Assessment showed that:

Groundwater and subsurface soil present noncarcinogenic and carcinogenic risks less than the United States Environmental Protection Agency (EPA) acceptable risk level to base personnel via indoor air inhalation.

In the future, groundwater and subsurface soil present noncarcinogenic and carcinogenic risks less than the EPA acceptable risk level to base personnel via indoor air inhalation. Subsurface soil and groundwater present noncarcinogenic and carcinogenic risks less than the EPA acceptable risk level to construction/utility workers. This analysis is based on the assumption that current conditions would be the same in the future.

Under hypothetical future scenarios, groundwater presents noncarcinogenic risks below or equal to the EPA acceptable level and carcinogenic risks within or at the upper end of the EPA acceptable risk range to base personnel, base/off-site resident adults, and base/off-site resident children. This analysis is based on the assumption that the shallow groundwater is used directly as a source of potable water.

2002 to 2008. Building T-91 was sampled on a biennial basis by Malcolm Pirnie under the basewide sampling program.

2008 to August 2011. Building T-91 was sampled by Plexus under the basewide sampling plan. The sampling frequency was increased from biennial to semi-annual sampling to determine the current trends of contaminant degradation.

2009. Plexus completed a Risk Assessment for Building T-91. The findings showed that there is no human health risk associated with site-related contaminants.

2011. An application of a N:P:K solution was administered from January to March 2011. The purpose of this treatment was to ensure that there were sufficient micro-nutrients for the indigenous microbial population.

2012. Plexus completed a Site Monitoring and Management Plan for Building T-91. Implementation of land use controls and changes to the sampling frequency were recommended based on site conditions, data trend analysis, and human health and ecological risk scenarios. The land use controls included restricting groundwater use as a potable water source and preventing disturbance of soil below 19 ft bgs.

4.0 Initial Conditions and Contaminants of Concern

The results of the Phase I and Phase II Site Investigations for Building T-91 showed that surface soils and shallow subsurface soils were contaminated with low-level concentrations of polycyclic aromatic hydrocarbons and that groundwater was impacted by petroleum compounds (CDM, 1994). Recommendations from the Phase II Site Investigation Report stated that soil contamination identified during the investigation did not appear to be related to disposal activities at Building T-91, but rather to former railroad activities and potential runoff from the tar roofs on buildings T-91 and T-93. Concentrations detected in the soils were comparable to soils in an industrial setting. In addition, the groundwater samples collected from the wells downgradient of Building T-91 did not contain any petroleum contaminants. The report also recommended that all wells associated with this site should be sampled regularly to monitor the groundwater characteristics.

Figure 4-1 illustrates the extent of groundwater contamination in 1992 that was determined during the implementation of the Phase II Remedial Investigation (CDM, 1994). In 1992, three monitoring wells (T-91-001, T-91-002, and T-91-004) exceeded current NYSDEC screening criteria. Groundwater COCs include BTEX and naphthalene (**Figure 4-1**).

5.0 Current Conditions and Data Trends

In 2012, a Site Monitoring and Management Plan was written for Building T-91. The Site Monitoring and Management plan recommended the implementation of land use controls including restrictions on groundwater use and soil disturbance below 19 feet bgs. Additionally, the plan recommended a reduction in sampling frequency, from semi-annual to every five years.

5.1 Current Conditions

The groundwater gauging program at Building T-91 has characterized the local hydrology associated with the unconfined surficial aquifer. **Figure 5-1** illustrates the elevation and direction of groundwater flow, to the southwest.

Groundwater was analyzed for volatile organic compounds and MNA parameters during Fall 2011 basewide sampling event. During the Fall 2011 sampling event, no site-related contaminants exceeded NYSDEC screening criteria (**Table 5-1, Figure 5-2**). Nutrient metals iron and manganese, which are ubiquitous to Fort Drum, exceeded NYSDEC screening criteria in T-91-001 (**Table 5-1**).

5.2 Time Series and Statistical Data Analysis

To assess groundwater contamination trends over time, time series plots have been evaluated for site-related contaminants. **Figures 5-3 through 5-5** illustrate time series data for BTEX and naphthalene. In addition, M-K analysis (**Table 5-2**) was performed for BTEX and naphthalene on groundwater monitoring wells T-91-001 and T-91-002. The results show that both wells exhibit decreasing or stable concentration trends.

5.3 MNA Evaluation

MNA parameter data collected during the Fall 2011 event (**Figure 5-6**) shows that groundwater exhibits an anoxic and reducing environment within the contaminant plume. The groundwater upgradient of the contaminant plume is aerobic in nature. The upgradient, oxygenated groundwater flowing into the contaminant plume is providing the required supply of oxygen that sustains aerobic biodegradation and promotes MNA. The apparent lack of oxygen within the contaminant plume demonstrates that the microbial community is using the available oxygen and sustaining biodegradation of contaminants compounds.

5.4 Plume Stability Evaluation

The plume at Building T-91 does not extend beyond the monitoring well pair of T-91-001 and T-91-002. The historical data review, however, shows that the plume is reducing in size. This is evident as the concentrations of site-related contaminants in both wells have decreased below NYSDEC screening criteria. T-91-002 is screened at a greater depth than T-91-001, thus confirming that the plume is also shrinking vertically.

5.5 Nutrient Application

To enhance biodegradation at the site, Plexus administered an N:P:K solution from January to March 2011 (Plexus, 2010a). This application provided addition micro-nutrients for the indigenous microbial population. **Figure 5-6** illustrates the measured MNA parameter concentrations at the site after the nutrient application. The MNA parameter concentration results show that in August 2011, after the application of nitrogen-based material, there remain no significant, elevated levels of these compounds in the groundwater. The absence of a significant, elevated level of total nitrogen especially indicates that these added nutrients were consumed by the microbial population and that the application was successful in promoting biodegradation.

6.0 Risk Assessment

As part of this Final Project Evaluation Report, an HHRA was performed for T-91 as an update to the 2009 HHRA (Plexus, 2010). Current site conditions indicate that all remaining contamination at the site is confined to groundwater and the smear zone. Impacted surface and shallow soils have been removed. Impacted groundwater at the site has been characterized and does not extend beyond the site boundary. Because there is no discharge of site-related contaminants to surface water and impacted surface soils have been removed, there are no exposure scenarios present for ecological receptors. Therefore an ecological risk assessment was not performed as part of this report.

Appendix A presents the findings of the HHRA for Building T-91. From an HHRA perspective, Building T-91 may be recommended for closure. Ingestion and dermal cancer risks for both the industrial worker and resident were not evaluated due to a lack of a naphthalene cancer slope factor. The adult residential cancer risk for inhalation exposure was well below the cancer risk threshold. The industrial worker HQ, as well as both the adult and child HQs, were below EPA's noncancer threshold.

There is no human health risk associated with site-related contaminants that are outlined in the 2002 Risk Assessment (Malcolm Pirnie, 2002).

7.0 Recommendations

Based on existing conditions, demonstrated trend data analysis, and current human health and ecological risk scenarios, the recommendation of this final project evaluation for Building T-91 is no further monitoring and site closeout. The basis of this recommendation is made on the following site conditions:

- There is no risk to any ecological or human receptors associated with the current conditions at Building T-91;
- The MNA remedial action has remediated the site in a manner that is fully protective of all receptors and is still active at the site;
- Contaminant concentrations at the AOC do not exceed Standards, Criteria and Guidance (SCG's) (6 New York Codes, Rules, and Regulations Part 703);
- And the contaminant plume is stable or shrinking based on statistical and trend data analysis.

The evaluation outlined in this report satisfies the three criteria for no further monitoring as outlined in the NYSDEC DER-10 Technical Guidance for Site Investigation and Remediation, section 6.4(c)3. The three criteria for no further remediation are as follows:

1. No further monitoring may be required for groundwater if:

i. Contaminant levels in the sentinel well do not exceed the applicable SCGs at any time during the monitoring program. The sentinel well is a well downgradient from the plume, which shows no impact from the site and which acts as an early detection for the leading edge of the plume from the site being monitored. This presumes that contaminants transported by groundwater have had sufficient time to reach the well, allowing for sorbtive retardation and other hydrogeological processes that may have slowed their migration. A proposal regarding the duration of the monitoring program at the sentinel well should be made by the person responsible for conducting the investigation and/or remediation, based upon site-specific data; and

ii. The contaminant plume length has been demonstrated to be stable or shrinking by sufficient and suitable groundwater monitoring. This requires concentration versus distance trend analysis, with suitable statistical validation, with the test applied to each individual contaminant detected in each monitoring well; and,

iii. The contaminant concentrations along the centerline of the plume have been demonstrated to be decreasing by sufficient and suitable groundwater monitoring. This requires concentration versus time trend analysis, with suitable statistical validation, with the test applied to each individual contaminant detected in each monitoring well and a demonstration that groundwater standards are met before reaching the compliance point identified in the decision document.

As presented within this report, the recommendation for no further monitoring and site closeout is in accordance with NYSDEC DER-10 Technical Guidance for Site Investigation and Remediation, sections 6.4(c)3 and 6.5.

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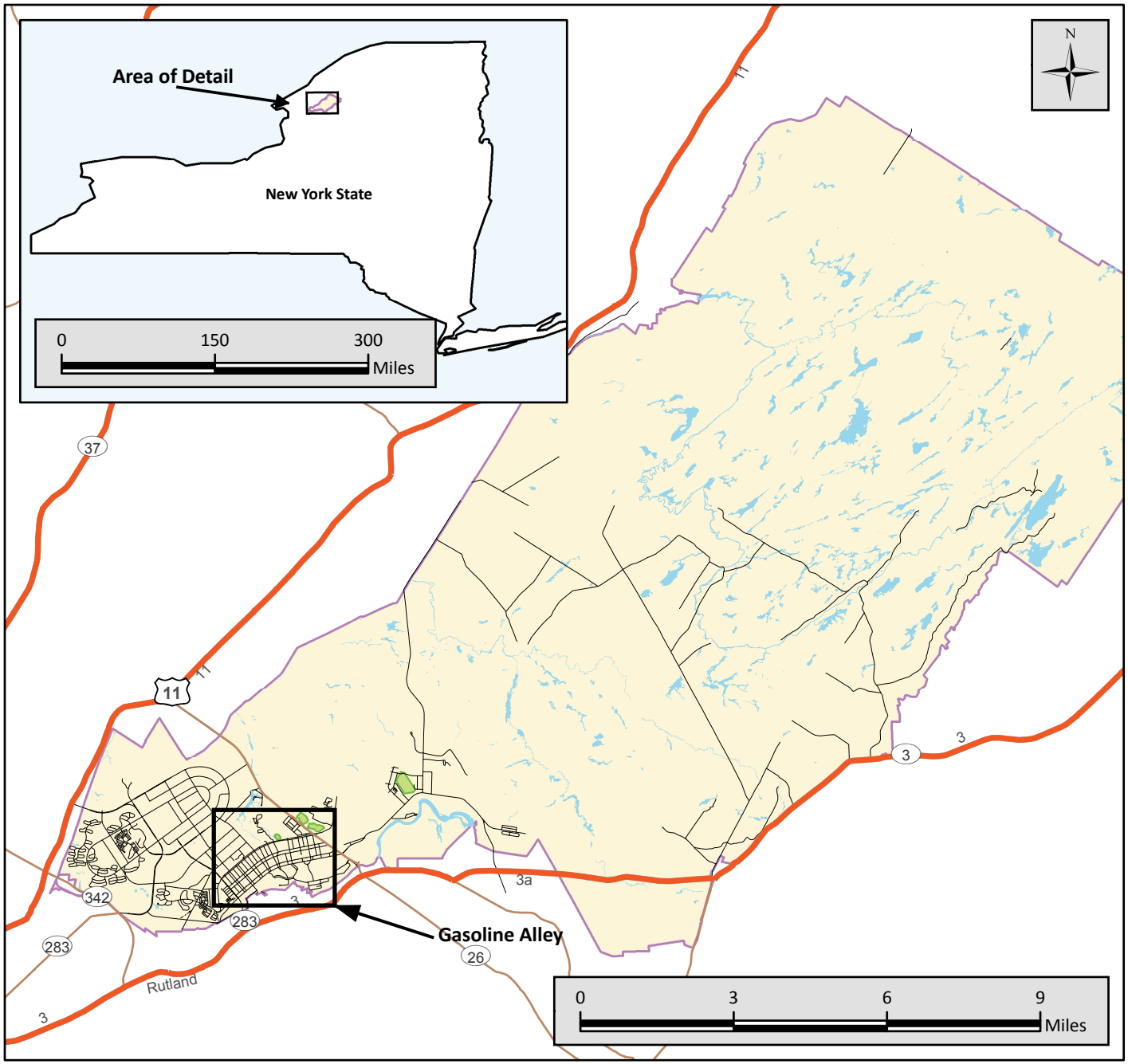
FIGURES



Legend

- Interstate
- Highway
- Major Road
- Local Road
- Fort Drum Roads
- Water
- Landfill
- Installation Area

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FIGURE 1-1

Site Location Map

Final Periodic Review Report for
Building T-91
Fort Drum, New York

Legend

- Fence Line
- Rail Road
- Paved Roadline
- Landfill Site
- Wetlands
- Building
- Paved Area

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FIGURE 1-2

Gasoline Alley Site Map

Final Periodic Review Report for Building T-91 Fort Drum, New York

Legend

- Monitoring Wells
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

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FIGURE 2-1

Building T-91 Site Layout Map

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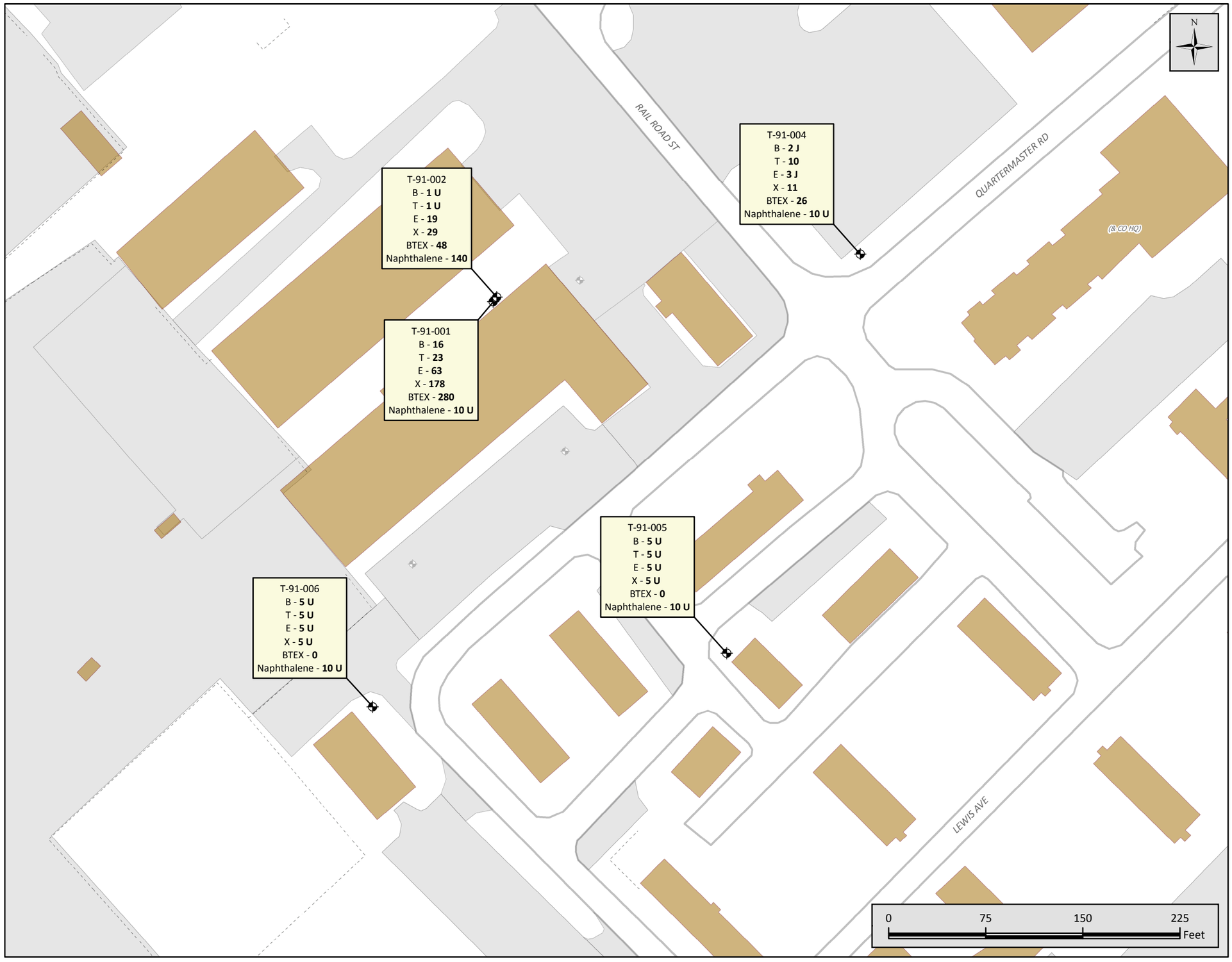

Legend

- Sampled Wells
- Other Monitoring Wells
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

BTEX Label Key:
Result values are expressed in units of µg/L followed by a qualifier if applicable.
µg/L = micrograms per liter

Location Well ID	Exceedence Criteria (µg/L):
B- **Benzene**	B - **1**
T- **Toluene**	T - **5**
E- **Ethyl Benzene**	E - **5**
X- **Total Xylenes**	X - **5**
BTEX- **Total BTEX**	
Naphthalene- **Naphthalene**	Naphthalene- **10**

Qualifer Key:
U - Value is less than the method detection limit (MDL)
J - Value is greater than the MDL, but less than the reporting limit (RL)

Data taken from the 1992 sampling event conducted by CDM summarized in the CDM, "Final Phase II Site Investigation Report for Building T-91, Fort Drum, NY"

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FIGURE 4-1

Building T-91 Initial BTEX and Naphthalene Concentrations in Groundwater, July 1992

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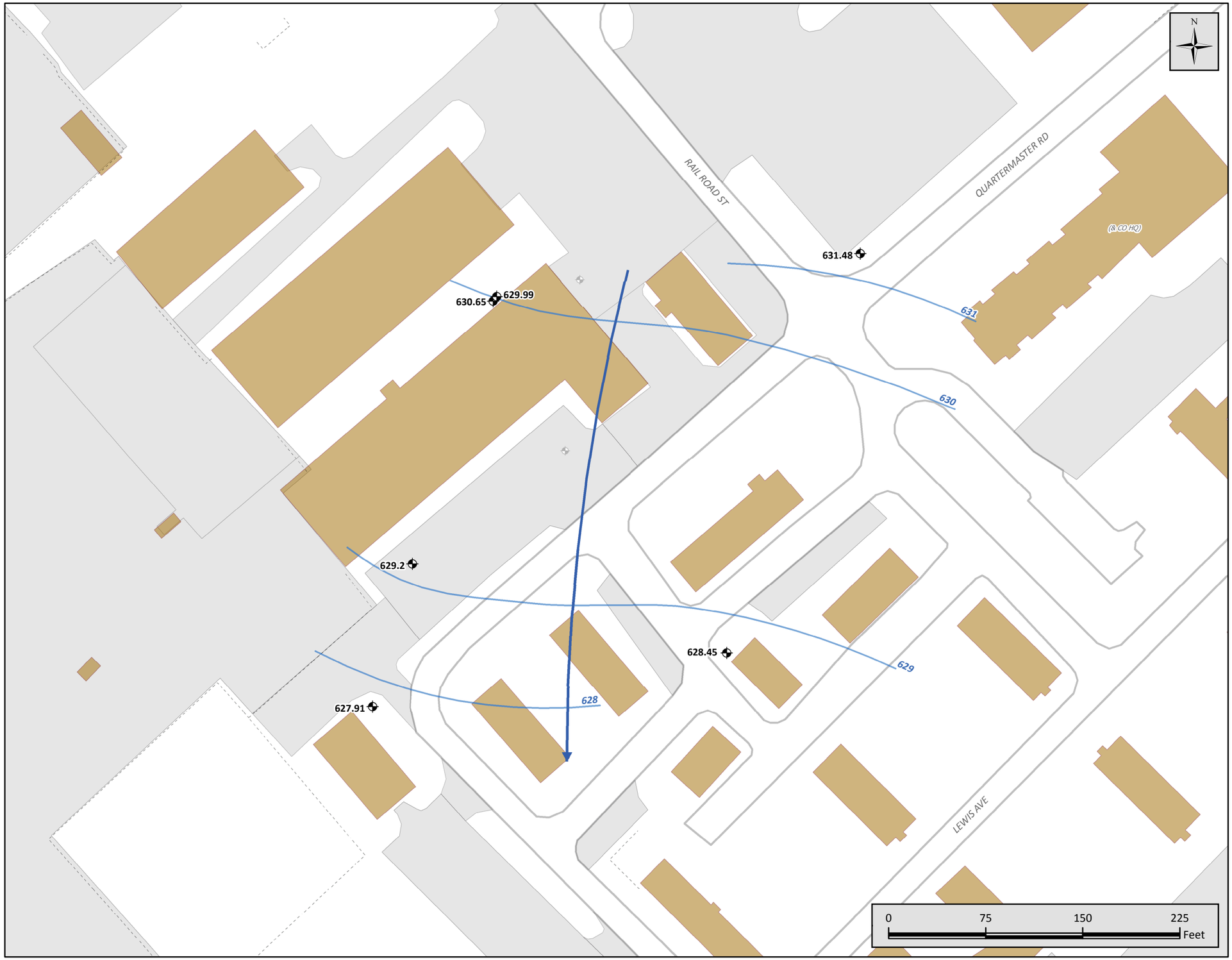

Legend

- Gauged Wells (ft MSL)
- Other Monitoring Wells
- Groundwater Flow Direction
- Groundwater Contour (ft MSL)
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

Abbreviation Key:
ft = Feet
MSL = Mean sea level

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FIGURE 5-1

Building T-91 Groundwater Contour Map, Fall 2011

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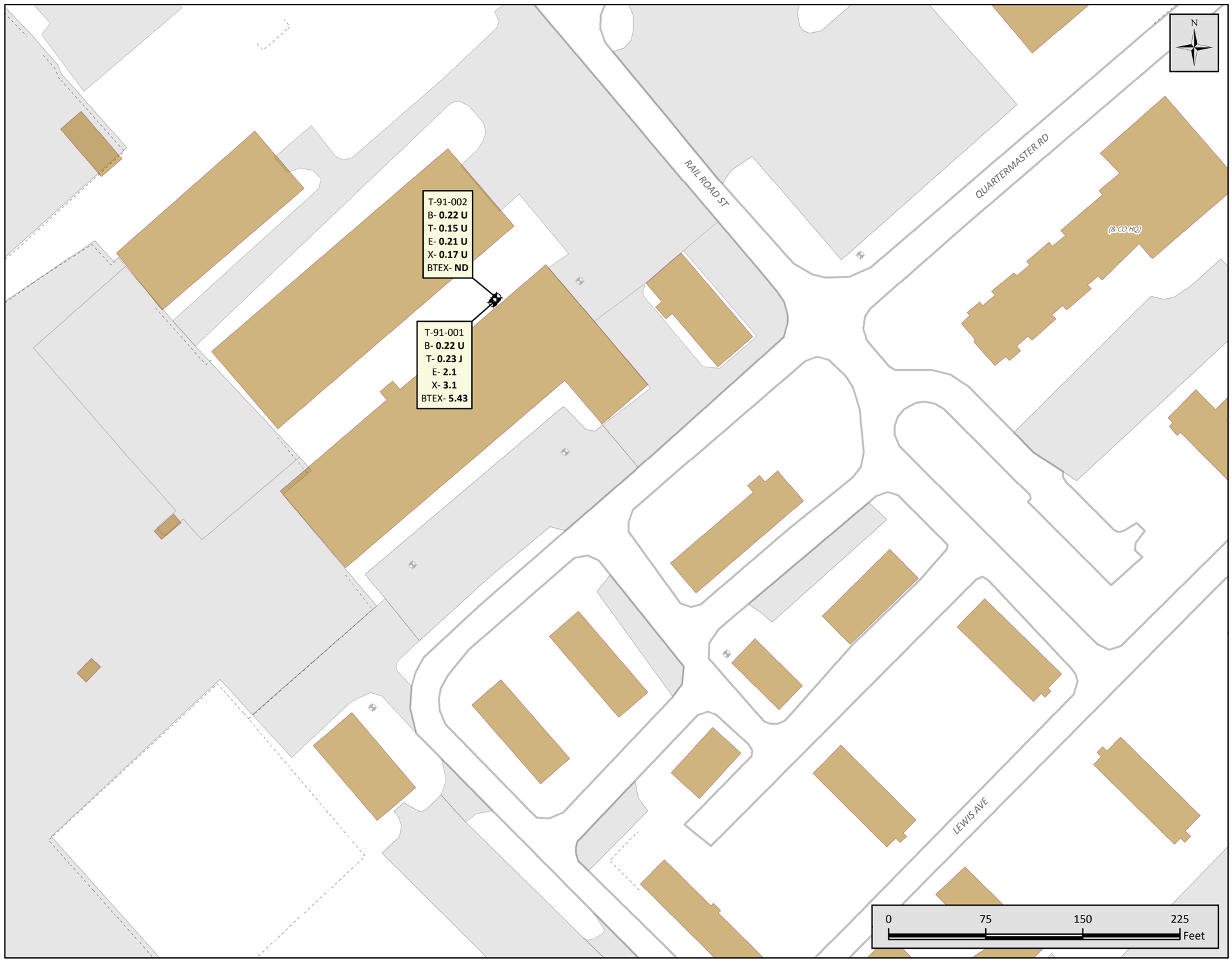

Legend

- Sampled Wells
- Other Monitoring Wells
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

BTEX Label Key:
Result values are expressed in units of µg/L followed by a qualifier if applicable.
µg/L = micrograms per liter

Location Well ID
B- **Benzene**
T- **Toluene**
E- **Ethyl Benzene**
X- **Total Xylenes**
BTEX- **Total BTEX**

Exceedence Criteria (µg/L):
B - **1**
T - **5**
E - **5**
X - **5**

Qualifer Key:
U - Value is less than the method detection limit (MDL)
J - Value is greater than the MDL, but less than the reporting limit (RL)

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FIGURE 5-2

Building T-91
BTEX Concentrations in Groundwater
Fall 2011

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Fort Drum, New York

T-91-002

Date	BTEX	Naphthalene
Q4, 2006	0	10
Q4, 2007	NS	NS
Q4, 2008	0	6.5
Q4, 2009	0	0
Q4, 2010	0	0
Q4, 2011	0	0

T-91-001

Date	BTEX	Naphthalene
Q4, 2006	64	110
Q4, 2007	NS	NS
Q4, 2008	27.3	53.3
Q4, 2009	24.9	56.2
Q4, 2010	8.3	14
Q4, 2011	5.43	7.4

RAIL ROAD ST

QUARTERMASTER RD

(& CO HQ)

LEWIS AVE

N

0 75 150 225 Feet

Legend

- Sampled Wells
- Other Monitoring Wells
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

Historical Total BTEX & Napthalene Label Key:
Result values are expressed in units of µg/L followed by a qualifier if applicable.
µg/L = micrograms per liter

Location Well ID

Date	BTEX	Naphthalene
Q4, 2006	0	10

Abbreviation Key:
BTEX = Total of Benzene, Toluene, Ethyl Benzene and Total Xylenes
Q = Quarter
NS = Not Sampled

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FIGURE 5-3

Building T-91 Historical BTEX & Naphthalene Concentrations in Groundwater, Fall 2006 – Fall 2011

Final Periodic Review Report for Building T-91 Fort Drum, New York

Figure 5-4:
BTEX and Napthalene Time Series Trend Graph for Monitoring Well T-91-001

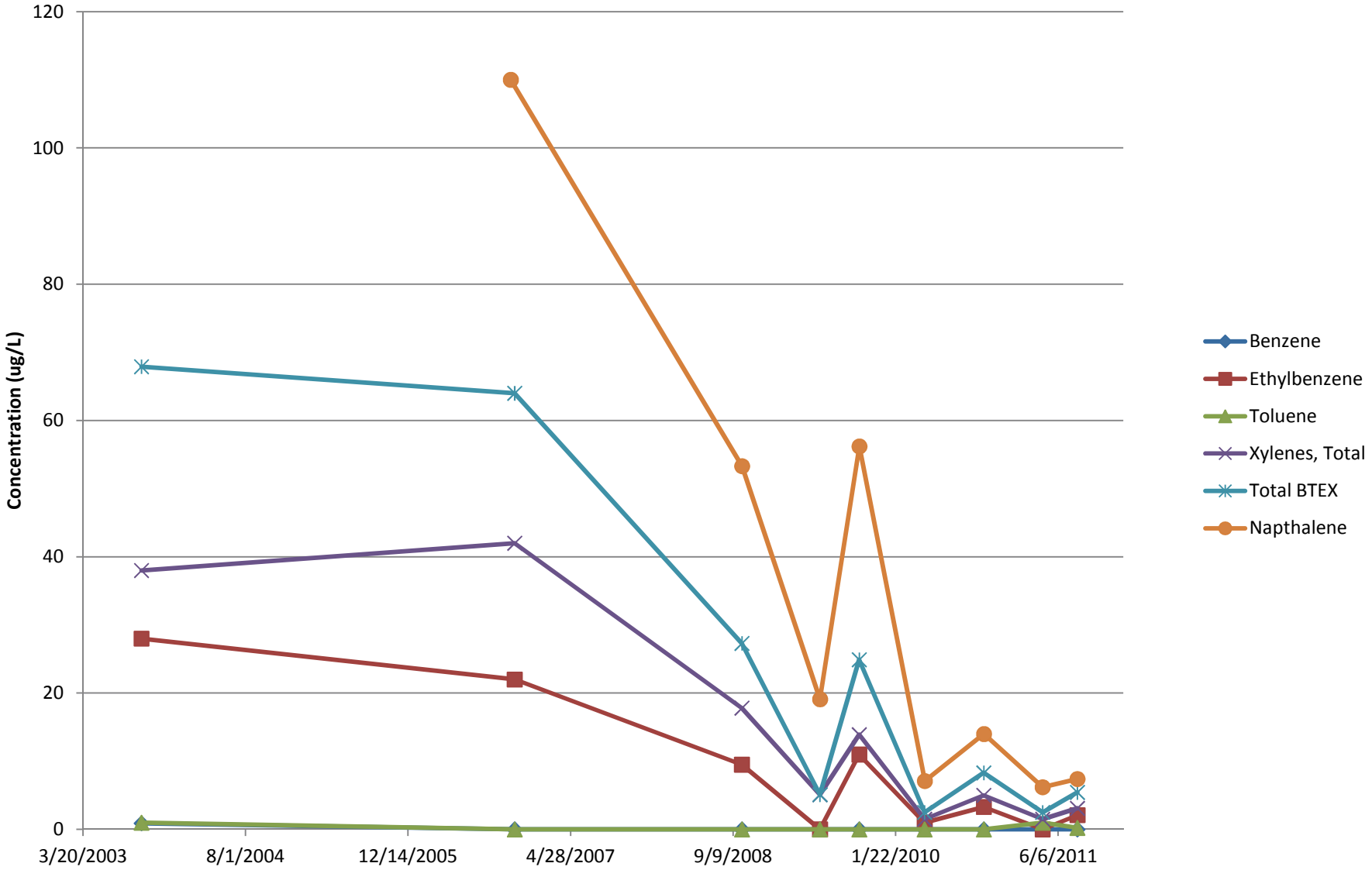
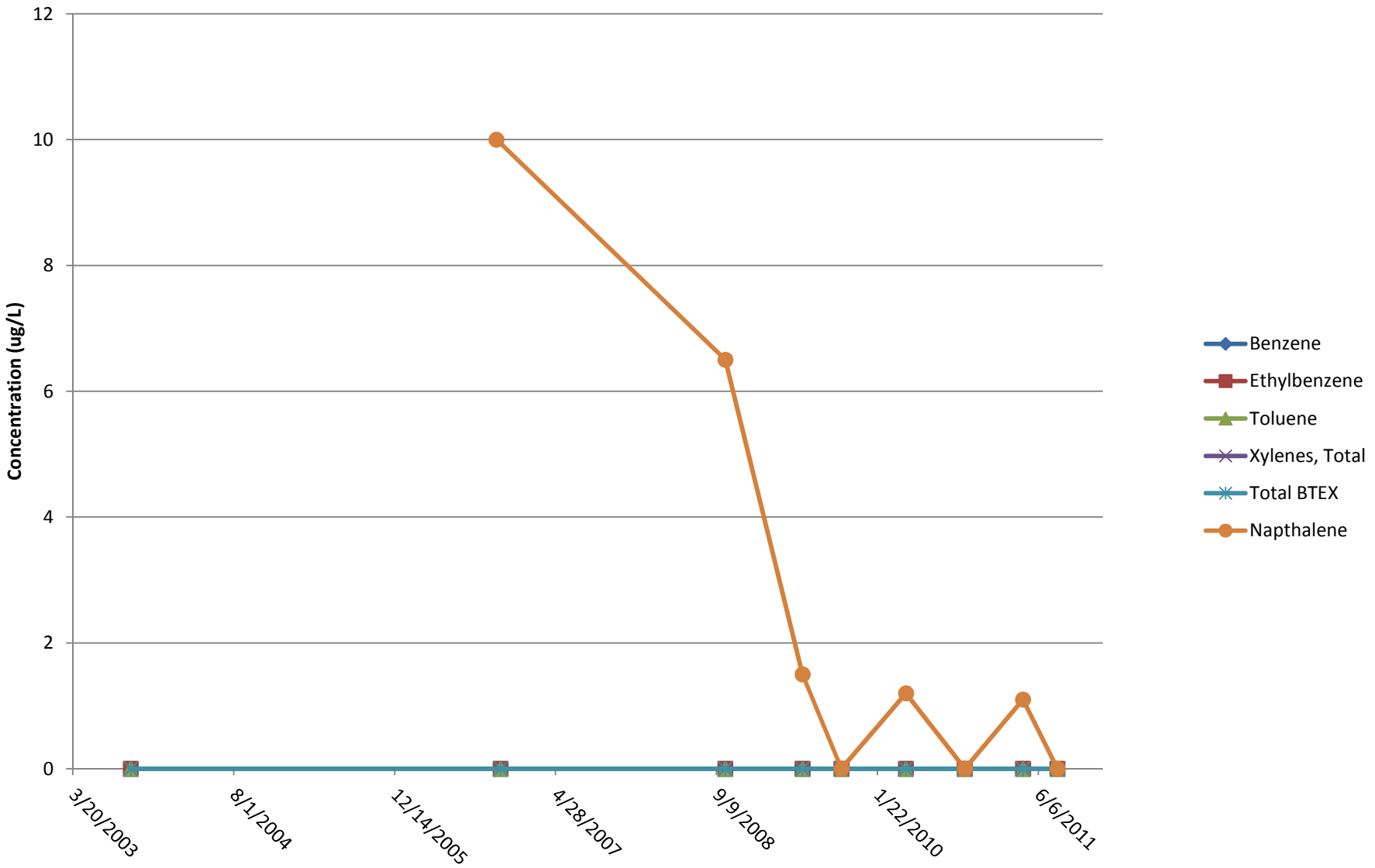
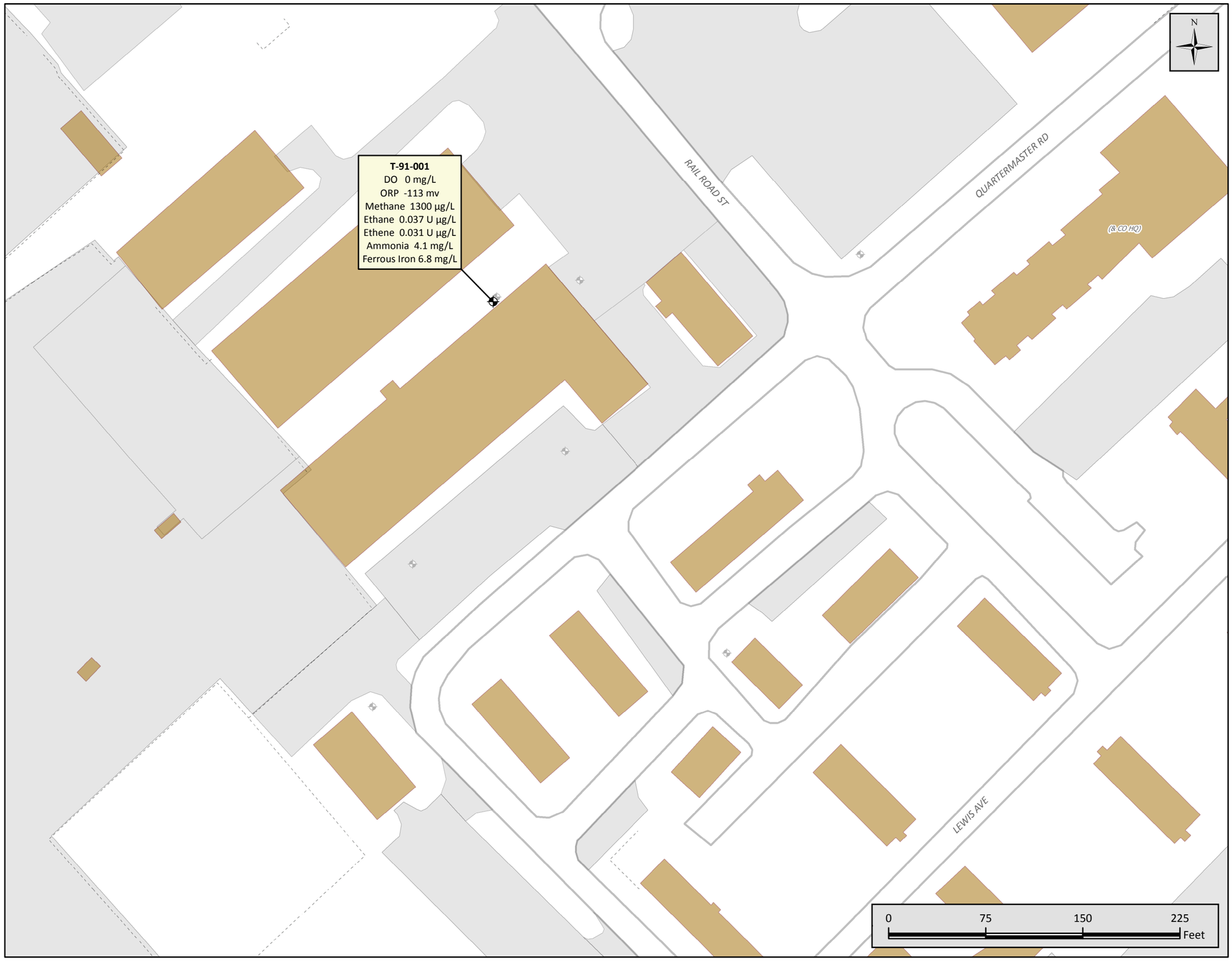


Figure 5-5:
BTEX and Napthalene Time Series Trend Graph for Monitoring Well T-91-002





Legend

- Sampled Wells
- Other Monitoring Wells
- Fence Line
- Rail Road
- Paved Roadline
- Building
- Paved Area

Monitored Natural Attenuation Label Key:
Result values are expressed in units of µg/L and mg/L followed by a qualifier if applicable

Abbreviation Key:
µg/L = micrograms per liter
DO - Dissolved Oxygen
mg/L = milligrams per liter
mV = millivolts
ORP - Oxidation Reduction Potential

Qualifer Key:
U - Value is less than the method detection limit (MDL)

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Date: April 2013

FIGURE 5-6

Building T-91
MNA Parameters
Fall 2011

Final Periodic Review Report for
Building T-91
Fort Drum, New York

TABLES

Table 5-1:

Historical BTEX and Naphthalene Concentrations at Building T-91 Monitoring Wells

Well Name	Sample Date	Benzene	Ethylbenzene	Toluene	Xylene (total)	Total BTEX	Naphthalene	Iron	Manganese
T-91-001	10-Jul-92	**16**	**63**	**23**	**178**	280	10 U	NS	NS
	26-Oct-06	5 U	**22**	5 U	**42**	64	**110**	NS	NS
	6-Oct-08	0.26 U	**9.5**	0.15 U	**17.8**	27.3	**53.3**	NS	NS
	3-Jun-09	0.23 U	4 U	0.3 U	**5.1**	5.1	**19.1**	NS	NS
	2-Oct-09	0.23 U	**11**	0.3 U	**13.9**	24.9	**56.2**	**58,000**	**770**
	21-Apr-10	0.23 U	1	0.3 U	1.5	2.5	7.1	NS	NS
	20-Oct-10	0.23 U	3.3	0.3 U	5	8.3	**14**	**33,300**	**696**
	20-Apr-11	0.23 U	1.6	0.3 U	2.3	3.9	6.2	NS	NS
	4-Aug-11	0.22 U	2.1	0.23 J	3.1	5.43	7.4	**19,800**	**319**
T-91-002	10-Jul-92	1 U	**19**	1 U	**29**	48	**140**	NS	NS
	26-Oct-06	5 U	5 U	5 U	15 U	0	**10**	NS	NS
	6-Oct-08	0.26 U	0.27 U	0.15 U	0.39 U	0	6.5	NS	NS
	3-Jun-09	0.23 U	0.27 U	0.3 U	0.25 U	0	1.6	NS	NS
	2-Oct-09	0.23 U	0.27 U	0.3 U	0.25 U	0	1.8	19.8 U	108
	20-Apr-10	0.23 U	0.27 U	0.3 U	0.25 U	0	1.2	NS	NS
	20-Oct-10	0.23 U	0.27 U	0.3 U	0.25 U	0	0.97 U	NS	NS
	20-Apr-11	0.23 U	0.27 U	0.3 U	0.25 U	0	1.1 J	NS	NS
	4-Aug-11	0.22 U	0.21 U	0.15 U	0.17 U	0	0.68 U	NS	NS

11 Concentration exceeds NYSDEC's groundwater screening criteria.

All analytical values shown are in units of µg/L (Micrograms per Liter) followed by a result qualifier if applicable.

NS - indicates that the well was not sampled for this analyte per the monitoring program requirements.

Qualifier Key

U - Analyte not detected in sample. Value reported is the quantitation/detection limit.

J - Detected analyte's concentration value reported is greater than the detection limit, but less than the reporting limit.

Table 5-2:

Mann-Kendall Trend Analysis for Monitoring Wells at Building T-91

Well	COC	N	N_D	S	α	Decreasing Trend?	Increasing Trend?
T-91-001	Benzene	10	1	-9	0.2420		
	Ethylbenzene	10	9	-16	0.0930		
	Toluene	10	2	-1	0.5000		
	Total BTEX	10	10	-24	0.0190	Yes	
	Xylenes, Total	10	10	-26	0.0110	Yes	
	Naphthalene	6	6	-9	0.0680		
T-91-002	Benzene	11	0	0	0.5310		
	Ethylbenzene	11	0	0	0.5310		
	Toluene	11	0	0	0.5310		
	Total BTEX	11	1	-8	0.2980		
	Xylenes, Total	11	1	-8	0.2980		
	Naphthalene	6	5	-7	0.1360		

Notes:

N: Number of Samples

N_D: Number of Detections

S: Man-Kendall Statistic

α: Significance Level

APPENDIX A
HUMAN HEALTH RISK ASSESSMENT

AVATAR ENVIRONMENTAL

TECHNICAL MEMORANDUM

TO: Greg Kendall, Plexus Scientific

FROM: Kristina Early, Avatar Environmental
cc: Charles Dobroski, Avatar Environmental

DATE: 10 June 2011

SUBJECT: Fort Drum, Gasoline Alley Building T-91 Groundwater Human Health Risk Assessment (HHRA)

Introduction

As a subcontractor to Plexus Scientific, Avatar Environmental was tasked with developing this Technical Memorandum to provide a summary of the potential human health risks resulting from exposure to refined petroleum and other chemical contamination in groundwater at the Gasoline Alley Building T-91 of Fort Drum. This risk assessment evaluates the most recent groundwater data with the intent of determining whether this area may undergo closure with regard to further environmental evaluations.

Data Evaluation/Reduction

Data evaluated in the HHRA include groundwater samples collected from Building T-91 in the spring of 2011. The following guidelines for data reduction were used to produce the data summary.

- If an analyte was not positively identified in any sample for a given medium because it was reported as a nondetect (indicated by a "U" qualifier), or because it was present as a result of blank contamination (indicated by a "B" qualifier for organics), it was not addressed for that medium;

- Analytical results with a "U" qualifier represent nondetect samples for the analyte evaluated. The full detection limit (DL) value was used for nondetect samples in subsequent calculations (i.e., the arithmetic mean and the 95 percent upper-confidence limit of the mean [95% UCL]); and

- If a sample duplicate was collected and analyzed, the average of the two reported concentrations was used for subsequent calculations unless there was a greater than 30% difference in water concentrations, in which case the higher of the two concentrations was used. In the case of a detected sample and a nondetect duplicate, the detected concentration was carried through subsequent calculations.

Table 1 presents the data summary for the groundwater at Building T-91.

A contaminant of potential concern (COPC) selection process was conducted to identify those analytes that were detected in the groundwater at levels that could pose a potential risk to potentially exposed human receptors. The criteria that were used to determine COPCs include:

- Non-detection – If an analyte was not detected in any samples, it was not evaluated as a COPC. Note that it was assumed that the analytical results met all of the project-specific data quality objectives (DQOs) and that a comparison of sample quantitation limits (SQLs) with benchmarks was unnecessary.

- A comparison of detected concentrations with screening criteria – If the maximum detected concentration for a given analyte was greater than the lower of its New York State Department of Environmental Conservation (NYSDEC) Ambient Water Quality Standards and Guidance Values for Class GA Groundwater (NYSDEC, 2008) or its NYSDEC Maximum Contaminant Levels (MCLs) for drinking water (NYSDEC, 2006), it was identified as a COPC.

Table 2 presents the COPC selection process for the analytes that were detected in groundwater at Building T-91. Note that only naphthalene was determined to be a COPC at Building T-91.

Exposure Setting

The following description of the exposure setting for the subject area is taken from the *September 2002 Final Risk Assessment* (Malcom Pirnie, 2002), *September 2000 Final Risk Assessment* (Malcom Pirnie, 2000), and the *2008 Annual Basewide Groundwater and Surface Water Monitoring Report* (Plexus Scientific, 2009):

> Fort Drum is an active military base located in upstate New York, approximately 10 miles northeast of Watertown, 80 miles north of Syracuse, and 25 miles southeast of the U.S./Canadian border. Fort Drum occupies a large portion of northeastern Jefferson County and a portion of western Lewis County and encompasses approximately 107,265 acres.
>
> Building T-91 is located at the intersection of First Street West and Warehouse Road. The site, a former vehicle maintenance facility, is currently being used as a wheeled vehicle maintenance shop. In the past, solvent and petroleum contaminated wastewater was discharged onto the ground via a drainage pipe. In addition, several USTs and aboveground storage tanks (ASTs) existed around the building.

Identification of Potentially Exposed Human Populations and Exposure Pathways

Based on the exposure setting and the current and potential future land uses, the potentially exposed populations include:

- Commercial/Industrial Worker. An employee could be exposed to contaminants in groundwater through potential consumption of drinking water (i.e., groundwater is assumed to be the source of drinking water). This worker is assumed to spend the majority of his/her time at work indoors.

- Resident Child and Adult. Building T-91 could be developed into a residential property in the future. Ingestion of, dermal contact with, and inhalation of COPCs in groundwater under future use conditions are evaluated. For dermal exposure to groundwater, adult exposure is associated with showering, and child exposure is associated with bathing. Inhalation of VOCs while showering is evaluated for the adult. Because the aerosolization of VOCs from bath water is not significant, this pathway is not evaluated for the bathing child.

Exposure Point Concentrations (EPCs)

EPCs are the representative COPC concentrations to which a receptor is assumed to be exposed. Guided by both the ProUCL Technical Manual (EPA, 2010a) and the ProUCL User's Guide (EPA, 2010b), it was determined that if fewer than 8 samples were collected, the EPC was based on the maximum detected concentration. Table 3 presents the EPC that was used to estimate the risks associated with groundwater exposure. Because a maximum of 2 samples was collected, the maximum detected concentration was used for the EPC.

Exposure Equations and Parameters

The mathematical models and exposure assumptions that were used to calculate the exposure doses (chronic daily intakes; CDIs) of naphthalene for each receptor population through the applicable exposure routes are presented in Tables 4 through 15. Exposure doses are dependent upon the magnitude, frequency, and duration of exposure. They are estimated by combining the COPC concentration (i.e., the EPC) and the exposure parameters. Two types of exposure doses are calculated. The cancer dose (lifetime average daily dose [LADD]) is averaged over a 70-year lifetime. The noncancer average daily dose (ADD) is averaged over the actual exposure duration for each receptor.

Summary of Toxicity Values Used in HHRA

Tables 16 through 19 present the available toxicity values (oral, dermal, and inhalation) for naphthalene, as well as the source, the EPA weight-of evidence category, the route of administration, and the critical effect.

Risk Results

The Fort Drum Building T-91 cancer risks and noncancer hazard indices (HIs) are presented in Tables 20 through 26.

Commercial/Industrial Worker

Naphthalene cancer risk: no cancer slope factors available for evaluation
Naphthalene noncancer hazard: HQ: 0.0031

Age-Adjusted Resident

Naphthalene cancer risk: Ingestion/Dermal – no cancer slope factors available for evaluation

Child Resident

Naphthalene noncancer hazard: HQ: 0.034

Adult Resident

Naphthalene cancer risk: Inhalation – 1.3E-09
Naphthalene noncancer hazard: HQ: Ingestion/Dermal – 0.015, Inhalation – 0.000037

Summary

From a HHRA perspective, Building T-91 could be recommended for closure. Ingestion and dermal cancer risks for both the industrial worker and resident were not evaluated due to a lack of a naphthalene cancer slope factor. The adult residential cancer risk for inhalation exposure was well below the cancer risk threshold. The industrial worker HQ, as well as both the adult and child HQs were below EPA's noncancer threshold.

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Table 1
Summary of Analytes Detected in 2011 Groundwater
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

CAS Number	Analyte	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency[a]	Detection Limits[b]	Arithmetic Mean[c]	Standard Deviation[c]
95636	1,2,4-Trimethylbenzene	3.90E+00	4.20E+00	µg/L	DUP-3	1/2	2.80E-01 - 2.80E-01	2.17E+00	2.67E+00
108678	1,3,5-Trimethylbenzene	4.40E-01	5.20E-01	µg/L	DUP-3	1/2	3.00E-01 - 3.00E-01	3.90E-01	1.27E-01
67641	Acetone	5.60E+00	5.90E+00	µg/L	T-91-001	1/2	2.90E+00 - 2.90E+00	4.33E+00	2.02E+00
67663	Chloroform	7.40E-01	7.40E-01	µg/L	T-91-002	1/2	2.30E-01 - 2.30E-01	4.85E-01	3.61E-01
100414	Ethylbenzene	1.60E+00	1.60E+00	µg/L	DUP-3, T-91-001	1/2	2.70E-01 - 2.70E-01	9.35E-01	9.40E-01
98828	Isopropylbenzene	9.30E-01	9.60E-01	µg/L	DUP-3	1/2	5.70E-01 - 5.70E-01	7.58E-01	2.65E-01
179601231	m,p-Xylene	1.10E+00	1.10E+00	µg/L	DUP-3, T-91-001	1/2	2.50E-01 - 2.50E-01	6.75E-01	6.01E-01
91203	Naphthalene	1.10E+00	6.40E+00	µg/L	DUP-3	2/2	NA	3.70E+00	3.68E+00
104518	n-Butylbenzene	4.90E-01	4.90E-01	µg/L	DUP-3	1/2	4.70E-01 - 4.70E-01	4.80E-01	1.41E-02
103651	n-Propylbenzene	1.50E+00	1.60E+00	µg/L	DUP-3	1/2	2.40E-01 - 2.40E-01	8.95E-01	9.26E-01
95476	o-Xylene	1.20E+00	1.20E+00	µg/L	DUP-3, T-91-001	1/2	2.50E-01 - 2.50E-01	7.25E-01	6.72E-01
99876	p-Isopropyltoluene	9.40E-01	1.00E+00	µg/L	DUP-3	1/2	6.90E-01 - 6.90E-01	8.30E-01	1.98E-01
135988	sec-Butylbenzene	1.30E+00	1.60E+00	µg/L	T-91-002	2/2	NA	1.45E+00	2.12E-01
1330207	Xylene (total)	2.30E+00	2.30E+00	µg/L	DUP-3, T-91-001	1/2	2.50E-01 - 2.50E-01	1.28E+00	1.45E+00

[a]Number of sampling locations at which analyte was detected compared with total number of sampling locations.

[b]Based on nondetected samples.

[c]Nondetects were included at the full detection limit.

µg/L = Micrograms per liter.

NA = Not applicable.

NC = Not calculated due to insufficient sample size.

Table 2
COPC Selection Process for Analytes Detected in 2011 Groundwater
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

CAS Number	Analyte	Maximum Concentration	Units	Location of Maximum Concentration	NYSDEC Human Health Screening Criteria[a] (µg/L)	Ratio of Maximum Concentration to NYSDEC Screening Criteria	COPC
95636	1,2,4-Trimethylbenzene	4.20E+00	µg/L	DUP-3	5.00E+00	0.84	
108678	1,3,5-Trimethylbenzene	5.20E-01	µg/L	DUP-3	5.00E+00	0.10	
67641	Acetone	5.90E+00	µg/L	T-91-001	5.00E+01	0.12	
67663	Chloroform	7.40E-01	µg/L	T-91-002	5.00E+00	0.15	
100414	Ethylbenzene	1.60E+00	µg/L	DUP-3, T-91-001	5.00E+00	0.32	
98828	Isopropylbenzene	9.60E-01	µg/L	DUP-3	5.00E+00	0.19	
179601231	m,p-Xylene	1.10E+00	µg/L	DUP-3, T-91-001	5.00E+00	0.22	
91203	Naphthalene	6.40E+00	µg/L	DUP-3	5.00E+00	1.28	X
104518	n-Butylbenzene	4.90E-01	µg/L	DUP-3	5.00E+00	0.098	
103651	n-Propylbenzene	1.60E+00	µg/L	DUP-3	5.00E+00	0.32	
95476	o-Xylene	1.20E+00	µg/L	DUP-3, T-91-001	5.00E+00	0.24	
99876	p-Isopropyltoluene	1.00E+00	µg/L	DUP-3	5.00E+00	0.20	
135988	sec-Butylbenzene	1.60E+00	µg/L	T-91-002	5.00E+00	0.32	
1330207	Xylene (total)	2.30E+00	µg/L	DUP-3, T-91-001	5.00E+00	0.46	

[a] Screening criteria based on the minimum of the NYSDEC Ambient Water Quality Standards for Class GA Groundwater and the NYSDEC Maximum Contaminant Levels (MCLs).

µg/L = Micrograms per liter.

NYSDEC = New York State Department of Environmental Conservation.

Table 3
Summary of Exposure Point Concentrations for COPCs in 2011 Groundwate
Fort Drum Gasoline Alley Facility - Building T-9
Fort Drum, NY

COPC	Maximum Detected Concentration (µg/L)	Data Distribution	Calculation Method	95% UCL (µg/L)	Exposure Point Concentration (µg/L)
Naphthalene	6.40E+00	ND	ND	NC	6.40E+00

NC=Not calculated. The maximum concentration used for EPC due to less than 4 detected values.

ND=Not determined. The maximum concentration used for EPC due to less than 4 detected values.

Table 4
Values Used for Daily Intake Calculations
Reasonable Maximum Exposure - Groundwater - Commercial/Industrial Worker
Fort Drum Gasoline Alley Facility
Fort Drum, NY

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Commercial/Industrial Worker
Receptor Age: Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation
Ingestion	Tapwater	EPC	Exposure Point Concentration	COPC-specific	µg/L	Calculated	Chronic daily intake (mg/kg-day) =
		IRW	Ingestion Rate of Water	2	L/day	EPA, 2002	EPC x IRW x CF x FI x EF x ED x 1/BW x 1/AT
		FI	Fraction Ingested	0.5	unitless	Professional Judgement	
		EF	Exposure Frequency	250	days/year	EPA, 2002	
		ED	Exposure Duration	25	years	EPA, 2002	
		CF	Conversion Factor	1.00E-03	mg/µg	-----	
		BW	Body Weight	70	kg	EPA, 1997	
		AT_C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
		AT_{NC}	Averaging Time (Non-Cancer)	9,125	days	Calculated	

Table 5
Values Used for Daily Intake Calculations
Reasonable Maximum Exposure - Groundwater - Resident
Fort Drum Gasoline Alley Facility
Fort Drum, NY

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Tapwater	EPC	Exposure Point Concentration	COPC-specific	µg/L	Calculated	Chronic daily intake (CDI)(mg/kg-day) =
Child/Adult (Cancer)		IFW_{adj}	Age-adjusted water ingestion factor	1.1	L-year/kg-day	Calculated	$EPC \times IFW_{adj} \times CF \times FI \times EF \times 1/AT_C$
		FI	Fraction Ingested	1	unitless	EPA, 1989	Where
		EF	Exposure Frequency	350	days/year	EPA, 2002	$IFW_{adj} = (IRW_c \times ED_c \times 1/BW_c) + (IRW_a \times ED_a \times 1/BW_a)$
		ED_c	Exposure Duration - child	6	years	EPA, 2002	
		ED_a	Exposure Duration - adult	24	years	EPA, 2002	
		IRW_c	Ingestion Rate of Water - child	1	L/day	EPA, 2002	
		IRW_a	Ingestion Rate of Water - adult	2	L/day	EPA, 2002	
		BW_c	Body Weight - child	15	kg	EPA, 1997	
		BW_a	Body Weight - adult	70	kg	EPA, 1997	
		CF	Conversion Factor	0.001	mg/µg	-----	
		AT_C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
		AT_{NC}	Averaging Time (Non-Cancer)	8,760	days	Calculated	
Ingestion	Tapwater	EPC	Exposure Point Concentration	COPC-specific	µg/L	Calculated	Chronic daily intake (CDI)(mg/kg-day) =
Child (Noncancer)		FI	Fraction Ingested	1	unitless	EPA, 1989	$EPC \times IRW_c \times CF \times FI \times EF \times ED_c \times 1/BW_c \times 1/AT$
		EF	Exposure Frequency	350	days/year	EPA, 2002	
		ED_c	Exposure Duration - child	6	years	EPA, 2002	
		IRW_c	Ingestion Rate of Water - child	1	L/day	EPA, 2002	
		BW_c	Body Weight - child	15	kg	EPA, 1997	
		CF	Conversion Factor	0.001	mg/µg	-----	
		AT_C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
		AT_{NC}	Averaging Time (Non-Cancer)	2,190	days	Calculated	
Ingestion	Tapwater	EPC	Exposure Point Concentration	COPC-specific	µg/L	Calculated	Chronic daily intake (CDI)(mg/kg-day) =
Adult (Noncancer)		FI	Fraction Ingested	1	unitless	EPA, 1989	$EPC \times IRW_a \times CF \times FI \times EF \times ED_a \times 1/BW_a \times 1/AT$
		EF	Exposure Frequency	350	days/year	EPA, 2002	
		ED_a	Exposure Duration - adult	24	years	EPA, 2002	
		IRW_a	Ingestion Rate of Water - adult	2	L/day	EPA, 2002	
		BW_a	Body Weight - adult	70	kg	EPA, 1997	
		CF	Conversion Factor	0.001	mg/µg	-----	
		AT_C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
		AT_{NC}	Averaging Time (Non-Cancer)	8,760	days	Calculated	

Table 5
Values Used for Daily Intake Calculations
Reasonable Maximum Exposure - Groundwater - Resident
Fort Drum Gasoline Alley Facility
Fort Drum, NY

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Tapwater	SFS_{adj}	Age-adjusted skin contact factor	8,811	event-year-cm^2/kg-day	Calculated	Dermally Absorbed Dose (DAD) (mg/kg-day) =
Child/Adult (Cancer)	While Bathing/	SA_c	Skin Surface Area Available for Contact - child	6,600	cm^2	EPA, 2004	$DA_{EVENT-adj} \times SFS_{adj} \times EF \times 1/AT_C$
	Showering	SA_a	Skin Surface Area Available for Contact - adult	18,000	cm^2	EPA, 2004	
		DA_{EVENT}	Absorbed Dose Per Event	See Table 6	mg/cm^2-event	EPA, 2004	$SFS_{adj} = (SA_c \times EV_c \times ED_c \times 1/BW_c) + (SA_a \times EV_a \times ED_a \times 1/BW_a)$
		EV_c	Event Frequency - child	1	event/day	EPA, 2004	$DA_{EVENT-adj}$ Calculations
		EV_a	Event Frequency - adult	1	event/day	EPA, 2004	$t_{event-adj} = (ED_c \times t_{event-c}) + (ED_a \times t_{event-a})/(ED_c + ED_a)$
		EF	Exposure Frequency	350	days/year	EPA, 2002	
		ED_c	Exposure Duration - child	6	years	EPA, 2002	if $t_{event-adj} \leq t^*$, then $DA_{EVENT-adj}$ (Organic) =
		ED_a	Exposure Duration - adult	24	years	EPA, 2002	$2\ FA \times K_p \times C_w \times CF_1 \times CF_2 \times \sqrt{(6\tau_{event} \times t_{event-adj}/\pi)}$
		BW_c	Body Weight - child	15	kg	EPA, 1997	
		BW_a	Body Weight - adult	70	kg	EPA, 1997	otherwise if $t_{event-adj} > t^*$, then $DA_{EVENT-adj}$ (Organic) =
		AT_C	Averaging Time (Cancer)	25,550	days	EPA, 1989	$FA \times K_p \times C_w \times CF_1 \times CF_2 \times$
		$t_{event-adj}$	Age-adjusted event duration	0.66	hr/event	Calculated	$[((t_{event-adj})/(1+B)) + 2\tau_{event}((1 + 3B + 3B^2)/(1+B)^2)$
		$t_{event-c}$	Event Duration - child	1	hr/event	EPA, 2004	
		$t_{event-a}$	Event Duration - adult	0.58	hr/event	EPA, 2004	$DA_{EVENT-adj}$ (Inorganic) =
		FA	Fraction Absorbed Water	See Table 6	unitless	EPA, 2004	$K_p \times C_w \times CF_1 \times CF_2 \times t_{event-adj}$
		K_p	Dermal Permeability Coefficient	See Table 6	cm/hour	EPA, 2004	
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	Calculated	
		CF_1	Conversion Factor	0.001	mg/µg	-----	
		CF_2	Conversion Factor	0.001	L/cm^3	-----	
		B	Ratio of Permeability Coefficient	See Table 6	unitless	EPA, 2004	
		t*	Time to Reach Steady State	See Table 6	hour	EPA, 2004	
		t_{event}	Lag Time Per Event	See Table 6	hr/event	EPA, 2004	

Table 5
Values Used for Daily Intake Calculations
Reasonable Maximum Exposure - Groundwater - Resident
Fort Drum Gasoline Alley Facility
Fort Drum, NY

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Tapwater	SA	Skin Surface Area Available for Contact	6,600	cm^2	EPA, 2004	Dermally Absorbed Dose (DAD) (mg/kg-day) =
Child (Noncancer)	While Bathing	DA_{EVENT}	Absorbed Dose Per Event	See Table 7	mg/cm^2-event	EPA, 2004	$DA_{EVENT} \times EV \times SA \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		EV	Event Frequency	1	event/day	EPA, 2004	
		EF	Exposure Frequency	350	days/year	EPA, 2002	$\underline{DA_{EVENT}\ Calculations}$
		ED	Exposure Duration	6	years	EPA, 2002	if $t_{event} \le t^*$, then DA_{EVENT} (Organic) =
		BW	Body Weight	15	kg	EPA, 1997	$2\ FA \times K_p \times C_w \times CF_1 \times CF_2 \times \sqrt{(6\tau_{event} \times t_{event}/\pi)}$
		AT_{NC}	Averaging Time (Non-Cancer)	2,190	days	Calculated	
		FA	Fraction Absorbed Water	See Table 7	unitless	EPA, 2004	otherwise if $t_{event} > t^*$, then DA_{EVENT} (Organic) =
		K_p	Dermal Permeability Coefficient	See Table 7	cm/hour	EPA, 2004	$FA \times K_p \times C_w \times CF_1 \times CF_2 \times$
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	Calculated	$[((t_{event})/(1+B)) + 2\tau_{event}((1 + 3B + 3B^2)/(1+B)^2)$
		CF_1	Conversion Factor	0.001	mg/µg	-----	
		CF_2	Conversion Factor	0.001	L/cm^3	-----	DA_{EVENT} (Inorganic) =
		B	Ratio of Permeability Coefficient	See Table 7	unitless	EPA, 2004	$K_p \times C_w \times CF_1 \times CF_2 \times t_{event}$
		t*	Time to Reach Steady State	See Table 7	hour	EPA, 2004	
		t_{event}	Lag Time Per Event	See Table 7	hr/event	EPA, 2004	
		t_{event}	Event Duration	1	hr/event	EPA, 2004	
Dermal	Tapwater	SA	Skin Surface Area Available for Contact	18,000	cm^2	EPA, 2004	Dermally Absorbed Dose (DAD) (mg/kg-day) =
Adult (Noncancer)	While Showering	DA_{EVENT}	Absorbed Dose Per Event	See Table 7	mg/cm^2-event	EPA, 2004	$DA_{EVENT} \times EV \times SA \times EF \times ED \times 1/BW \times 1/AT_{NC}$
		EV	Event Frequency	1	event/day	EPA, 2004	
		EF	Exposure Frequency	350	days/year	EPA, 2002	$\underline{DA_{EVENT}\ Calculations}$
		ED	Exposure Duration	24	years	EPA, 2002	if $t_{event} \le t^*$, then DA_{EVENT} (Organic) =
		BW	Body Weight	70	kg	EPA, 1997	$2\ FA \times K_p \times C_w \times CF_1 \times CF_2 \times \sqrt{(6\tau_{event} \times t_{event}/\pi)}$
		AT_{NC}	Averaging Time (Non-Cancer)	8,760	days	Calculated	
		FA	Fraction Absorbed Water	See Table 7	unitless	EPA, 2004	otherwise if $t_{event} > t^*$, then DA_{EVENT} (Organic) =
		K_p	Dermal Permeability Coefficient	See Table 7	cm/hour	EPA, 2004	$FA \times K_p \times C_w \times CF_1 \times CF_2 \times$
		C_w	Chemical Concentration in Water	COPC-specific	µg/L	Calculated	$[((t_{event})/(1+B)) + 2\tau_{event}((1 + 3B + 3B^2)/(1+B)^2)$
		CF_1	Conversion Factor	0.001	mg/µg	-----	
		CF_2	Conversion Factor	0.001	L/cm^3	-----	DA_{EVENT} (Inorganic) =
		B	Ratio of Permeability Coefficient	See Table 7	unitless	EPA, 2004	$K_p \times C_w \times CF_1 \times CF_2 \times t_{event}$
		t*	Time to Reach Steady State	See Table 7	hour	EPA, 2004	
		t_{event}	Lag Time Per Event	See Table 7	hr/event	EPA, 2004	
		t_{event}	Event Duration	0.58	hr/event	EPA, 2004	

Table 5
Values Used for Daily Intake Calculations
Reasonable Maximum Exposure - Groundwater - Resident
Fort Drum Gasoline Alley Facility
Fort Drum, NY

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater
Receptor Population: Residents
Receptor Age: Child/Adult

Exposure Route	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Inhalation	Tapwater	E	Inhalation Exposure per Shower	See Tables 8 through 15	mg/kg/day	Calculated	Exposure Concentration (EC)(mg/m^3) =
Adult	While Showering	BW	Body Weight	70	kg	EPA, 1989	E x BW x CF1 x 1/VR x CF2 x EF x ED x 1/AT
		CF1	Conversion Factor	1.00E+03	L/m^3	-----	
		VR	Ventilation Rate	1.50E+01	L/minute	Foster and Chrostowski, 1987	
		CF2	Conversion Factor	6.94E-04	d/min	-----	
		EF	Exposure Frequency	350	days/year	EPA, 2002	
		ED	Exposure Duration	24	years	EPA, 2002	
		AT-C	Averaging Time (Cancer)	25,550	hours	EPA, 2009b	
		AT-NC	Averaging Time (Non-Cancer)	8,760	hours	EPA, 2009b	

Table 6

Age-Adjusted Absorbed Dose per Event (DA_{event}) Calculations[a]
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	EPC[b] (µg/L)	EPC[b] (mg/cm^3)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t^* (hr)	DA_{event} (mg/cm^2-event)[c] Age-Adjusted
Naphthalene	6.40E+00	6.40E-06	1.0	4.70E-02	5.60E-01	2.00E-01	1.34E+00	5.06E-07

[a] EPA, 2004
[b] See Table 3
[c] t_{event} was age-adjusted assuming t_{event} of 1 for 6 years and t_{event} 0.58 for 24 years. Adjusted value equals 0.66.
[d] In the absence of chemical-specific data, the FA was conservatively assumed to be 1.
[e] Calculated based on Equation 3.8 in EPA, 2004.
[f] Calculated based on Equation A.4 in EPA, 2004.
[g] Calculated based on Equation A.1 in EPA, 2004.

B = Ratio of the permeability coefficient of a COPC through the stratum corneum relative to its permeability coefficient across the viable epidermis.
FA = Fraction absorbed.
K_p = Dermal permeability coefficient.
NA = Not applicable.
τ_{event} = Lag time per event.
t^* = Time to reach steady-state.

Table 7

Child and Adult Absorbed Dose per Event (DA_{event}) Calculations[a]
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	EPC[b] (µg/L)	EPC[b] (mg/cm^3)	FA (unitless)	K_p (cm/hr)	τ_{event} (hr/event)	B (unitless)	t^* (hr)	DA_{event} (mg/cm^2-event)[c] Child	DA_{event} (mg/cm^2-event)[c] Adult
Naphthalene	6.40E+00	6.40E-06	1.0	4.70E-02	5.60E-01	2.00E-01	1.34E+00	6.22E-07	4.74E-07

[a] EPA, 2004
[b] See Table 3
[c] Calculated based on Equation 3.2 or 3.3 for organics and Equation 3.4 for inorganics in EPA, 2004a where t_{event} equals 1.0 for children and 0.58 for adults.
[d] In the absence of chemical-specific data, the FA was conservatively assumed to be 1.
[e] Calculated based on Equation 3.8 in EPA, 2004.
[f] Calculated based on Equation A.4 in EPA, 2004.
[g] Calculated based on Equation A.1 in EPA, 2004.

B = Ratio of the permeability coefficient of a COPC through the stratum corneum relative to its permeability coefficient across the viable epidermis.
FA = Fraction absorbed.
K_p = Dermal permeability coefficient.
NA = Not applicable.
τ_{event} = Lag time per event.
t^* = Time to reach steady-state.

Table 8

Inhalation Exposure Per Shower (E)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$E = \frac{VR \times S}{BW \times R \times 10^{6}} \times \frac{D_S + \exp(-R \times D_T)}{R - \frac{\exp[R \times (D_S - D_T)]}{R}}$$

Parameter	Definition	Value	Reference
E	Inhalation exposure per shower ($\mu g/m^3$).		
VR	Ventilation rate (L/minute).	15	Foster and Chrostowski, 1987
S	Indoor VOC generation rate ($\mu g/m^3$-minute).	Calculated	See Table 9
BW	Body weight (kg).	70	EPA, 1989
R	Air exchange rate ($minute^{-1}$).	90	Foster and Chrostowski, 1987; upper-bound value
CF	Conversion factor.	10^6	Foster and Chrostowski, 1987
Ds	Shower duration (minute).	34.8	EPA, 1997; RME value

Table 9

Indoor VOC Generation Rate (S)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$S = \frac{C_{WD} \times FR}{SV}$$

Parameter	Definition	Value	Reference
S	Indoor VOC generation rate (µg/m^3-minute).		
C_{WD}	Concentration leaving shower droplet after time t_s (µg/L).	Calculated	See Table 10
FR	Indoor shower water flow rate (L/minute).	10	Foster and Chrostowski, 1987
SV	Shower room air volume (m^3).	12	Professional Judgement

Table 10

Concentration Leaving Shower Droplet After Time T_S (C_{WD})
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$C_{WD} = C_{WO} \times \left(1 - \exp\left(-\frac{K_{aL} \times t_s}{60 \times d}\right)\right)$$

Parameter	Definition	Value	Reference
C_{WD}	Concentration leaving shower droplet after time t_s (µg/L).		
C_{WO}	Shower water concentration (µg/L).	COPC-Specific	See Table 3
K_{aL}	Adjusted overall mass transfer coefficient (cm/hr).	Calculated	See Table 11
t_s	Shower droplet drop time (seconds).	0.5	Foster and Chrostowski, 2003
d	Shower droplet diameter (mm).	1	Foster and Chrostowski, 1987

Table 11

Adjusted Overall Mass Transfer Coefficient (Ka_L)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$K_{aL} = K_L \times \left(\frac{T_1 \times \mu_s}{T_s \times \mu_1} \right)^{-0.5}$$

Parameter	Definition	Value	Reference
Ka_L	Adjusted overall mass transfer coefficient (cm/hr).		
K_L	Overall mass transfer coeeficient (cm/hr).	Calculated	See Table 12
T_1	Calibration water temperature of K_L (K).	293	Foster and Chrostowski, 1987
μ_s	Water viscosity at T_s (cp).	0.59	Foster and Chrostowski, 1987
T_s	Shower water temperature (K).	318	Foster and Chrostowski, 1987; upper-bound value
μ_1	Water viscosity at T_1 (cp).	1.002	Foster and Chrostowski, 2003

Table 12

Overall Mass Transfer Coefficient (K_L)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$K_L = \left(\frac{1}{k_{l(VOC)}} + \frac{R \times T}{H \times k_{g(VOC)}} \right)^{-1}$$

Parameter	Definition	Value	Reference
K_L	Overall mass transfer coefficient (cm/hr).		
$k_{l\,(VOC)}$	Liquid-film mass transfer coefficient for VOC (cm/hr).	Calculated; COPC-Specific	See Table 13
R	Gas constant (atm-m^3/mol-K).	0.000082	Foster and Chrostowski, 1987
T	Absolute temperature (K).	293	Foster and Chrostowski, 1987
H	Henry's law constant (atm-m^3/mol).	COPC-Specific	See Table 15
$k_{g\,(VOC)}$	Gas-film mass transfer coefficient for VOC (cm/hr).	Calculated; COPC-Specific	See Table 14

Table 13

Liquid-Film Mass Transfer Coefficient ($k_{l\,(VOC)}$)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$k_{l(VOC)} = k_{l(CO_2)} \times \left(\frac{44}{MW_{VOC}} \right)^{0.5}$$

Parameter	Definition	Value	Reference
$k_{l\,(VOC)}$	Liquid-film mass transfer coefficient for VOC (cm/hr).		
$k_{l\,(CO2)}$	Liquid-film mass transfer coefficient for CO_2(cm/hr).	20	Foster and Chrostowski, 1987
MW_{VOC}	Molecular weight of VOC (g/mol).	COPC-Specific	See Table 15

Table 14

Gas-Film Mass Transfer Coefficient ($kg_{(VOC)}$)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

$$k_{g(VOC)} = k_{g(H_2O)} \times \left(\frac{18}{MW_{VOC}} \right)^{0.5}$$

Parameter	Definition	Value	Reference
$K_{g(VOC)}$	Gas-film mass transfer coefficient for VOC (cm/hr).		
$kg_{(H2O)}$	Gas-film mass transfer coefficient for H_2O (cm/hr).	3,000	Foster and Chrostowski, 1987
MW_{VOC}	Molecular weight of VOC (g/mol).	COPC-Specific	See Table 15

Table 15

COPC-Specific Henry's Law Constant (H) and Molecular Weight (MW)
Fort Drum Gasoline Alley Facility – Building T-91
Fort Drum, NY

COPC	H (atm-m^3/mol)	MW (g/mol)
Naphthalene	4.4E-04 (HSDB, 2010)	128.17 (HSDB, 2010)

Table 16
Noncancer Toxicity Data - Oral and Dermal
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	Oral RfD Value	Oral RfD Units	GI_{abs} Oral Absorption Efficiency for Dermal[a]	Dermal RfD[a] Value	Dermal RfD[a] Units	Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	Source(s)	Date(s)[b]
Naphthalene	2.00E-02	(mg/kg-day)	1.0	2.00E-02	(mg/kg-day)	Body Weight	3,000	IRIS	6/8/2011

[a]Source: EPA, 2004.

[b]Represents date source was searched.

Definitions: IRIS=Integrated Risk Information System
RfD=Reference dose

Table 17
Noncancer Toxicity Data - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	Inhalation RfC Value	Inhalation RfC Units	Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	Source(s)	Date(s)[a]
Naphthalene	3.00E-03	mg/m^3	Respiratory System	3,000	IRIS	6/8/2011

[a]Represents date source was searched.

Definitions: IRIS=Integrated Risk Information System
RfC=Reference concentration

Table 18
Cancer Toxicity Data - Oral and Dermal
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	Oral CSF		GI_{abs} Oral Absorption Efficiency for Dermal[a]	Dermal CSF[a]		Weight of Evidence/ Cancer Guideline Description	Source(s)	Date(s)[b]
	Value	Units		Value	Units			
Naphthalene	NA	---	---	NA	---	C	IRIS	6/8/2011

[a]Source: EPA, 2004.
[b]Represents date source was searched

Definitions: C - Possible human carcinogen.
CSF = Cancer slope factor
IRIS=Integrated Risk Information System
NA=Not available

Table 19
Cancer Toxicity Data - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	Unit Risk		Weight of Evidence/ Cancer Guideline Description	Source(s)	Date(s)[a]
	Value	Units			
Naphthalene	3.40E-05	$(\mu g/m^3)^{-1}$	C	CalEPA	6/8/2011

[a]Represents date source was searched.

Definitions: C - Possible human carcinogen.
CalEPA=California Environmental Protection Agency

Table 20

asonable Maximum Exposure Doses and Cancer Risks for Indoor Worker Exposure to 2011 Groundw
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

COPC	EPC (µg/L)	Cancer		
		Exposure Dose		Cancer Risk
		Tapwater Ingestion (mg/kg-day)	Oral CSF $(mg/kg\text{-}day)^{-1}$	Tapwater Ingestion
Naphthalene	6.40E+00	2.24E-05	NA	NA
			Total	**---**

Table 21

Reasonable Maximum Exposure Doses and Hazard Quotients for Indoor Worker Exposure to 2011 Groundwater
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

		Noncancer			
		Exposure Dose			Hazard Quotient
COPC	EPC (µg/L)	Tapwater Ingestion (mg/kg-day)	Oral RfD (mg/kg-day)	Primary Target Organ	Tapwater Ingestion
Naphthalene	6.40E+00	6.26E-05	2.00E-02	Body Weight	0.0031
				Total	**0.0031**
				Total Body Weight HI	**0.0031**

Table 22

Reasonable Maximum Exposure Doses and Hazrd Quotients for Residential Exposure to 2011 Groundwater - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

		Cancer						
		Age-Adjusted Exposure Doses				Age-Adjusted Cancer Risks		
COPC	EPC (µg/L)	Tapwater Ingestion (mg/kg-day)	Dermal Contact (mg/kg-day)	Oral CSF $(mg/kg\text{-}day)^{-1}$	Dermal CSF $(mg/kg\text{-}day)^{-1}$	Tapwater Ingestion	Dermal Contact	Total
Naphthalene	6.40E+00	9.52E-05	6.10E-05	NA	NA	NA	NA	NA
					Total	---	---	---

Table 23

Reasonable Maximum Exposure Doses and Hazrd Quotients for Residential Exposure to 201
Groundwater - Inhalation
Fort Drum Gasoline Alley Facility - Building T-9
Fort Drum, NY

		Cancer		
		Adult Exposure Concentrations		Cancer Risks
COPC	EPC (µg/L)	Inhalation (mg/m^3)	URF $(\mu g/m^3)^{-1}$	Inhalation
Naphthalene	6.40E+00	3.80E-08	3.40E-05	1.3E-09
			Total	**1.3E-09**

Table 24

Reasonable Maximum Exposure Doses and Hazrd Quotients for Residential Exposure to 2011 Groundwater - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

		Noncancer							
		Child Exposure Doses					Child Hazard Quotients		
COPC	EPC (µg/L)	Tapwater Ingestion (mg/kg-day)	Dermal Contact (mg/kg-day)	Oral RfD (mg/kg-day)	Dermal RfD (mg/kg-day)	Primary Target Organ	Tapwater Ingestion	Dermal Contact	Hazard Index
Naphthalene	6.40E+00	4.09E-04	2.63E-04	2.00E-02	2.00E-02	Body Weight	0.020	0.013	0.034
								Total	**0.034**
								Total Body Weight HI	**0.034**

Table 25

Reasonable Maximum Exposure Doses and Hazrd Quotients for Residential Exposure to 2011 Groundwater - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

		Noncancer							
		Adult Exposure Doses					Adult Hazard Quotients		
COPC	EPC (µg/L)	Tapwater Ingestion (mg/kg-day)	Dermal Contact (mg/kg-day)	Oral RfD (mg/kg-day)	Dermal RfD (mg/kg-day)	Primary Target Organ	Tapwater Ingestion	Dermal Contact	Hazard Index
Naphthalene	6.40E+00	1.75E-04	1.17E-04	2.00E-02	2.00E-02	Body Weight	0.0088	0.0058	0.015
								Total	**0.015**
								Total Body Weight HI	**0.015**

Table 26

Reasonable Maximum Exposure Doses and Hazrd Quotients for Residential Exposure to 2011 Groundwater - Inhalation
Fort Drum Gasoline Alley Facility - Building T-91
Fort Drum, NY

		Noncancer			
		Adult Exposure Concentrations			Hazard Quotients
COPC	EPC (µg/L)	Inhalation (mg/m^3)	RfC (mg/m^3)	Target Organ	Inhalation
Naphthalene	6.40E+00	1.11E-07	3.00E-03	Respiratory System	0.000037
				Total	**0.000037**
				Total Respiratory System HI	**0.000037**