FOURTH
FIVE-YEAR REVIEW REPORT FOR
GREENWOOD CHEMICAL SUPERFUND SITE
ALBEMARLE COUNTY, VIRGINIA

Prepared by

U.S. Environmental Protection Agency
Region III
Philadelphia, Pennsylvania

SEPTEMBER 2013

Approved by: Date: 9/9/2013

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List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Difference
GCC	Greenwood Chemical Company
GWI/FFS	Groundwater Investigation/Focused Feasibility Study
GMNC	Contaminated Groundwater Migration Not Under Control
HEUC	Current Human Exposure Controlled
HI	Hazard Index
IUR	Inhalation Unit Risk,
LTRA	Long Term Remedial Action
MCL	Maximum Contaminant Level
MG	Million Gallons
NCP	National Contingency Plan (the "National Oil and Hazardous Substances Pollution Contingency Plan")
NPL	National Priorities List
O&M	Operation and Maintenance
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PRP	Potentially Responsible Party
RA	Remedial Action
RAO	Remedial Action Objective
RD	Remedial Design
RfC	Reference Concentration
RfD	Reference Dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
RSE	Remedial System Evaluation
RCRA	Resource Conservation and Recovery Act
SFO	Slope Factor Oral
SWRAU	Site-Wide Ready for Anticipated Reuse
SSC	State Superfund Contract
TAL	Target Analyte List
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCL	Target Compound List
TIC	Tentatively Identified Compound
USACE	United States Army Corps of Engineers
VDEQ	Virginia Department of Environmental Quality
VPDES	Virginia Pollution Discharge Elimination System
VOC	Volatile Organic Compound

Executive Summary

The remedy for the Greenwood Chemical Site in Newtown, Virginia (Site) included dismantling a former chemical production facility, packaging and transporting drums and miscellaneous abandoned chemicals off-site for proper disposal, draining chemical lagoons, excavating sludge, contaminated soil and buried drums for off-site treatment and/or disposal, pumping contaminated groundwater for treatment in an on-Site water treatment plant, institutional controls and monitoring. The Site has been addressed in four operable units (OUs):

- OU1 – Lagoons and disposal areas were excavated and transported to a permitted thermal destruction facility for treatment;
- OU2 – Ground water recovery wells were installed for "hot-spot" removal to prevent groundwater from migrating toward drinking water sources and treat recovered water in the on-Site treatment plant;
- OU3 – Former manufacturing buildings removed; and,
- OU4 – Ground water recovery wells used to contain contaminated groundwater within a waste management area (below OU1 excavations) to restore ground water quality within the area of attainment, and treat recovered water in the on-Site treatment plant.

The four OUs have been completed and are operational and functional. The Site achieved construction completion with the signing of the Preliminary Close-Out Report on September 30, 2005. The trigger for this Fourth Five-Year Review was the signature of the last five year review on September 29, 2008.

The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term institutional controls must be placed on the Site to ensure protectiveness.

As part of this Five Year Review the GPRA Measures have also been reviewed. The GPRA Measures and their status are provided as follows:

Environmental Indicators
Human Health: Current Human Exposure Controlled (HEUC)
Groundwater Migration: Contaminated Groundwater Migration Not Under Control (GMNC)

Site-wide RAU
The Site is not Site-Wide Ready for Anticipated Use (SWRAU) but is expected to achieve SWRAU on 12/30/14.

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site Name: Greenwood Chemical Superfund Site		
EPA ID: VAD003125374		
Region: 3	**State:** VA	**City/County:** Newtown/Albemarle

SITE STATUS	
NPL Status: Final	
Multiple OUs? Yes	**Has the site achieved construction completion?** Yes

REVIEW STATUS
Lead agency: State **If "Other Federal Agency" was selected above, enter Agency name:**
Author name (Federal or State Project Manager): Eric Newman
Author affiliation: U.S. EPA Region 3, HSCD
Review period: 3/15/13 - signature date
Date of site inspection: 8/20/13
Type of review: Statutory
Review number: 4
Triggering action date: 9/29/2008
Due date *(five years after triggering action date)*: 9/29/2013

Issues/Recommendations

OU(s) without Issues/Recommendations Identified in the Five-Year Review:
OU3

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 2/4	Issue Category: Institutional Controls			
	Issue: Implement institutional controls included ESD to the OU2/4 ROD			
	Recommendation: Implement Institutional Controls			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	Yes	EPA	EPA	12/30/2014

OU(s): 2/4	Issue Category: Monitoring			
	Issue: Long-term groundwater monitoring is required to assess and confirm that MCLs will be achieved throughout the Area of Attainment within a reasonable time period.			
	Recommendation: Monitor groundwater quality trends outside the Waste Management Area to confirm that MCLs will be achieved throughout the Area of Attainment within a reasonable time period			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	No	State	EPA	9/30/2018

OU(s): 1	Issue Category: No Issue			
	Issue: On February 17, 2012, EPA released the final non-cancer dioxin reassessment, publishing a non-cancer toxicity value, or reference dose (RfD), for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in EPA's Integrated Risk Information System (IRIS). Dioxin was never sampled for at the Site.			
	Recommendation: Limited sampling for TCDD in surface soil outside the perimeter of previously excavated areas should be completed to confirm that dioxin in not a concern at the Site.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
No	No	EPA	EPA	9/30/2014

Protectiveness Statement(s)

Operable Unit:	*Protectiveness Determination:*	*Addendum Due Date (if applicable): N/A*
1	Protective	

Protectiveness Statement:
The remedy at OU1 is protective of human health and the environment. Contaminated soil and waste material was excavated and transported off-Site for treatment and/or disposal to minimize migration to groundwater and direct exposure. The excavated areas were backfilled with clean soil. The remedial action objectives have been met.

Operable Unit:	*Protectiveness Determination:*	*Addendum Due Date (if applicable): N/A*
2/4	Short-term Protective	

Protectiveness Statement:
The remedy at OU2/4 currently protects human health and the environment because hydraulic containment has been achieved and there is no current exposure to contaminated groundwater. However, in order for the remedy to be protective in the long term institutional controls must be placed on the Site to ensure protectiveness.

Operable Unit:	*Protectiveness Determination:*	*Addendum Due Date (if applicable): N/A*
3	Protective	

Protectiveness Statement:
The remedy at OU3 is protective of human health and the environment. The former manufacturing buildings and chemical wastes stored within those buildings were dismantled and properly disposed off-Site. The remedial action objectives have been met.

Site wide Protectiveness Statement (if applicable)

Protectiveness Determination:	*Addendum Due Date (if applicable):*
Short-term Protective	

Protectiveness Statement:
The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term institutional controls must be placed on the Site to ensure protectiveness.

Five-Year Review Report

I. Introduction

The purpose of the five-year review is to determine whether the remedy at a Site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in five-year review reports. In addition, five year review reports identify issues found during the review, if any, and recommendations to address them.

The United States Environmental Protection Agency (EPA) is preparing this five year review report pursuant to the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) § 121 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). CERCLA §121states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The Agency interpreted this requirement further in the NCP; 40 Code of Federal Regulations §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

The EPA Region 3 has conducted a five-year review of the remedial actions implemented at the Greenwood Chemical Superfund Site, Newtown, Albemarle County, Virginia. See Figure 1. This review was conducted from March 2013 through September 2013. The purpose of the five-year review is to determine whether the remedy at the Site is protective of human health and the environment. The methods, findings, and conclusions of the review are documented in this report.

This is the fourth five-year review for the Greenwood Chemical Site. The triggering action for this review is the date of the third five-year review: September 29, 2008. The five-year review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the Site above levels that allow for unrestricted use.

II. Site Chronology

Table 1, below, summarizes important events and relevant dates in the chronology of the Greenwood Chemical Site.

Table 1: Chronology of Site Events

Event	Date
Chemical Manufacturing Operations	1947-1985
Finalized on National Priorities List (NPL)	July 22, 1987
EPA begins Emergency Removal Actions	October 15, 1987
Operable Unit 1 (OU1) Record of Decision (ROD) issued requiring excavation, treatment and disposal of surface soil and sludge and off-Site disposal of abandoned chemicals.	December 29, 1989
Operable Unit 2 (OU2) Interim ROD issued requiring groundwater pump and treat to be implemented as a preliminary action.	December 31, 1990
Explanation of Significant Differences (ESD) No. 1 clarified that former manufacturing buildings needed to be demolished to access contaminated soil. Referred to as OU3.	July 17, 1991
OU1 State Superfund Contract (SSC) signed	October 17, 1991
EPA accepted the OU3 Remedial Action Report documenting demolition and disposal of buildings	October 15, 1993
ESD-2 clarified that excavation required by OU1 ROD would extend to practical limits of excavation; deeper contamination would be addressed by an OU4 Record of Decision.	March 24, 1994
EPA completed Remedial Design for OU1; excavation, treatment , off-Site disposal of contaminated soil and sludge	June 30, 1994
EPA accepted the OU1 Remedial Action Report documenting completion	September 3,1996
EPA completed Remedial Design for Interim Remedy OU2, including water treatment plant	September 29, 1997
First Five-Year Review issued	January 23, 1998
Final inspection and acceptance of constructed water treatment plant (Interim OU2)	May 9, 2000
Interim OU2 remedy determined to Operational and Functional	May 15, 2002
EPA accepted the Interim OU2 Remedial Action Report documenting completion	September 19, 2003
Second Five-Year Review issued	September 29, 2003
Issue Action Memo, Remove Lagoons 4&5 and arsenic-contaminated surface soil	June 22, 2004 – May 2005
OU2 (final) and OU4 ROD issued requiring containment of deep soils and achieving groundwater performance standards with upgraded pump and treat system	September 22, 2005
Preliminary Closeout Report issued	September 30, 2005
EPA accepts Interim OU2 Remedial Action Report	July 10, 2006
Third Five-Year Review issued	September 29, 2008
Operations transferred from EPA to VDEQ	March 15, 2012
ESD for OU 2/4 ROD issued requiring new buildings on Site to be constructed in a manner that protects occupants from vapor intrusion from underlying contaminated ground water.	July 24, 2013

III. Background

Physical Characteristics

The Greenwood Chemical Site is located at 634 Newtown Road in the village of Newtown, Albemarle County, Virginia between the cities of Waynesboro and Charlottesville (Site). See Figure 1. The Site is owned by the Greenwood Chemical Company (GCC) and encompasses 33.59 acres, of which approximately18 acres were used for chemical manufacturing and waste disposal activities.

EPA dismantled and removed the former chemical production buildings and other facility features. The Site is currently inactive except for an on-Site water treatment plant for recovered groundwater operated as a long-term response action. See Figure 2. The entire Site is enclosed by a chain-link fence. The gate is opened during weekday business hours to accept deliveries at the treatment plant. The gate is locked in the evenings and on weekends.

The setting is rural and land use surrounding the Site is generally undeveloped woodlands or agricultural. There is a residential area along Summers Rest Road east of the northern property boundary. The Mt. Zion Baptist Church is located adjacent the northwest corner of the Site. The Mt. Zion Baptist Church owns the undeveloped woodland along the western property boundary. The properties east and south of the Site are agricultural, currently used for cattle pastures. The farms in the area are generally 100+ acres and include a residence. Interstate 64 passes 100 yards north of the Site.

The topography slopes to the south-southeast and levels off at the southern end of the Site. Groundwater beneath the Site is not currently being used, however, surrounding properties do utilize groundwater for potable and agricultural purposes. Surface water features on the Site are limited to a small pond, referred to as "South Pond," and several intermittent streams which serve as tributaries to a perennial stream designated as "West Stream" located south of the Site. The groundwater treatment plant discharges clean water to one of the intermittent streams flowing to West Stream. West Stream meanders through cattle pastures and ultimately enters Stockton Creek several miles south of the Site.

Land and Resource Use

The historic land use of the Site was agricultural until 1946. Starting in 1947 a chemical manufacturing plant specializing in pharmaceutical intermediates began operations. From 1947 until 1985, chemicals including pharmaceutical, dye and paint intermediates, plant growth regulators and photographic chemicals were manufactured on-Site. The two main areas of the property utilized by GCC for business operations are known as the "manufacturing area" and the "drum disposal area." A more detailed Site location map with features associated with historic land use is presented in Figure 3. Historic features within the manufacturing area included chemical processing buildings, offices and laboratory space, storage trailers and sheds, a pump house, a concrete bunker, five treatment lagoons and several abandoned structures.

Major manufacturing operations at the Site ceased in 1985; EPA and the Virginia Department of Environmental Quality (VDEQ) response teams began to clean the Site up shortly thereafter. From the late 1980's through the 1990's the GCC remained an active corporation and maintained an inventory of laboratory chemicals in storage units on Site. In 2004 EPA found that GCC abandoned scores of small containers of hazardous substances within trailers and degraded laboratory facilities. The business component of the facility has been inactive since that time.

The projected land use for the former Greenwood Chemical Site is light industrial, recreational or conservancy/open space; however, local zoning restrictions on the property have reverted to agricultural use only. The other land uses surrounding the Site are expected to remain the same. Response actions completed by EPA anticipate safe and beneficial use of the Site for industrial or recreational purposes.

Hydrogeology

The bedrock aquifer underlying the Site is used as a drinking water source in surrounding residential areas. The area surrounding the Site is not presently serviced with public water. The closest residential well is located approximately 400 feet from the Site, while the closest downgradient well is approximately 2,500 feet from the Site. The dominant groundwater flow direction is to the east-southeast in the direction of Stockton Creek and its tributaries.

The topography of the Site slopes predominantly to the southeast and levels off at the southern end. Total relief across the Site is approximately 196 feet with an average grade of 10 percent. The majority of the Site is covered with overburden ranging in thickness from 0 - 15 feet. Groundwater at the Site is present in both the overburden and underlying fractured bedrock. Two water bearing units (aquifers) have been identified in the overburden and bedrock. Aquifer testing indicates that the two water bearing units exhibit a high degree of hydraulic interconnection sufficient to consider the two units to be part of a single aquifer system. Significant movement within the bedrock is limited to its uppermost 50 feet. The water table at the Site is encountered at depths ranging from 5 feet to 35 feet below ground surface.

The water table generally follows surface topography. Groundwater in the overburden layer flows in a southeasterly direction toward West Stream, a tributary of Stockton Creek into which it discharges. The bedrock groundwater flow system is controlled by the nature and extent of bedrock fracturing. The direction of groundwater flow in the bedrock is also in a southeasterly direction. Groundwater located in the sloped areas of the Site generally has a downward vertical gradient (water moves downward from the overburden to the shallow bedrock). Topography at the southern end of the Site levels off and the vertical gradient of the groundwater is upward. The water table is generally located at or above the top of the bedrock.

In the southern portion of the Site, the groundwater elevations are at, or slightly above, ground surface elevations. Since the groundwater is found close to the surface in the southern

portion of the Site, this indicates that the area serves as a groundwater discharge area. The West Stream and associated features at the southern periphery of the Site are probably groundwater discharge features.

History of Contamination

The Greenwood Chemical Company operated a small volume batch chemical manufacturing facility. Chemical manufacturing operations began in approximately 1947 under the name of Cockerille Chemical Company. The facility was sold to GCC in 1968 and continued to operate under that name until its closure. In April 1985, a toluene vapor fire destroyed the main processing building and resulted in the death of four workers. The plant ceased operations shortly thereafter. The facility produced chemicals for application in industrial, agricultural, pharmaceutical and photographic processes. The primary compounds manufactured at the Site during the 1980s included naphthalene acetic acid, 1-naphthaldehyde, and naphthoic acid. In addition, arsenic salts were used as catalysts in the production of chloromethylnaphthalene, an intermediary in the production of naphthalene acetic acid. Production processes used toluene, naphthalene derivatives, sodium cyanide and inorganic arsenic salts. In addition, naphthalene derivatives, sodium cyanide, sulfuric acid, hydrogen peroxide and paraformaldehyde were also used. Manufacturing activities involved the handling of large numbers of drums containing waste, feedstock, intermediate and final products.

In the course of these operations liquid wastes were discharged through floor drains in the process buildings to a series of unlined lagoons adjacent to the plant. The unlined lagoons were interconnected by unlined drainage ditches or above-ground piping. Liquid hazardous waste was routinely spilled onto process building floors and drained into the ground beneath and adjacent to the process buildings. In addition, drums were systematically buried on plant property. Trenches were used for the disposal of large quantities of 55-gallon drums containing hazardous substances. This activity resulted in the contamination of soil, groundwater, surface water and lagoon sludge. Contamination in groundwater consists primarily of volatile organic compounds (VOCs) including 1,2-dichloroethane, carbon tetrachloride and vinyl chloride, semi-volatile organic compounds including naphthalene and other organic compounds such as bis (2-chloroethyl) ether.

Initial Response

In June 1985 the Virginia Department of Health completed a Preliminary Assessment that documented the presence of numerous unidentified drums of chemicals and chemicals in the waste lagoons. The report concluded by recommending that EPA conduct a detailed site investigation to further assess the potential for harm to the public health and environment at the Site.

In 1986, EPA evaluated the Site for a possible removal action. Between May 1986 and December 1987, the EPA Emergency Response Team and Technical Assistance Team planned and implemented a detailed sampling of the lagoons, lagoon sludge, and surface and subsurface

soils. In addition, monitoring wells were installed to conduct a hydrogeological investigation and a magnetometer and soil gas survey was conducted. Analysis of the samples from the various media showed the presence of numerous hazardous substances at the Site.

EPA proposed the Greenwood Chemical Site for inclusion on the CERCLA National Priorities List (NPL) in March 1987 and placed the Site on the NPL on July 22, 1987 (see 55 Fed Reg. 27263).

Between 1987 and 1990, EPA conducted two removal actions which included the removal of drums and smaller containers of chemicals (both buried and surface), the removal and treatment of lagoon water and sludges. In 1987, approximately 400 buried drums and 32 pressurized gas cylinders were excavated and removed from the Site. Waste water from lagoons 1, 2 and 3 was pumped into lagoon 4, treated with activated carbon, and released to lagoon 5. In addition contaminated lagoon sludges were excavated and removed from the Site for disposal. Also, certain sludges were stabilized onsite with kiln dust and placed in a temporary lined vault constructed within the lagoon 3 excavation area. In November 1989, EPA determined that further removal action was necessary after heavy rains in the region damaged the temporary soil/synthetic membrane cap covering the former drum disposal area. EPA repaired the temporary cover and several drainage swales were constructed around the waste lagoons to prevent further erosion.

Basis for Taking Action

In October 1988 EPA initiated a site-wide Remedial Investigation. EPA conducted a baseline risk assessment using all available data collected during previous removal work and identified data gaps. Several data gaps were identified in the baseline risk assessment; however, it became clear that some initial steps could be taken to address obvious environmental problems at the Site. In order to simplify the management of the Site, EPA has divided the Site into components or Operable Units (OUs). The Operable Units for the Site are listed as follows:

- OU1: Source control remedy (soil)
- OU2: Interim groundwater and lagoon water remedy
- OU3: Removal of Process Buildings and waste chemicals
- 2004/2005 Removal (not assigned an OU #): Surface Soil, Lagoons 4 and 5, laboratory chemicals
- OU2/4: Final groundwater and deep soil source areas

EPA has issued three Records of Decision (RODs) and issued one Action Memorandum for the Site after placing it on the NPL. The first ROD addressed the OU1 source control remedy. The second ROD addressed the OU2 interim groundwater and lagoon water remedy.

The third ROD reaffirmed the groundwater pump and treat remedy selected as an interim action and established performance standards for groundwater (OU2). The third ROD also addressed remaining deep soil contamination (OU4) located beneath areas excavated as part of OU1. See Section IV (Remedial Actions) for a detailed discussion of respective remedy decisions.

A Remedial Investigation and Feasibility Study (RI/FS) for the entire Greenwood Chemical Site was completed in August 1990. The report characterized the nature and extent of soil, surface water, sediment and groundwater contamination. The 1990 RI/FS process, including several preliminary reports, provided the basis for Records of Decision for OU1, OU2, the 1991 Explanation of Significant Differences (ESD) which defined OU3, and the 1994 ESD.

The baseline risk assessment determined that risk pathways driving the risk at the Site under current and future use scenarios were dermal contact and ingestion of contaminated soil and ingestion of contaminated groundwater. The baseline risk assessment completed for the OU1 (1989) and OU2 (1990) RODs assumed a future residential land use scenario. The baseline risk assessment completed for the final OU2/4 ROD (2005) assumed industrial and recreational future land use based on recommendations from state and local officials.

Soil

The carcinogenic risks were highest for exposures to surface soil due to elevated concentrations of arsenic. Arsenic was the primary contributor to both the total excess cancer risk and the non-carcinogenic risk for exposure to soil[a]. The soil cleanup levels selected for organic compounds were based on the potential for migration to groundwater because the soil to groundwater performance standards were more conservative (i.e., lower) than cleanup concentrations developed for direct contact with soil assuming residential use. See Table 2 for soil cleanup standards for organics used during OU1 soil excavation[b]. The arsenic cleanup level in soil (27 mg/kg) was based on the direct exposure route because it was lower than the soil to groundwater target.

Groundwater

The 1990 interim OU2 ROD established that groundwater beneath the Site was grossly contaminated, primarily in the center of the Site (beneath the manufacturing area and the drum disposal area). The eleven contaminants identified as driving the risk assuming ground water consumption were:

Groundwater

[a] The primary ecological risk driver was also arsenic in surface soil.
[b] In areas where arsenic was the only contaminant of concern present, excavation was deferred to the removal response taken in 2004/2005.

Arsenic	Non-carcinogenic polycyclic aromatic hydrocarbons (PAHs)
Benzene	Semi-volatile Tentatively Identified Compounds (TICs)
Methylene Chloride	Toluene
Trichloroethene	Volatile TICs
Chlorobenzene	Cyanide
Tetrachlorethene	

The interim ROD deferred establishment of groundwater cleanup levels to a subsequent ROD. See Operable Unit 2 (Final) and Operable Unit 4 Remedy Selection on Page 14 for final groundwater cleanup level discussion.

Lagoons 4 and 5

The response action for lagoon water was based on cyanide concentrations which exceeded the Virginia Water Quality Criteria for cyanide (5.2 ug/l). The cyanide levels presented an unacceptable risk to aquatic life. Once the lagoon was drained, the sludge/sediment was determined to exceed the soil cleanup level for arsenic.

IV. Remedial Actions

Operable Unit 1 Remedy Selection

On December 29, 1989, EPA issued the OU1 ROD selecting a remedy to address contaminated soils remaining in the lagoons and other disposal areas after emergency removal actions had been completed to address the sludges from those areas. The remedial action objectives are to prevent direct exposure to contaminated soils and to eliminate the continued migration of contaminants to the underlying groundwater. As stated above, the OU1 ROD was based on a baseline risk assessment and focused feasibility study conducted by EPA utilizing data collected during previous removal actions.

The ROD developed cleanup standards for each compound considering: 1) the direct contact exposure route; and, 2) its potential to migrate from soil to groundwater. The cleanup standards developed for the protection of groundwater were more stringent than the standards developed for direct contact in each case except arsenic. The selected remedy included excavation and offsite treatment and/or disposal of soils exceeding site-specific cleanup standards. See Table 2. The major components of the selected remedy include:

- Excavation of soil exceeding risk-based cleanup levels (soil associated with Lagoons 1, 2, 3 and Backfill North were estimated at 4,500 cubic yards[c]);
- Off-Site treatment of contaminated soil in a Resource Conservation and Recovery Act (RCRA)-permitted thermal destruction facility (i.e., incinerator);
- Treated soil was to be analyzed and stabilized/solidified in compliance with RCRA land ban restrictions, if necessary, prior to its disposal in a RCRA-permitted Subtitle C landfill;
- Excavated areas were to be backfilled with clean fill and re-vegetated; and,
- Abandoned chemicals located in on-Site buildings were to be treated via thermal destruction and disposed of off-Site.

Operable Unit 3[d] Remedy Selection (Explanation of Significant Differences-1)

An Explanation of Significant Differences (ESD-1) augmenting the remedy selected in the OU1 ROD was issued on July 17, 1991. The OU1 ROD had been issued based on preliminary nature and extent of contamination data available at the time. The final RI Report completed in September 1990 identified additional contaminated soils exceeding risk-based soil cleanup levels (identified in the OU1 ROD) extending beneath on-Site Process Buildings A, B and C. ESD-1 required the removal of the process buildings to allow delineation of soils exceeding cleanup levels. The primary changes described in ESD-1 were:

- The Process Buildings A, B, and C were to be dismantled, decontaminated to the extent possible and appropriately disposed of in an off-Site landfill. Contaminated demolition debris was to be disposed of in a RCRA Subtitle C landfill; nonhazardous debris was to be disposed of in a RCRA Subtitle D landfill;

ESD-2 (Modification to OU1 Remedy Selection)

An Explanation of Significant Differences (ESD-2) modifying the remedy selected in the OU1 ROD was issued on March 24, 1994. ESD-2 presented the findings of soil sampling completed during pre-design activities in the footprint of the demolished process buildings and other disposal areas refining the extent of contamination estimates. ESD-2 asserted that contaminated soils in the source areas to be addressed by OU1 extended beyond the depth of feasible excavation. The ESD-2 determined 15-feet to be the practical limit of cost-effective excavation and established that EPA would evaluate appropriate response actions for the deeper contaminated soils as Operable Unit 4. Further, ESD-2 modified the cleanup levels presented in the OU1 ROD based on an extensive fate and transport modeling program completed as part of pre-design activities[e]. See Table 2. The fate and transport model used more site specific

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[c] These soils were considered to be a principal threat to human health and the environment and are shown in Table 2

[d] Removal of process buildings and waste chemicals are referred to as Operable Unit 3 for administrative tracking purposes.

[e] The soil performance standard established in ESD-2 were the only soil performance standards implemented. Accordingly, the list of soil performance standards included in the 1989 ROD are not included in this Five-Year Review Report

information and a revised model.

ESD-2 determined that the remedy for OU1 would address contaminated soil in the following additional areas of the Site:

- The Backfill North area extending to and beneath former Process Building A;
- An area including the location of former process Buildings B and C; and
- The former Drum Disposal Area, the Waste Dump area, the Northeast Drum Area, and other areas if subsequent sampling revealed contaminant concentrations above risk-based levels.

The area of contaminated soil requiring remediation increased from the 1.5 acres estimated in the original OU1 ROD to approximately 7 acres. The estimated volume of soil to be transported off-Site for treatment and/or disposal increased from 4,500 cubic yards to approximately 11,000 cubic yards. ESD-2 also noted the following clarification to the original remedy:

- Certain areas on the Site were only contaminated with elevated levels of arsenic. These arsenic-contaminated soils do not pose an unacceptable risk through the groundwater pathway but only through direct contact. Noting that the incineration technology selected for OU1 is inappropriate for arsenic, EPA deferred the remediation of these arsenic-contaminated soils to a subsequent decision document.

OU1 and OU3 Remedy Implementation

From initial EPA involvement with the Site through the March 15, 2012 transfer of operations to VDEQ, the Superfund has been used to finance all investigation and remediation activity. A total of 30 Potentially Responsible Parties (PRPs) were ultimately identified, including former owners and operators of the facility and various entities which did business with Greenwood Chemical. The major PRPs for the Site were issued a Unilateral Administrative Order in 1994 to conduct the OU1 remedial action (RA) but the PRPs declined to perform the RA. Thereafter, EPA made the decision to proceed with cleanup utilizing the Superfund. All subsequent removal and remedial activities through the recent transfer to VDEQ have been accomplished with Superfund financing. EPA has recovered a portion of its response costs from 15 PRPs pursuant to several judicial settlements.

The work associated with OU3 was the first remedial action to be performed at the Site. The former process buildings A, B and C and the abandoned chemicals stored in these buildings presented an obstacle to efficient excavation of contaminated soils required for OU1. In accordance with an interagency agreement, on November 27, 1991, the U.S. Army Corps of Engineers (USACE) awarded the contract to OHM Remediation Services Corp to remove the abandoned chemicals within the process buildings and subsequently demolish the process

buildings under the direction of the Rapid Response Team, thereby initiating RA. OHM mobilized to the Site in December 1991 to begin construction in the field. Major milestones included:

- Installation of a security fence;
- Removal of abandoned chemical containers in and around the buildings;
- Demolition, decontamination and off-Site disposal of 4 concrete block buildings (process buildings A, B and C and a laboratory/office building);
- Removal of metal shed (storage shed/garage); and,
- Decontamination and proper disposal of six aboveground chemical storage tanks, one underground chemical storage tank and associated piping.

The OU3 work was completed in a manner consistent with the requirements of the July 1991 ESD and all project work plans. USACE maintained a continuous presence on Site and performed routine inspections throughout field implementation. In March 1993 EPA, USACE and VDEQ conducted the final inspection and concluded that construction had been completed in accordance with the project work plans. The final inspection did not result in the development of a punch list. On October 15, 1993, the EPA Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the RA for OU3.

On June 30, 1990, EPA entered into an interagency agreement with the U.S. Army Corps of Engineers (USACE) to develop a remedial design (RD) for the remedy selected in the OU1 ROD. The USACE completed the RD consistent with the remedy selected in the OU1 ROD and modified by the ESD-2 on June 30, 1994. In accordance with an interagency agreement, on August 31, 1995 the USACE awarded a contract to Ogden Remediation Services to construct the remedy in accordance with the approved RD, thereby initiating the RA. Ogden mobilized to the Site in February 1996 to begin construction in the field. Major milestones included the following:

- Excavation of approximately 11,000 yd^3 of contaminated soil from the areas discussed above;
- Shipment by rail of contaminated soils to a thermal destruction facility (incinerator) in Utah for treatment;
- Disposal of residue (ash) in an adjacent RCRA Subtitle C landfill;
- Implementation of stormwater drainage controls around excavation areas; and,
- Backfilling, regrading and revegetation of excavation areas.

The work was completed and a prefinal inspection resulted in the development of a punch list of items which needed to be addressed. On August 8, 1997 EPA, USACE and VDEQ conducted the final inspection and concluded that construction had been completed in accordance with the remedial design plans and specifications. On September 3, 1997, the EPA Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the RA for OU1.

Operable Unit 2 (Interim) Remedy Selection

On December 31, 1990, EPA issued an Interim ROD for operable unit 2 initiating a pump and treat remedy to minimize migration of contaminated groundwater toward residential wells. The ROD was considered "interim" because the selection of groundwater cleanup goals was deferred to a subsequent ROD after further study. The remedial action objectives are to minimize migration of contaminants toward residential wells, eliminate unacceptable environmental risks in Lagoons 4 and 5, and to obtain additional information regarding aquifer characteristics to assist in designing a final groundwater remedy. As stated above, the interim OU2 ROD was based on a baseline risk assessment and a groundwater focused feasibility study conducted by EPA utilizing data collected during Remedial Investigation. The major components of the interim OU2 selected remedy include:

- Installation and operation of groundwater recovery wells to prevent migration of contaminated groundwater from the Site;
- Monitoring the effectiveness of the groundwater extraction network and systematic optimization to meet objectives over time; and
- Construction and operation of a water treatment plant to treat the recovered groundwater and surface water collected in Lagoons 4 and 5. The treatment plant discharge to surface water (tributary to West Stream) must meet VPDES criteria.

Operable Unit 2 (Interim) Remedy Implementation

On February 20, 1992, EPA awarded a work assignment to CH2M Hill to develop a remedial design for the remedy selected in the interim OU2 ROD. CH2M Hill completed the RD on September 19, 1997. In accordance with an interagency agreement, on July 2, 1998 the U.S. Army Corps of Engineers awarded a contract to Norair Engineering to construct the remedy selected in interim OU2 ROD in accordance with the approved RD, thereby initiating the RA. Norair mobilized to the Site on September 18, 1998 to begin construction in the field.

Major milestones included the following:

- Installing and operating of five bedrock groundwater recovery wells (BR-2, BR-7, MW-23, BR-8 and BR-6);
- Installing of a floating pump assembly and pumping surface water from Lagoon 5 to the on-Site water treatment plant;
- Constructing a water treatment plant utilizing the following treatment train: precipitation, ultraviolet/chemical oxidation and carbon adsorption;
- Install plumbing necessary to convey recovered groundwater and lagoon surface water to the treatment plant;
- Beginning to operate the water treatment plant so that discharge consistently achieves VPDES criteria; and
- Installing an expanded monitoring well network.

The work was constructed in accordance with the remedial design plans and specifications. The final inspection and EPA/USACE, and VDEQ acceptance was completed May 9, 2000. The water treatment system began continuous operations on May 15, 2000, including initiation of routine groundwater monitoring. During the initial year the treatment plant operators were on-Site making equipment adjustments (as necessary) to ensure consistent and effective operation of the treatment system. Field testing and laboratory analyses confirmed that the plant was operating satisfactorily. On May 15, 2001, EPA and VDEQ determined the water treatment system to be operational and functional. On September 19, 2003, the EPA Remedial Branch Chief accepted the Remedial Action Report documenting successful completion of the interim RA for OU2.

2004/2005 Removal Remedy Selection – Surface Soil, Lagoons 4 and 5 (No Operable Unit #)

On June 22, 2004 EPA issued an Action Memorandum to address additional laboratory chemicals abandoned by GCC, properly close out Lagoons 4 and 5, and to address the remaining arsenic-contaminated surface soil. The primary components of the removal response action include:

- Excavation and off-Site disposal contaminated lagoon sludge (Lagoons 4 and 5) and surface soil with arsenic concentration greater than 27 mg/kg.
- Backfill with 2 feet clean soil.
- Removal and proper off-Site disposal of laboratory chemicals abandoned on-Site.

2004/2005 Removal Remedy Implementation

On June 28, 2004, EPA mobilized to the Site with Kemron Environmental, Inc. to begin removal activities. All chemicals were removed from buildings and trailers, containers were laboratory packed for off-Site Disposal. On October 4, 2004, the drums were picked up for disposal by Chemical Analytics, Inc.

Between August 2004 and November 2004, EPA drained the lagoons by pumping the water to the on-site treatment plant and closed out the lagoons. Dewatered sludge/sediment was excavated until confirmation samples demonstrated arsenic concentrations below 27 mg/kg. The former lagoons were then backfilled with clean soil and seeded.

Between June 2004 and June 2005, EPA delineated all areas containing greater than 27 mg/kg arsenic in soil. The soil sampling program determined that no excavated soils were RCRA-characteristic waste. Approximately 19,500 tons of arsenic-contaminated soil and sludge was excavated, sampled and appropriately disposed in a solid waste landfill. EPA implemented an extensive confirmation sampling program to document that all soils with elevated arsenic concentrations were removed. The excavations were backfilled with a minimum 2-feet clean soil and seeded for erosion control.

Operable Unit 2 (Final) and Operable Unit 4 Remedy Selection

On September 22, 2005, EPA issued a final ROD for groundwater (OU2) and deep soil contamination[f] (OU4). The ROD (OU2/4 ROD) established groundwater performance standards for the second operable unit interim action pump and treat system. In addition, the OU2/4 ROD defined the area including the deep soil contamination as a "waste management area." The OU2/4 ROD selected hydraulic containment of the waste management area utilizing an enhanced version of the pump and treat system selected for interim OU2. The remedial action objective was to contain the contaminant plume within the waste management area and to restore groundwater quality in the area of attainment. The response action was based on the Groundwater Investigation and Focused Feasibility Study (GWI/FFS) completed in June 2005. The GWI/FFS included a groundwater capture zone analyses that recommended additional wells be added to the existing five-well groundwater extraction network.

In summary, the enhanced groundwater pump-and-treat system and associated groundwater cleanup standards was the selected remedy for OU2 and OU4. The risk-based performance standards are specified in Table 3 and will be achieved throughout the area of attainment within 30 years. The major components of the selected remedy include the following:

- Continued operation of an enhanced groundwater pump and treat system to prevent migration of contaminated groundwater to the area of attainment[g];
- Continued treatment of recovered groundwater to achieve VPDES discharge standards prior to discharge to on-Site stream;
- Soil cover over the former drum disposal and manufacturing areas[h];
- Long-term groundwater monitoring; and,
- Institutional controls to be implemented and maintained by the property owner to ensure that prospective users of the Site are aware that deep soil contamination is present, and to prevent: the extraction of groundwater from the aquifer beneath the Site for use as a potable water source; any interference with the groundwater extractions wells, treatment system, and related equipment; and any removal of the soil cover without the written permission of VDEQ, and EPA as appropriate.

ESD (Modification to Institutional Controls Selected in OU2/4 ROD)

An Explanation of Significant Differences (ESD) modifying the institutional controls that were selected in the OU2/4 ROD was issued on July 24, 2013. The ESD determined that there is potential for vapor intrusion into future buildings constructed near groundwater contaminated by VOCs. The ESD added a land use restriction requiring that any new habitable building constructed over or within 100 feet of the groundwater contaminated by VOCs above MCLs should include, at a minimum, a foundation vapor barrier and the subsurface piping for a sub-

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[f] Deep soil contamination located beneath areas excavated during OU1remedial action is referred to as OU4.
[g] The groundwater pump and treat system was initiated per interim OU2 ROD. The final OU2/4 ROD established groundwater cleanup goals and an "area of attainment" setting forth the point of compliance.
[h] Installation of the clean soil cover was completed during the 2004/2005 removal response activities.

slab depressurization system.

Additionally, the ESD expanded the types of institutional controls that may be used. The Greenwood Chemical Company had abandoned the Site property, stopped paying property taxes and dissolved as a company. There is currently no party authorized to enter into an Environmental Covenant and Easement implementing the Institutional Controls for the Site property. The ESD expanded the types of institutional controls that may be used to implement the restrictions to include other forms of notice including listing on State or local Registries of Contaminated Sites and advisories.

Final OU2 and OU4 Remedy Implementation

EPA determined that the groundwater related components of the remedy selected in the Final OU2/4 ROD were most efficiently implemented as optimization upgrades to the in-progress interim OU2 remedy. Accordingly, on June 30, 2005, EPA issued a revision to the OU2 Operation and Maintenance (O&M) work assignment directing TetraTech, EPA's contractor, to install additional groundwater recovery wells to the existing five-well network. The additional wells were required to establish hydraulic containment of the waste management area so that groundwater performance standards would be achieved at the "area of attainment." Remedial design documents for system upgrades were prepared by TetraTech. Final specifications and drawings were approved by EPA on September 12, 2005. TetraTech mobilized to the Site to initiate well installation based on preliminary designs on August 15, 2005. The major components of the enhanced pump and treat remedy implemented at the Site include:

- Six additional recovery wells installed using the 1) drilling, 2) geophysical survey, 3) hydro-fracturing, 4) targeted zone screening sequence;
- Locking vaults were installed over each recovery well;
- Piping and wiring necessary to connect the new wells to the treatment plant were installed;
- Pumps were installed and the Programmable Logic Controller was modified; and
- Long term groundwater monitoring was refined to measure effectiveness of recovery well network.

The work was completed in a manner consistent with the EPA-approved design and work plans. The work was monitored, inspected and audited by construction quality assurance and construction quality control personnel. In addition, EPA and VDEQ personnel performed periodic inspections during the implementation of the response action.

EPA and the State conducted a pre-final inspection on September 29, 2005 and the expanded 11-recovery well network has been in operation since December 2005. A final inspection conducted on May 16, 2006 confirmed that all significant items on the punch list had been satisfactorily addressed. On July 10, 2006, the Associate Director, Office of Superfund Remediation accepted the Interim Remedial Action Report documenting successful completion

of the RA for OU2. The report is considered "interim" because groundwater performance standards are projected to take 30 years to be achieved. On March 15, 2012, EPA transferred responsibility for ongoing operations to VDEQ.

The groundwater treatment plant effluent has consistently met its respective VPDES discharge limits. A groundwater monitoring program is in effect to evaluate the effectiveness of establishing the hydraulic containment necessary to achieve groundwater performance standards at the area of attainment. See Long Term Monitoring/Operation and Maintenance below.

The soil cover that was selected as a final remedy over the former drum disposal and manufacturing areas was acknowledged in the OU2/4 ROD to have been already completed during Removal Response actions conducted by EPA in 2004 and 2005 (see discussion above).

The Preliminary Closeout Report was issued for the Site on September 30, 2005. The Report documents that the EPA completed construction activities at the Greenwood Chemical Superfund Site in accordance with *Closeout Procedures For National Priorities Sites* (OSWER Directive 9320.2-09A-P).

In recognition that the Site had been abandoned, pursuant to Virginia Code § 10.1-1406.1, the Circuit Court of Albemarle County granted access to VDEQ under Court Order (Case No.: CL12000268-00) for the purpose of performing remediation at the Site. VADEP representatives are on the Site operating the water treatment plant on a daily basis. No activities have been observed that would violate the institutional controls. The subject property is fenced and the gate is locked each night and weekend. EPA is currently in discussion with State and local officials in effort to post a notice of land use restrictions to the Albemarle County GIS-Web alerting citizens that certain activities are prohibited on the Site in additional to local zoning restrictions. Institutional controls are not yet in place.

Long-Term Monitoring/System Operation and Maintenance (O&M)

Response actions associated with OU1, OU3 and the 2004/2005 Removal did not include any operation and maintenance activities. These response actions required demolition/excavation and off-Site treatment and/or disposal of materials at appropriately permitted facilities. All areas were subsequently backfilled with clean fill and vegetated.

The long-term operations, maintenance and monitoring requirements for the Greenwood Chemical Site are set forth in the final OU2/4 ROD. EPA managed the long term response action (LTRA) at the Greenwood Chemical Site utilizing federal funds and a 10% cost share from the Commonwealth of Virginia until March 15, 2012. EPA had contracted EA Engineering Science to conduct O&M at the Site in accordance with the work plan dated December 7, 2007. Through March 15, 2012 operation of the water treatment system was conducted in accordance with the O&M Manual prepared by CH2M Hill dated June 2001, as amended. Operational changes had been made to the manual to incorporate treatment system upgrades.

On March 15, 2012, EPA transferred responsibility for ongoing operations to VDEQ. VDEQ contracted Environmental Alliance, Inc., to take over and conduct ongoing operation and maintenance activities at the Site. The primary activities associated with O&M include the following:

- Operation of the groundwater recovery well network and water treatment facility.
- Inspection and maintenance of each component of the treatment system.
- Monitoring treatment plant effluent quality and submission of monthly discharge monitoring reports to demonstrate compliance with the Virginia State Water Control Law, Code of Virginia §§ 62.1-44.2 et. seq., and the site-specific discharge limits established in accordance with VPDES Regulations (VR 680-14-01).
- Environmental monitoring appropriate to evaluate the effectiveness of the groundwater recovery well network in establishing hydraulic containment of the waste management area. Monitoring includes generation of potentiometric maps and water quality sampling to measure progress toward meeting performance standards in the area of attainment.
- Inspection and maintenance of access to water treatment facility and all environmental monitoring points.
- Adjusting and upgrading the recovery well network as appropriate to maintain hydraulic containment and optimize water treatment system.
- Annual sampling of residential wells participating in a voluntary program.
- Preparation of Quarterly Monitoring Reports and Annual O&M Reports. Annual O&M Reports assess LTRA activities and include an engineering evaluation of system effectiveness and optimization analyses.

The water treatment plant is consistently operating as designed. Since the Third Five-Year Review was issued in September 2008 there have been no significant changes to the treatment system.

The treatment system increased treatment flow rates from approximately 6 million gallons/year to 17- 19 million gallons/year in 2006 after the additional 6 extraction wells went online. Routine effluent monitoring has documented that the water quality discharged from the treatment facility meets numeric limits established by VDEQ.

The water treatment plant has one full-time operator and one part time operator on staff. Operational uptime at the treatment plant was more than 93% and 95% in 2010 and 2011, respectively. The short downtimes that did occur were due to power outages and system

maintenance (e.g., carbon replacement).

Downgradient and side-gradient residential wells have been sampled annually. No site-related contaminants have ever been detected above EPA Maximum Contaminant Levels (MCLs) or above any other risk-based action levels.

O&M costs associated with the groundwater pump and treat system include the following categories:

- Labor
- Utilities (electricity)
- Consumables (treatment chemicals)
- Engineering Support/Technical Oversight
- Sampling and Monitoring (process, groundwater, discharge)
- Non-Routine Operations (sludge generation and disposal)
- Installation/abandonment of extraction and monitoring wells to optimize system

Operation costs for the last three years that EPA has complete cost information, extending through July 2011, are listed in Table 4. The August 2008 through July 2011 costs represent routine operation of the expanded 11-recovery well network. Annual costs of routine operation and maintenance activities associated with the treatment plant are expected to be relatively stable. The O&M costs for operation of the expanded recovery well system have been generally consistent with the final OU2/4 ROD estimated costs of approximately $463,000 per year.

Table 4- Annual System Operations/O&M Costs

Dates		Total Cost rounded to nearest $1,000
From	To	
8/1/2008	7/31/2009	$487,000
8/1/2009	7/31/2010	$525,000
8/1/2010	7/31/2011	$482,00

Due to the low rate of solids generation, the sludge (solids) handling system including the filter press is only operated approximately once per year. The treatment system generates approximately 8-10 tons of filter cake annually. RCRA TCLP testing of the sludge has consistently demonstrated that the sludge is non-hazardous. The filter cake is disposed in a solid waste landfill within Virginia. The sludge is defined as a "special waste" under the Virginia Waste Management Regulations.

A treatment system value engineering and efficiency analyses completed in 2011 determined that the VGAC filtration component of the system was not required to meet air emissions standards or risk based concentrations and shutting it down would decrease O&M costs at the plant. EPA removed the VGAC filter media on February 6, 2012.

Groundwater and treatment plant effluent monitoring results are summarized in the Quarterly Operations and Groundwater Monitoring Reports and Annual O&M Reports and are discussed in the data review section of this document.

V. Progress Since the Last Review

The third five-year review for the Site was completed in September 2008. The primary progress achieved since the last review has been establishing groundwater containment, optimizing the treatment plant and monitoring activities to increase cost-effectiveness, and

issuing an ESD modifying the institutional controls that were selected in OU2/4 ROD.

Protectiveness Statements from the Third Five-Year Review (Italics)

*The remedy at **OU1** is protective of human health and the environment. Contaminated soil and waste material was excavated and transported off-Site for treatment and/or disposal to minimize migration to groundwater and direct exposure. The excavated areas were backfilled with clean soil. The remedial action objectives have been met.*

*The remedy at **OU2/4** is expected to be protective of human health and the environment, and in the interim, exposure pathways that could result in unacceptable risks are being controlled. Complete hydraulic containment has not yet been achieved but there is no current exposure to contaminated groundwater. In order for the remedy to be protective in the long term the following actions must be taken: 1) adjust the recovery well alignment until complete hydraulic containment of the waste management area is achieved; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls on the Site.*

*The remedy at **OU3** is protective of human health and the environment. The former manufacturing buildings and chemical wastes stored within those buildings were dismantled and properly disposed off-Site. The remedial action objectives have been met*

The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because complete hydraulic containment has not been achieved and institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term the following actions must be taken: 1) adjust the recovery well alignment to establish hydraulic containment of the waste management area to restore groundwater quality in the area of attainment; 2) evaluate the vapor intrusion pathway; and, 3) implement institutional controls.

Progress Since Third Five-Year Review – The Long-Term Remedial Action has been completed. The Operation, Maintenance and Monitoring work is on-going and the enhanced recovery well system appears to have achieved hydraulic containment by preventing contaminated groundwater from migrating out of the Waste Management Area. The goal is to restore the aquifer in the area of attainment (beyond the boundaries of the Waste Management Area) within approximately 30 years.

The expanded 11-recovery well network has been in operation since December 2005. The Annual Long Term Monitoring reports completed by EPA between 2008 and 2011 include a capture zone analysis to assess whether the extraction system is achieving hydraulic containment. Conducting a capture zone analysis is difficult in fractured rock lithologies due to the limited understanding of fracture orientation and connectivity. The capture zone analysis relies on a weight of evidence approach in identifying the capture zone by evaluating groundwater elevation data (potentiometric maps) and groundwater contaminant concentrations

over time. The groundwater contour maps generated using bedrock well elevation data (see Figure 4) suggest that the recovery wells are creating an inward gradient. The contours are more pronounced along the southern portion of the extraction well field where the topography begins to level off. Comparing TCE concentration contours from 2009 to 2011, the 1 µg/L contour line has indicated a modest but measurable contraction on the downgradient portion of the Site. This indicates that the 11 recovery wells are preventing migration of impacted groundwater.

An Explanation of Significant Differences (ESD) modifying the institutional controls that were selected in the OU2/4 ROD was issued on July 24, 2013. The ESD determined that there is potential for vapor intrusion into future buildings constructed near groundwater contaminated by VOCs. The ESD added a land use restriction requiring that any new habitable building constructed over or within 100 feet of the groundwater contaminated by VOCs above MCLs should include, at a minimum, a foundation vapor barrier and the subsurface piping for a sub-slab depressurization system. Additionally, the ESD expanded the types of institutional controls that may be used.

The Circuit Court of Albemarle County granted access to VDEQ under Court Order for the purpose of performing remediation at the Site. EPA is currently in discussion with State and local officials in effort to post a notice of land use restrictions to the Albemarle County GIS-Web alerting citizens that certain activities are prohibited on the Site in additional to local zoning restrictions. Institutional controls are not yet in place.

In accordance with the OU2 SSC, responsibility for continued operation and maintenance of the facility transitioned from EPA to VDEQ on March 15, 2012.

See Table 5 for recap of the Recommendations for Follow-up that were identified during the Third Five-Year Review and a summary of the progress made in relation to the issues.

VI. Five-Year Review Process

Administrative Components

EPA notified EA Engineering and Science, and state and local officials of the initiation of the five-year review in March 2013. The Greenwood Chemical Five-Year Review Team was led by Eric Newman, EPA's Remedial Project Manager (RPM), with EPA technical support staff Kathy Davies (Hydrogeologist), Nancy Jafolla (Toxicologist), and Trish Taylor (Community Involvement Coordinator). Kevin Greene, VDEQ Program Manager, assisted in the review as the representative of the support agency. The five-year review schedule extended from March through September 2013. The five-year review included the following administrative components:

- Community Involvement;
- Document Review;

- Data Compilation and Review;
- Site Inspection;
- Interviews and Public Notification; and
- Five-Year Review Report Development and Review.

Community Involvement

The plan and schedule established for public outreach during the conduct of the five-year review process included public announcements and communications with local officials and residents. EPA also contacted and interviewed area citizens who had attended the Open House held in at the Greenwood Chemical Site on March 8, 2012, participated in the annual residential sampling program or otherwise contacted EPA regarding the Site. EPA contacted and provided a comprehensive update of Site progress to local emergency response and public health officials including:

- Jack McClelland, Virginia Department of Health – Thomas Jefferson Health District
- Amelia McCulley, Albemarle County Director of Zoning
- Mark Graham, Albemarle County Director of Community Development
- Shawn Maddox, Assistant Fire Marshall, Albemarle County Fire and Rescue

A notice announcing that EPA was conducting a five-year review for the Site was published in the Charlottesville, Virginia *Daily Progress* on June 19, 2013.

Document Review

Documents reviewed in the process of conducting this five-year review included the last five-year review, the 1989 ROD, the 1990 Interim ROD, the 1991 and 1994 ESDs, the June 2004 Action Memorandum, the 2005 On-Scene Coordinator Report, the 2005 final OU2/4 ROD, the 2013 ESD, the 2007 through 2012 Annual O&M Reports including treatment plant operational data, and 2008 through 2012 Quarterly and Annual Monitoring Reports (treatment plant discharge and groundwater monitoring). A complete list of documents reviewed can be found in Attachment A.

An assessment of the Applicable or Relevant and Appropriate Requirements (ARARs) was conducted during the document review. The assessment determined that the ARARs are being met and/or are still appropriate for the remedies in place at the Site. The major ARARs include:

- MCLs and non-zero MCLGs are still promulgated under the Safe Drinking Water Act, 40 CFR § 141.11-16; 40 CFR §§ 141.50-51 and are still relevant and appropriate to the groundwater cleanup remedy in the area of attainment.

- MCLs and non-zero MCLGs are still promulgated under the Virginia Waterworks Regulation, 12 VAC 5-590-440, Tables 2.2 and 2.3 and are still relevant and appropriate to the groundwater cleanup remedy in the area of attainment.

- Discharge limitations into surface waters of the Commonwealth are still promulgated under the Virginia Pollutant Discharge Elimination System, 9 VAC 25-31-10 to 940 and are still applicable to the effluent discharge from the on-Site water treatment facility. A permit is not required for on-Site discharge; however, the substantive standards must be attained.

EPA and VDEQ completed a reassessment of the water treatment effluent quality and updated the Sampling and Analyses Plan in January 2009 to incorporate any changes made to the Virginia Ambient Surface Quality Standards. As part of the process the VDEQ VPDES program conducted a statistical analysis of the Greenwood Chemical Treatment Plant discharge reports between 2001 and 2008 and provided EPA with recommended Discharge Monitoring Report modifications in October 2008. VDEQ recommended that metals (aluminum, calcium, chromium (III), chromium (VI), copper, lead, mercury, and zinc) be removed from the monthly discharge monitoring requirements. VDEQ also recommended that the previously requested organics (benzene, bis-2-chloroethyl ether, bis-2-ethylhexyl phthalate, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichlorobenzene, 1,2-dichloroehtane, methylene chloride, naphthalene, tetrachloroethene, trichloroethene, toluene, and vinyl chloride) be removed from discharge monitoring requirements based on 8 years of effluent data demonstrating consistent abatement of organic contaminants by the treatment plant.

EPA accepted the VDEQ recommendations for the purposes of formal VPDES Discharge Monitoring Report requirements. EPA utilized the VDEQ Piedmont Region Water Quality Spreadsheet (Piedmont Spreadsheet) to generate new water quality criteria parameters, based upon the existing DMR and known Site contaminants. After comparing the Piedmont Spreadsheets to the new VPDES discharge monitoring report limits, EPA established informal performance goals for nickel, benzene, bis-2-chloroethyl ether, carbon tetrachloride, 1,2-dichloroethane, tetrachloroethene, trichloroethene, and vinyl chloride. See Table 6 for the 2008 discharge monitoring reporting limits and the informal performance goals. The informal performance goals allow EPA to monitor the effectiveness of the treatment system and confirm ARAR compliance.

Data Review

Groundwater Monitoring

Groundwater monitoring has been conducted at the Greenwood Chemical Site since the late 1980s.

The final OU2/4 selected remedy requires hydraulic containment of the waste management area so that the groundwater performance standards can be met in the area of attainment within 30 years. EPA has tailored the groundwater monitoring program to collect the data necessary to assess the effectiveness of the recovery well network and to measure water quality in the area of attainment.

There are currently 59 groundwater/overburden wells and 11 extraction wells located across the Site and hydraulically down gradient of the Site. The groundwater monitoring plan includes approximately 29 wells for quarterly monitoring (including extraction wells) and 40 wells for annual water quality monitoring. Water level measurements can be collected from all 59 groundwater monitoring wells to generate potentiometric maps.

In addition, residential well sampling has been conducted on an annual basis, generally in April or May. The last sampling event reviewed was conducted in February 2012. Over the last five years 10 residential wells within an approximate one-half mile radius of the Site have participated in the voluntary sampling program. No site–related contaminants have ever been detected above MCLs or above any other risk-based action level in a residential well.

The groundwater samples are analyzed for Target Compound List (TCL) volatile and semi-volatile organic compounds and Target Analyte List (TAL) metals. A data validation package is submitted for each set of quarterly results. This five-year review focused on the quarterly reports presented in the 2007 through 2012 Annual O&M Reports including treatment plant operational data, and 2008 through 2012 Quarterly and Annual Monitoring Reports.

Flow rates and water quality data from extraction wells were reviewed along with potentiometric maps to evaluate the effectiveness of the recovery well network in establishing hydraulic containment of the waste management area. The most concentrated portion of the "plume" within the waste management area appears to be located at the center of the Site between recovery wells MW-23, CW-4 and CW-3, north and east of the treatment plant. This is consistent with previous years, as MW-23 was originally placed in the center of the former manufacturing area as a hot-spot recovery well. The water level measurements and associated contour maps indicate that the recovery wells arrayed across the Site are containing groundwater moving down-slope toward the southern boundary. In July 2008 EPA installed 3 additional monitoring wells (PMW-6, PMW-7 and PMW-8) downgradient of monitoring well PMW-5 to better understand groundwater flow along the eastern property boundary. The additional data points confirm that the new recovery wells CW-4, CW-5 and CW-6 have cut off the groundwater moving to the east in the vicinity of monitoring well PMW-5. Hydraulic containment of the waste management area has been achieved with the current extraction well alignment; however, further adjustments to the recovery well system (i.e., adding wells or changing extraction well alignment) may be useful to optimize the system.

The expanded 11-well extraction system has been in operation for seven years. The data review confirmed that the groundwater in the area of attainment remains above groundwater performance standards. Data trends will need to be graphed over the next several years to confirm that the project is on track to meet performance standards within 30 years.

The review team looked at the water quality along the property boundary to determine if contaminants are migrating off the Site property. The four perimeter monitoring well locations (PMW-1, PMW-2, PMW-3 and PMW-4) that were placed along the southern property boundary all meet MCLs but do not yet meet the more conservative site-specific groundwater performance

standards[i]. The two off-Site wells west of the property boundary near the former drum disposal area (MW-19 and BR-04) meet both MCLs and site specific performance standards. The well placed along the eastern boundary of the property (PMW-5) remains contaminated with trichloroethene at concentrations more than a magnitude greater than the MCL. Three new extraction wells (CW-4, CW-5 and CW-6) were placed upgradient of PMW-5 in 2005. CW-4 and CW-5 are recovering relatively high concentrations of trichloroethene but a reduction in trichloroethene concentration at PMW-5 is not yet evident. The three off-Site wells east of PMW-5 (PMW-6, PMW-7 and PMW-8) all meet MCLs, demonstrating that the contaminant plume has been confined to the Greenwood Site.

Groundwater Pump and Treat System

Table 7 shows the average influent concentrations to the treatment plant from 2002 through 2012. The average influent concentrations have been fairly constant since the extraction system was expanded.

The total volume of groundwater treated in 2012 was 17.34 million gallons (MG) and the cumulative quantity of groundwater treated is approximately 163 MG. Table 8 presents the annual groundwater and lagoon water recovery and treatment rates from 2001 to 2012. Lagoons 4 and 5 were closed in November 2004; the six new recovery wells came on-line in December 2005.

Table 8: Treatment Plant Flow Rates 2001-2012

Year	Lagoon Water (gal/yr)	Groundwater (gal/yr)	Total (gal/yr)
2001	0 (Zero)	5,928,652	5,928,652
2002	258,539	4,775,987	5,034,526
2003	430,847	5,961,277	6,392,124
2004	2,212,850	6,549,862	8,762,712
2005	0 (Zero)	6,878,236	6,878,236
2006	0 (Zero)	17,638,447	17,638,447
2007	0 (Zero)	19,409,215	19,409,215
2008	0 (Zero)	18,954,023	18,954,023
2009	0 (Zero)	18,510,558	18,510,558
2010	0 (Zero)	19,050,941	19,050,941
2011	0 (Zero)	19,148,420	19,148,420
2012	0 (Zero)	17,344,503	17,344,503

Based on the plant flow rate and influent contaminant concentrations, the mass of organic contaminants removed from the groundwater has increased from 25.2 pounds in 2003 (the first full year of operational data) to a maximum of 72.4 pounds in 2010. The 2012 organic mass

[i] The site specific performance standards are lower than MCLs to account for the potential cumulative risk of multiple contaminants.

removed was 69.8 pounds. See Table 7.

Monitoring of the groundwater treatment system effluent for VPDES discharge requirements is conducted on a monthly basis and Discharge Monitoring Reports are submitted to VDEQ. VPDES discharge parameters include flow, pH, total cyanide. In addition, plant effluent is tested for whole effluent toxicity and chronic whole effluent toxicity on a quarterly basis. Review of the monthly discharge monitoring reports submitted from 2008 through 2012 confirmed effluent discharge was within the VPDES required limits except for the following exceedences:

- Cyanide 09/2011
- Cyanide 10/2011
- Chronic toxicity to *C. dubia* reproduction 5/2010

The data for the September 2011 effluent sampling (collected on 7 September 2011) were received on 4 October 2011 indicating an exceedence for cyanide had occurred. It was decided to check the cyanide data from the October 2011 effluent sampling event (collected on 4 October 2011) to determine if the September exceedence was an anomaly. The cyanide results from the October 2011 sampling event also exceeded the cyanide discharge limit (5.2 µg/L) but the results were qualified due to the presence of elevated cyanide in the quality control field blank. It was determined that the glassware used for cyanide sample collection had potentially become contaminated, and was replaced with new glassware. The November 2011 and future cyanide effluent sampling events did not exceed VDEQ permit equivalent limits.

The validated data for the May 2010 *C. dubia* chronic toxicity testing (collected 17 to 21 May 2010) were received on 4 October 2010. The validation noted that the feeding regime for the chronic daphnid test varied from that recommended in the applicable guidance, but this was not thought to be an issue of concern. The validated data for the August 2010 *C. dubia* chronic toxicity testing were also received on 4 October 2010. The August 2010 *C. dubia* chronic toxicity testing did not fail the VDEQ permit equivalent limits. The plant operational data for May 2010 were evaluated, but no significant exceptions to normal operations were detected in the evaluation. The October chronic toxicity sampling event was conducted from 4 to 8 October 2010, and a request was made to the laboratory to provide the unvalidated data as soon as practicable. The unvalidated data were provided on 22 October 2010, and the October 2010 *C. dubia* chronic toxicity testing did not fail the VDEQ permit equivalent limits. Subsequent sampling events conducted in 2011 and 2012 did not demonstrate any failure of chronic toxicity to *C. dubia.*

In addition to monitoring for the parameters required by the VPDES DMR, the groundwater treatment system effluent was sampled for other known site contaminants to monitor the effectiveness of the treatment plant. Effluent data was screened against EPA's informal performance goals (See Table 6). All informal performance goals were met with the exception of carbon tetrachloride on two occasions in 2009 (April and July) and again on two occasions in 2011 (June and September). Historically, carbon tetrachloride has been the first

compound to break through the first of two 5,000 lb carbon filters in the treatment facility, indicating that replacing the carbon media in the lead filter tank needs to be scheduled. In each instance, changing the carbon filter media successfully achieved the informal performance goal in the effluent.

Site Inspection

On August 20, 2013 Eric Newman, EPA's Remedial Project Manager for the Site and Kevin Greene, VDEQ's Program Manager and project lead responsible for ongoing operations, maintenance and monitoring at the Site conducted a systematic Site inspection specifically focused on evaluating the condition of engineered features and the protectiveness of the constructed remedy as part of the five-year review process. Also attending the Site Inspection was John Fellinger, EA Engineering and Science; William "Billy" Barnes, Petrus Environmental Services; and, Matt Richardson and Jim Bernard, Environmental Alliance. Virginia DEQ representatives maintain a continuous presence on the Site to operate the government-financed water treatment plant. Weather at the time of inspection was sunny, hot, and humid.

The objective of the inspection was to assess the protectiveness of the remedy, including the integrity of the soil cover and the operation of the wastewater treatment plant. The water treatment plant was physically inspected with a walk through. Each monitoring and recovery well was inspected and determined to be in operable condition; proper access to wells has been maintained. The soil cover constructed over the former drum disposal and former manufacturing areas were inspected and found to be well vegetated. Conveyance details such as ditches and culverts, and treatment plant discharge points were observed to be free of debris. All components of the remedial action were confirmed operational and functional. No significant issues have been identified regarding the physical condition of the Site, the monitoring points or the operation of the water treatment plant.

Institutional controls are not yet in place to prohibit disturbance of the implemented remedy or use of groundwater for potable purposes. During the Site inspection no activities were observed or reported that would violate the land use restrictions called for in the OU 2/4 ROD as augmented by the 2013 ESD. The subject property was fenced, the soil cover and surrounding areas were undisturbed, and no new uses of groundwater were observed. The gate to the facility is only opened during standard business hours.

Interviews

EPA RPM Newman conducted many interviews with VDEQ personnel and support contractors operating the treatment plant, local residents and local officials to inform them that EPA was completing the Five-Year Review process to confirm that the constructed remedy remains protective. In addition to continuing communications with local officials discussed the Community Involvement section above, in July/August 2013, Mr. Newman called several area residents who participate in the voluntary residential well sampling program and other residents who have contacted EPA to inquire about the Site in recent years. During each interview Mr.

Newman outlined the review process, including a detailed review of environmental monitoring and maintenance reports, a field inspection of the constructed remedy, and a literature review to confirm that the performance standards remain protective when considering the most up-to-date regulatory standards and toxicity data of site-related compounds. Mr. Newman conveyed the importance of communicating with local citizens and public officials to learn of any concerns related to the Site.

None of the citizens interviewed expressed any specific concerns related to the Site. The local citizens were aware of the cleanup work that EPA has completed and that responsibility for continuing operations at the Site were transitioned to VDEQ. Several citizens confirmed having read the Fact Sheet EPA sent to the community in 2012 describing the status of on-going cleanup activity and the March 2012 transfer of operational responsibility from EPA to VDEQ. One of the adjacent landowners stated that the government cleanup and monitoring activities have been ongoing for "....30-years, when is it enough already?" She stated that her concerns about the impact of the site on the local environment have been reduced but that local landowners will always have the stigma of having land near a Superfund Site. She expressed concern that land values and marketability will be negatively impacted in the long term. Mr. Newman acknowledged her concerns and expressed the importance of VDEQ's continued diligence maintaining hydraulic containment of contaminated groundwater at the Site and conducting environmental monitoring appropriate to demonstrate continued effectiveness. Based on the interviews, the local citizens are comfortable with the work completed. The citizens expressed general satisfaction that EPA does maintain an interest in the Sites and reviews them for continued protectiveness after cleanups have occurred.

VII. Technical Assessment

Question A: Is the Remedy functioning as intended by the decision documents?

Yes. The remedy is functioning as intended by the decision documents but not all remedial action objectives have been met. The recovery well network is capturing groundwater and treating the groundwater successfully before discharge. Hydraulic containment has been demonstrated along the eastern, southern, and western edges of the waste management area (north is upgradient). The extent of the plume has been reduced and the area of the plume exceeding MCLs is limited to the Site property (See Figure 5).

Concentrations of contaminants in groundwater beyond the waste management area (i.e., area of attainment) remain above MCLs. Natural attenuation processes expected to further reduce concentrations in groundwater within the area of attainment are very slow. Data trends will need to be graphed over the next several years to statistically confirm that the project is on track to meet performance standards within 30 years.

The groundwater treatment facility functioning as designed and effluent meets appropriate VPDES discharge standards for all organic and inorganic parameters and effluent passed toxicity tests. No impact has been detected in any residential drinking water wells or

agricultural wells around the Site.

EPA is currently in discussion with State and local officials in effort to post a notice of land use restrictions to the Albemarle County GIS-Web alerting citizens that certain activities are prohibited on the Site in additional to local zoning restrictions. Institutional controls are not yet in place.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?

Changes in Standards and TBCs

Have standards identified in the ROD been revised, and does this call into question the protectiveness of the remedy? Do newly promulgated standards call into question the protectiveness of the remedy? Have TBCs used in selecting cleanup levels at the site changed, and could this affect the protectiveness of the remedy?

The groundwater performance standards were established in the 2005 ROD: 1,2-dichloroethane 5.0 ug/L; bis (2-chloroethyl) ether 0.5 ug/L; carbon tetrachloride 4.0 ug/L; tetrachloroethene 0.8 ug/L; trichloroethene 1.0 ug/L; and vinyl chloride 0.5 ug/L. These standards are at or below current federal and State Maximum Contaminant Levels (MCLs) of 1,2-dichloroethane 5.0 ug/L; carbon tetrachloride 5.0 ug/L; tetrachloroethene 5.0 ug/L; trichloroethene 5.0 ug/L; and vinyl chloride 2.0 ug/L. Bis (2-chloroethyl) ether [BCEE] does not have a promulgated federal or State MCL and the BCEE toxicity factors considered in the site-specific risk assessment remain unchanged. In summary, the cleanup standards currently in effect are at or below current MCLs.

Changes in Exposure Pathways

Has land use or expected land use on or near the site changed?

No, local zoning for the Site remains agricultural use only. Local land use remains mixed residential, woodlands and agricultural.

Have human health or ecological routes of exposure or receptors been newly identified or changed in a way that could affect the protectiveness of the remedy? Are there newly identified contaminants or contaminant sources? Are there unanticipated toxic byproducts of the remedy not previously addressed by the decision documents? Have physical site conditions or the understanding of these conditions changed in a way that could affect the protectiveness of the remedy?

Local land use zoning continues to limit the Site to agricultural use only. The Records of Decision also considered potential future use of the Greenwood Chemical Site for recreational or industrial purposes; however, this would require a change in the local zoning to allow such use.

The Third Five-Year Review completed in September 2008 noted that the potential for vapor intrusion into habitable buildings above or near the plume of VOC contaminated groundwater had not been evaluated in the OU2/4 ROD. The report recommended that EPA assess the potential for vapor intrusion to buildings which may be constructed during future redevelopment of the property should local zoning be modified to allow such land use.

Groundwater monitoring demonstrates that the plume of contaminated groundwater exceeding MCLs has been confined to the Greenwood Chemical site property. The only existing habitable building on Site is the water treatment plant which has been subject to air sampling and modeling and determined to be safe for plant workers. However, groundwater within the Waste Management Area is contaminated with volatile chemicals measured at concentrations several orders of magnitude above its respective MCL and the water table is relatively shallow.

An ESD modifying the institutional controls that were selected in the OU2/4 ROD was issued on July 24, 2013. The ESD determined that there would be potential for unsafe exposure to occupants due to vapor intrusion into hypothetical future buildings constructed near groundwater contaminated by VOCs. The ESD added a land use restriction requiring that any new habitable building constructed over or within 100 feet of the groundwater contaminated by VOCs above MCLs include, at a minimum, a foundation vapor barrier and the subsurface piping for a sub-slab depressurization system. This vapor mitigation system would prevent potentially unsafe exposures to building occupants.

Changes in Toxicity and Other Contaminant Characteristics

Have toxicity factors for contaminants of concern at the site changed in a way that could affect the protectiveness of the remedy? Have other contaminant characteristics changed in a way that could affect the protectiveness of the remedy?

The toxicity data for contaminants remaining at the Greenwood Chemical Site were reassessed for the final OU2/4 ROD issued in 2005. The toxicity factors listed in Tables 2A and 2B of the 2005 ROD have changed since then; however the final OU2/4 ROD levels issued in 2005 are still protective. ROD contaminant toxicity changes established after the 2008 Five-Year Review are listed in Table 9.

Table 10 provides the 2013 recalculated Risk-Based Remedial Goals derived from the new toxicity values in comparison to the existing 2005 Risk-Based Remedial Goals. The 2013 Risk-Based Remedial Goals are equal to or higher than the 2005 Risk-Based Remedial Goals for all contaminants except tetrachloroethene, which has a slightly lower non-carcinogenetic value; however, the Final 2005 Risk-Based Remedial Goal for tetrachloroethene is lower than the 2013 calculated non-carcinogenetic Risk-Based Remedial goal, so the 2005 Final Risk-Based Remedial Goals are still protective. The groundwater performance standards have not been met yet but the extent of the plume is well-defined.

The 27 mg/kg soil cleanup standard for arsenic contaminated surface soil was established

in the 2004/2005 Removal Action. The exposure assumptions and toxicity factors for arsenic have not changed and this cleanup concentration remains protective.

Soil cleanup standards for organic compounds were developed in the OU1 ROD and modified by ESD-2. See Table 2. The baseline risk assessment and back-calculated cleanup standards completed for OU1 assumed the future land use to be residential. The soil cleanup levels selected for organic compounds were based on the potential for migration to groundwater because the soil to groundwater performance standards were more conservative (i.e., lower) than cleanup concentrations developed for direct contact and residential use. The soil cleanup standards set forth in ESD-2 were compared to the May 2013 Region III RBC Table for industrial land use[j]. The analysis determined that the OU1 cleanup levels for carcinogens represent a cancer risk within or less than EPA's acceptable risk range of 10^{-4} to10^{-6} for all compounds.

The OU1 soil cleanup levels for site-related non-carcinogenic compounds represent a Hazard Index of approximately 1.0 if they all affected the same target organ, with the exceptions of chlorobenzene and tetrahydrofuran. The OU1 cleanup level for chlorobenzene would represent an HI of 5.5 if chlorobenzene remained in surface soil at 7,708 mg/kg. This would be above EPA's target of less than 1.0 HI. The OU1 cleanup level for tetrahydrofuran would represent an HI of 1.0 if tetrahydrofuran remained in surface soil at 97,269 mg/kg (i.e., 9.72% tetrahydrofuran). This is at EPA's target of 1.0 HI. It is very unlikely that chlorobenzene or tetrahydrofuran remains in surface soil at these high levels for the reasons stated below.

- Table 6 of the OU1 ROD reports that the maximum concentration of chlorobenzene measured at the site was 150 mg/kg. The presence of chlorobenzene was a potential contaminant of concern, but chlorobenzene was not driving the cleanup at the Site. The 150 mg/kg chlorobenzene measured before the cleanup began would only present 0.1 HI to an industrial worker. Again, it is possible that chlorobenzene was present at higher concentrations in areas of actual waste material, but it is unlikely that it was present at elevated concentrations in soil after the disposal areas were excavated.
- Table 6 of the OU1 ROD reports that the maximum concentration of tetrahydrofuran measured at the site was 2.5 mg/kg. Again, it is possible that tetrahydrofuran was present at higher concentrations in areas of actual waste material (e.g., in a drum), but it is unlikely that it was present in soil after the disposal areas were excavated. The lagoons and disposal areas remediated during OU1 remedial action were contaminated with multiple contaminants. Excavation proceeded until the lateral extent of the excavation was confirmed clean or the depth reached approximately 15 feet. Chlorobenzene and tetrahydrofuran would be collocated with other contaminants and therefore would have been excavated to concentrations on average much lower than 7,708 mg/kg/97,269 mg/kg, respectively, due to the proximity of other contaminants with much lower cleanup targets. For example, cleanup levels for benzene, chloroform and 1,2-dichloroethane are more than 4 orders of magnitude lower that the chlorobenzene cleanup level.

[j] EPA's 2005 Record of Decision established that the reasonably anticipated future land use at the Site is recreational or industrial.

- The excavation areas and former manufacturing area was covered with a minimum of 2 feet of clean soil and vegetated.

Based on these considerations, EPA has a high degree of confidence that the OU1 cleanup levels remain protective of human health for the future industrial land use scenario.

On February 17, 2012, EPA released the final non-cancer dioxin reassessment, publishing a non-cancer toxicity value, or reference dose, for 2,3,7,8- tetrachlorodibenzo-p-dioxin in EPA's Integrated Risk Information System. The new reference dose is now the recommended value "to be considered" for use in developing site-specific dioxin preliminary remediation goals and cleanup levels under CERCLA and the NCP. EPA's Office of Solid Waste and Emergency Response has proposed to revise the interim preliminary remediation goals for dioxin and dioxin-like compounds, based on technical assessment of scientific and environmental data. The new preliminary remediation goals calculated using the new reference dose of 0.7 picograms per kilogram-day and EPA non-adjusted exposure factors is 0.6654 µg/kg *TEQ* for commercial/industrial soil (based on toxicity equivalence quotients, which add up the toxicity of all dioxin-like contaminants). A review of historical sampling data indicates that dioxins were not sampled for during past investigations completed at the Site. Limited sampling for dioxin in surface soil outside the perimeter of previously excavated areas should be considered to confirm that dioxin is not a concern at the Site.

Changes in Risk Assessment Methods

Have standardized risk assessment methodologies changed in a way that could affect the protectiveness of the remedy?

There have not been significant changes in EPA's risk assessment guidance since the final 2005 ROD.

There have been significant changes in EPA's human health risk assessment guidance since the original risk assessment was performed. These include changes in dermal guidance, inhalation methodologies and exposure factors. The original risk assessment assumed a conservative residential future land use and the ROD chose even lower performance standards because the soil to groundwater migration model generated lower concentrations. Accordingly, these changes are not expected to affect the protectiveness of the remedy.

The remedial investigation and Record of Decision were completed prior to the development of the current ecological risk assessment guidance. The decision documents did not specifically establish ecologically protective remedial action objectives or cleanup values. While these ecologically protective objectives and values have not been specified, the available data indicates that the remedial action is protective of ecological receptors. Contaminated soil was excavated and treated / disposed of offsite. Groundwater is being captured and treated; the area of capture prevents contaminated groundwater from discharging to area surface water bodies. Monitoring data does not indicate the potential for unacceptable ecological risk.

Expected Progress Towards Meeting RAOs

Is the remedy progressing as expected?

Yes. The remedy has met all remedial action objectives established by the EPA decision documents with the exception of meeting groundwater performance standards throughout the area of attainment. Hydraulic containment of the waste management area has been achieved with the current extraction well alignment.

Several wells located along the western edge of the site within the area of attainment demonstrated contaminant concentrations at or below the target groundwater performance standards, based upon sampling conducted in 2012; however, there are wells located in the eastern and central portions of the area of attainment which do not currently meet the groundwater performance standards. Continued monitoring and data/trend analysis of the wells within the area of attainment will be necessary to ensure that remedial action objectives will be achieved within the estimated 30-year timeframe.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

No other information has come to light that would call into question the protectiveness of the remedy.

Technical Assessment Summary

In summary, groundwater cleanup within the area of attainment is progressing with the operation of the groundwater treatment system, and hydraulic containment has been demonstrated along the edges of the waste management area (i.e., down- and side-gradient from waste management area). Adjustments to the recovery well alignment may be useful to optimize hydraulic containment. Data trends will need to be graphed over the next several years to confirm that the project is on track to meet performance standards within 30 years. EPA has added additional institutional controls in the first ESD for the OU2/OU4 ROD to address potential vapor intrusion issues at the site when considering hypothetical future use of the property. Institutional controls are not yet in place. Direct contact with soil is not expected to pose unacceptable risks under current conditions (i.e., exposure is currently being prevented); however, limited surface soil sampling for dioxins should be completed.

VIII. Issues

The table below summarizes the issues identified during this Five-Year Review for the Greenwood Chemical Superfund Site.

Table 11: Issues

Issues	Affects Current Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
1. Implement institutional controls included ESD to the OU2/4 ROD	N	Y
2. Long-term groundwater monitoring is required to assess and confirm that MCLs will be achieved throughout the Area of Attainment within a reasonable time period	N	N
3. On February 17, 2012, EPA released the final non-cancer dioxin reassessment, publishing a non-cancer toxicity value, or reference dose (RfD), for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in EPA's Integrated Risk Information System (IRIS). Dioxin was never sampled for at the Site.	N	N

IX. Recommendations and Follow-up Actions

Table 12: Recommendations and Follow-up Actions

Issue	Recommendations and Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness (Y/N)	
					Current	Future
1.	Implement Institutional Controls	EPA	EPA	12/30/2014	N	Y
2.	Monitor groundwater quality trends outside the Waste Management Area to confirm that MCLs will be achieved throughout the Area of Attainment within a reasonable time period	VDEQ	EPA	8/30/2018	N	N
3.	Limited sampling for TCDD in surface soil outside the perimeter of previously excavated areas should be completed to confirm that dioxin in not a concern at the Site.	EPA	EPA	9/30/2014	N	N

X. Protectiveness Statement

The remedy at OU1 is protective of human health and the environment. Contaminated soil and waste material was excavated and transported off-Site for treatment and/or disposal to minimize migration to groundwater and direct exposure. The excavated areas were backfilled with clean soil. The remedial action objectives have been met.

The remedy at OU2/4 currently protects human health and the environment because hydraulic containment has been achieved and there is no current exposure to contaminated groundwater. However, in order for the remedy to be protective in the long term institutional controls must be placed on the Site to ensure protectiveness.

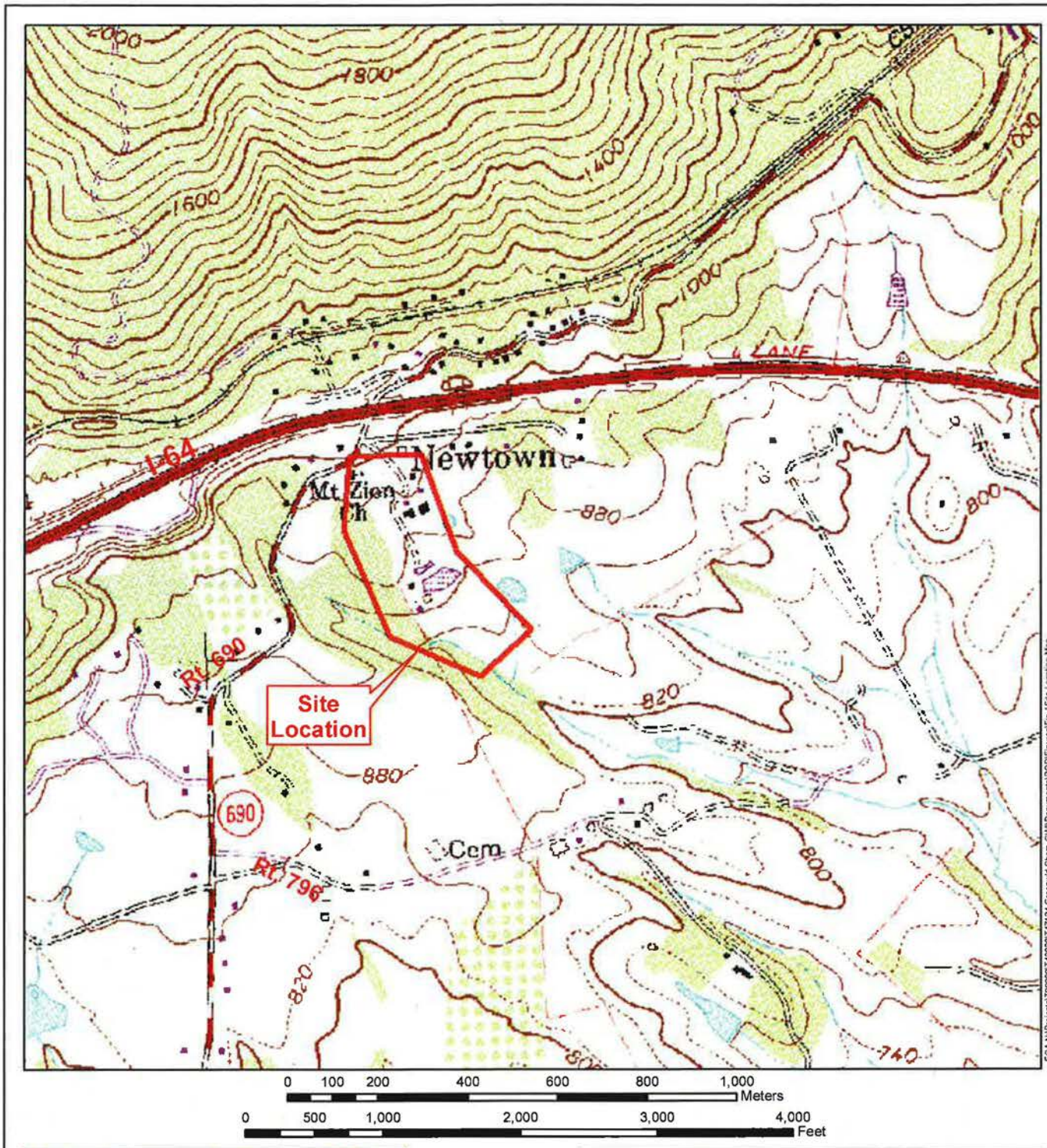
The remedy at OU3 is protective of human health and the environment. The former manufacturing buildings and chemical wastes stored within those buildings were dismantled and properly disposed off-Site. The remedial action objectives have been met.

The remedial actions at OUs 1 and 3 are protective and remedial actions at OUs 2 and 4 are protective in the short term. Because institutional controls are not in place remedial actions are not protective in the long term. There is no current exposure to contaminated groundwater; however, in order for the remedy to be protective in the long-term institutional controls must be placed on the Site to ensure protectiveness.

XI. Next Review

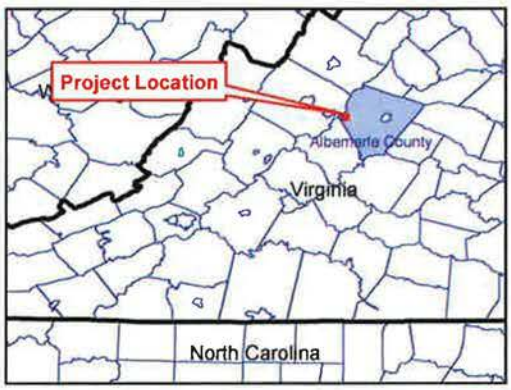
Since Site conditions do not allow for unlimited use and unrestricted exposure, EPA will need to conduct another five-year review of the Greenwood Chemical Site by September 2018, five years from the date of this review.

FIGURES



0 100 200 400 600 800 1,000 Meters

0 500 1,000 2,000 3,000 4,000 Feet



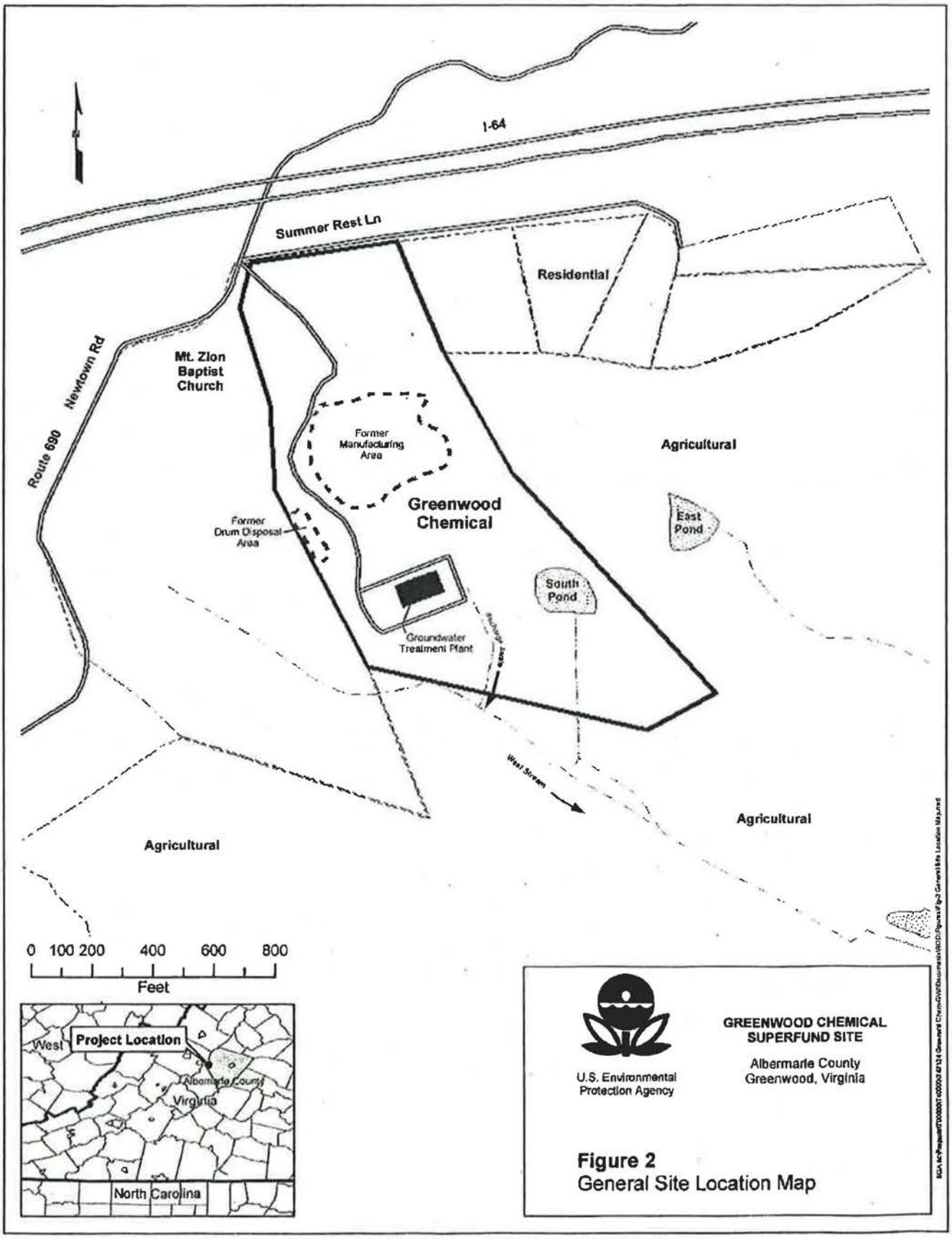
N

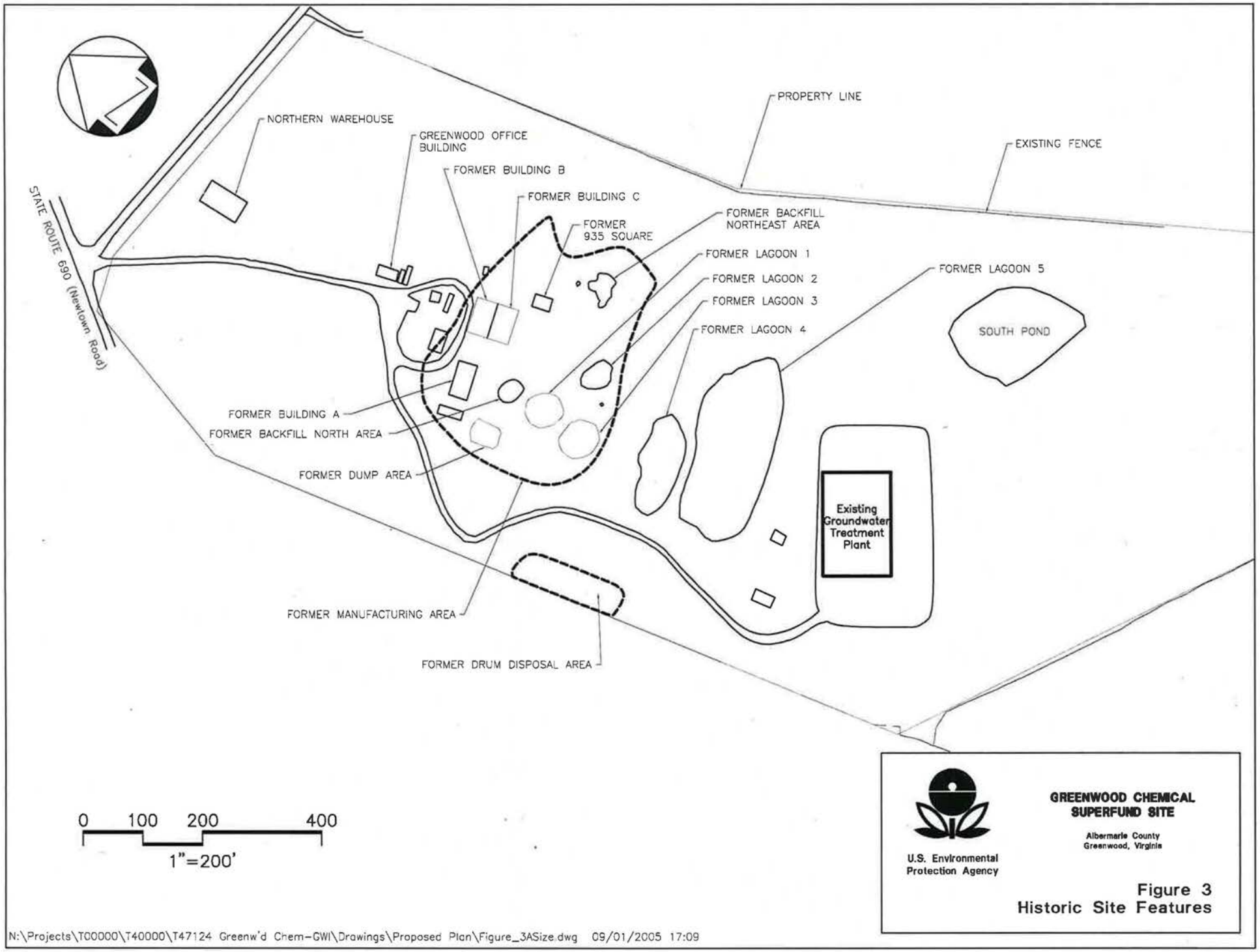
U.S. Environmental Protection Agency

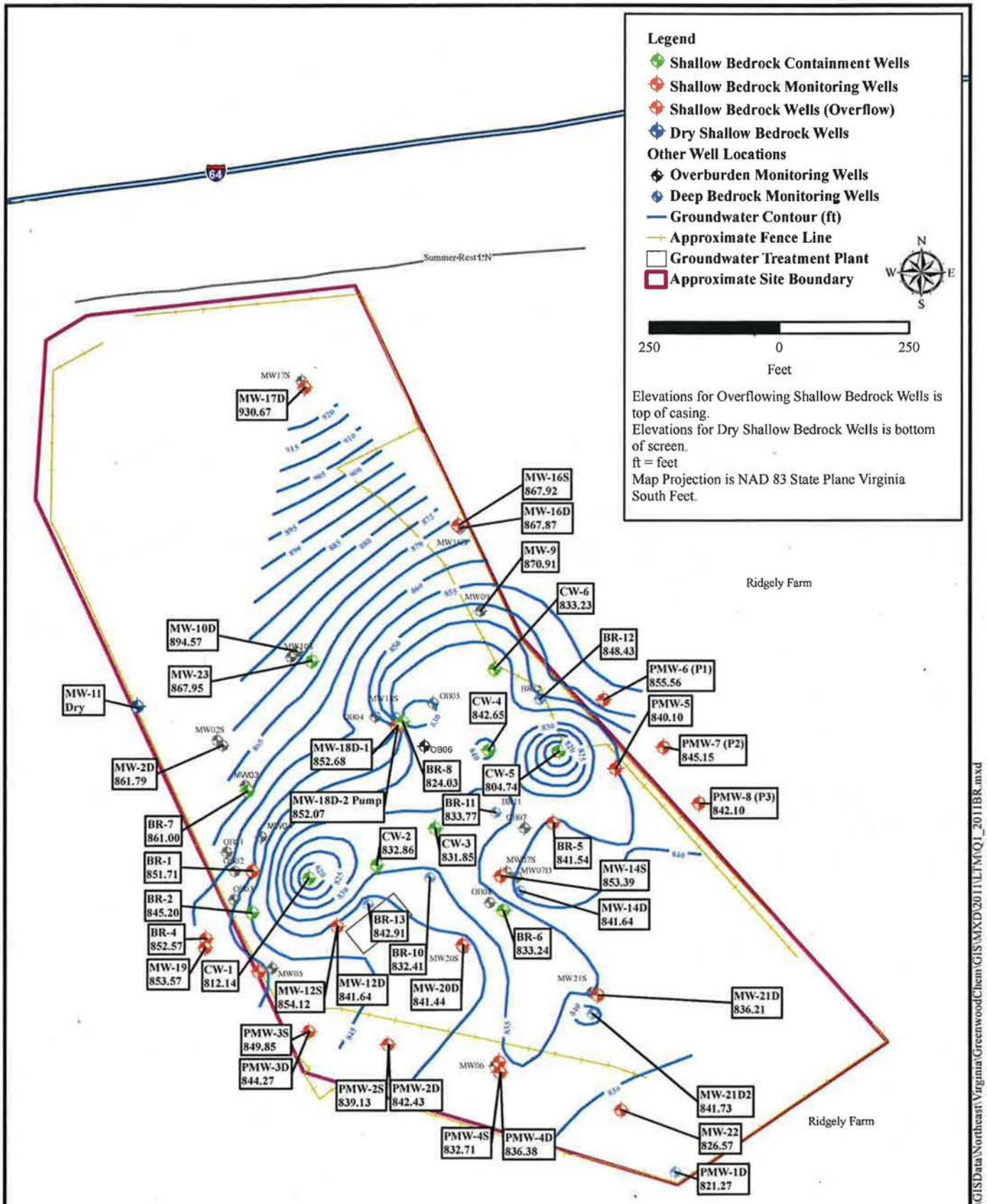
GREENWOOD CHEMICAL SUPERFUND SITE

Albermarle County
Greenwood, Virginia

Figure 1
Site Location Map


I-64
Summer Rest Ln
Residential
Mt. Zion Baptist Church
Newtown Rd
Route 690
Former Manufacturing Area
Agricultural
Greenwood Chemical
Former Drum Disposal Area
East Pond
South Pond
Groundwater Treatment Plant
West Stream
Agricultural
Agricultural
0 100 200 400 600 800
Feet
West
Project Location
Albemarle County
Virginia
North Carolina
U.S. Environmental Protection Agency
GREENWOOD CHEMICAL SUPERFUND SITE
Albemarle County
Greenwood, Virginia
Figure 2
General Site Location Map

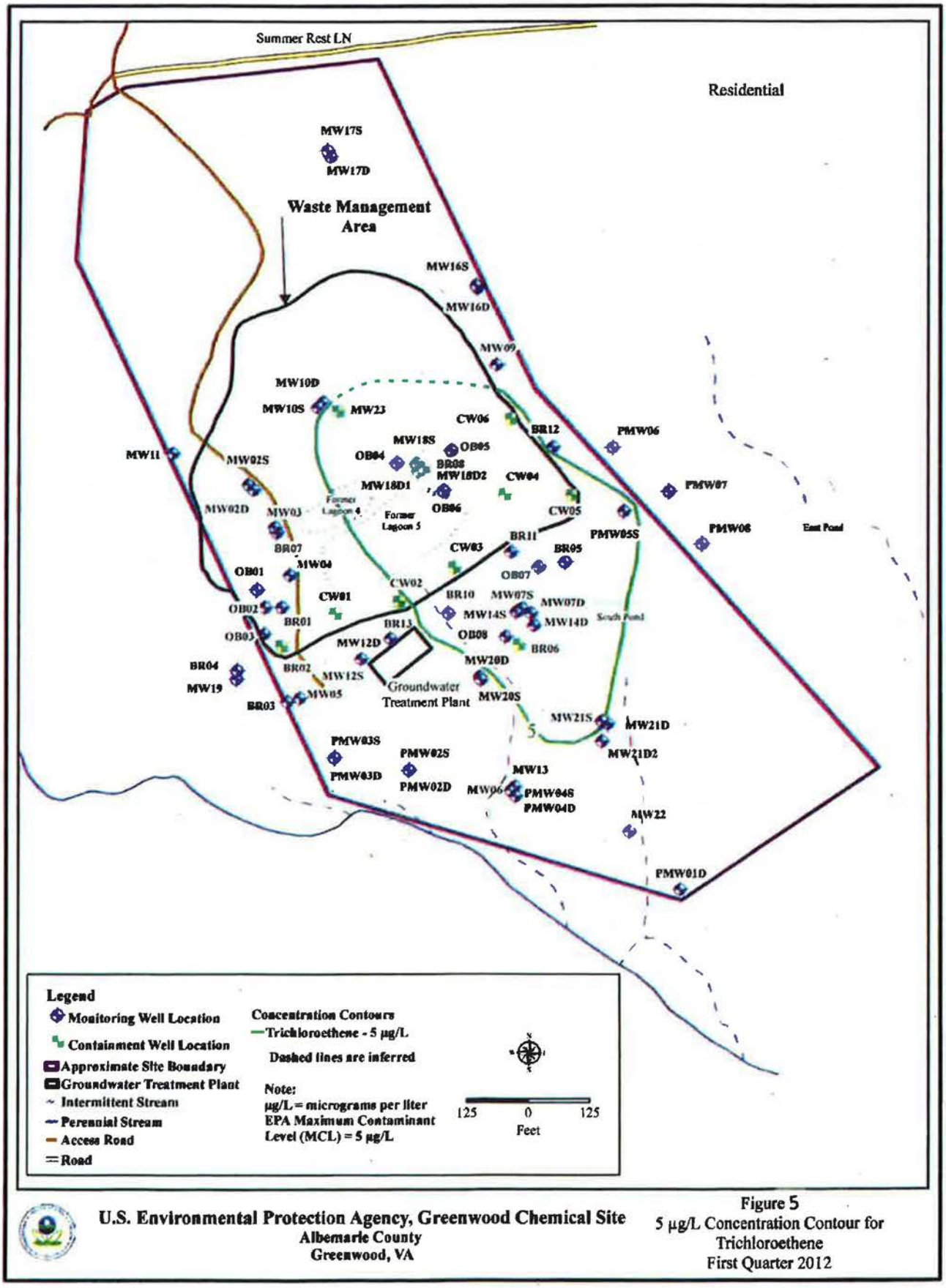

NORTHERN WAREHOUSE
GREENWOOD OFFICE BUILDING
FORMER BUILDING B
FORMER BUILDING C
FORMER 935 SQUARE
PROPERTY LINE
EXISTING FENCE
FORMER BACKFILL NORTHEAST AREA
FORMER LAGOON 1
FORMER LAGOON 2
FORMER LAGOON 3
FORMER LAGOON 4
FORMER LAGOON 5
SOUTH POND
STATE ROUTE 690 (Newtown Road)
FORMER BUILDING A
FORMER BACKFILL NORTH AREA
FORMER DUMP AREA
FORMER MANUFACTURING AREA
FORMER DRUM DISPOSAL AREA
Existing Groundwater Treatment Plant
0 100 200 400
1"=200'
U.S. Environmental Protection Agency
GREENWOOD CHEMICAL SUPERFUND SITE
Albermarle County
Greenwood, Virginia
Figure 3
Historic Site Features
N:\Projects\T00000\T40000\T47124 Greenw'd Chem-GWI\Drawings\Proposed Plan\Figure_3ASize.dwg 09/01/2005 17:09



U.S. Environmental Protection Agency
Greenwood Chemical Site
Albemarle County
Greenwood, VA

FIGURE 4
GROUNDWATER ELEVATION CONTOURS FOR BEDROCK WELLS NOVEMBER 2012

\\LOVETONFEDERAL\GISData\Northeast\Virginia\GreenwoodChem\GIS\MXD\2011\LTM\Q1_2011BR.mxd



U.S. Environmental Protection Agency, Greenwood Chemical Site
Albemarle County
Greenwood, VA

Figure 5
5 µg/L Concentration Contour for Trichloroethene
First Quarter 2012

TABLES

Note: Tables 1, 4, 8, 11 and 12 are embedded in text

Table 2

SOIL CLEANUP LEVELS FOR CONTAMINANTS AT GREENWOOD CHEMICAL SUPERFUND SITE

	SOURCE AREA ACTION LIMITS (GROUNDWATER PROTECTION)	DRUM DISPOSAL ACTION LIMITS (GROUNDWATER PROTECTION)
CLEANUP LEVELS		
Volatile Organics	**mg/kg**	**mg/kg**
Benzene	0.225	0.0224
Chlorobenzene	7,708.7	*
Methylene Chloride	2,665.1	10.83
Tetrachloroethylene	*	0.2364
Trichloroethylene	*	0.0974
Toluene	40,917.6	101.4
1,2-Dichloroethane	0.124	*
Acetone	1,462.1	*
Tetrahydrofuran	97,269	*
Chloroform	0.219	0.3262
Semi-Volatile Organics		
Semi-Volatile TICs	*	158.6
4-Chloroanaline	565.7	*

Notes:

* Soil excavation for the referenced hazardous substances is not required because their cleanup levels have not been exeeded in the referenced area. See "Final Fate & Transport Modeling For Determination of Soil Cleanup Goals Protective of Ground water (February, 1993), Table ES-1, p. ES-3.

1. EPA has determined that acetone present in the Northern Warehouse Area may also require remediation, and through the risk-based modeling has determined that the cleanup level for acetone in this area is 10.1 mg/kg. However, the acetone cleanup level is not presented in this table because, to date, EPA has documented only one exceedance of this cleanup level in this area. Whether remediation of this area is necessary will depend upon additional soil sampling.

Table 3
Groundwater Performance Standards
(Excerpt from 2005 OU2/4 ROD)

In accordance with the NCP, cleanup options that include leaving the deep soils contamination in place require establishment of an area of attainment beyond the waste management area. Accordingly, EPA has developed chemical-specific cleanup goals for ground water which would not only meet the relevant and appropriate standards for drinking water but would also be sufficient to address the cumulative risk presented by multiple contaminants within the "area of attainment."

Table 3
Risk-Based Remedial Goals ("RBRG") for Ground Water - Area of Attainment

Chemical of Potential Concern	PQL (ug/l)*	MCL (ug/l)	Final RBRG (ug/l)
1,2-Dichloroethane	0.5	5.0	5.0
Bis(2-Chloroethyl)Ether	0.01	no MCL	0.5
Carbon Tetrachloride	0.5	5.0	4.0
Tetrachloroethene	0.5	5.0	0.8
Trichloroethene	0.5	5.0	1.0
Vinyl Chloride	0.5	2.0	0.5

* The RBRG of 0.5 ug/L selected for vinyl chloride is the **practical quantitation limit ("PQL")** and represents an approximate risk level of 4×10^{-5}. The final RBRG for each of the other five contaminants was set at a level equivalent to a 1×10^{-5} risk.

The ground water risk-based remediation goals ("RBRGs") set forth in Table 1 fall within the acceptable risk range of a cancer risk of 1×10^{-4} to 1×10^{-6} and a HI of 1, and assume that all six contaminants are present in a single well. In fact, the contamination at the Site varies by location, and no more than two contaminants above RBRGs were found in any one monitoring well. In summary, the contaminant-specific ground water cleanup goals were established at levels which: 1) comply with ARARs; 2) are detectable in a laboratory; and, 3) would achieve a cumulative risk within EPA's target risk range.

Table 5
Recommendations for Follow-up Actions from the Third Five-Year Review
-- 2013 Update --

1) Adjust alignment of recovery well network to establish hydraulic containment of the waste management area.
EPA and VDEQ have continued operation and monitoring of the groundwater extraction and treatment system. The Annual Long Term Monitoring reports completed by EPA between 2008 and 2011 include a capture zone analysis to assess whether the extraction system is achieving hydraulic containment. The capture zone analysis relies on a weight of evidence approach in identifying the capture zone by evaluating groundwater elevation data (potentiometric maps) and groundwater contaminant concentrations over time. The analyses indicate that the expanded 11-well extraction network has achieved hydraulic containment.
2) Develop and implement a plan for assessing vapor intrusion into potential future structures.
An ESD modifying the institutional controls that were selected in the OU2/4 ROD was issued on July 24, 2013. The ESD determined that there would be potential for unsafe exposure to occupants due to vapor intrusion into hypothetical future buildings constructed near groundwater contaminated by VOCs. The ESD added a land use restriction requiring that any new habitable building constructed over or within 100 feet of the groundwater contaminated by VOCs above MCLs include, at a minimum, a foundation vapor barrier and the subsurface piping for a sub-slab depressurization system. This vapor mitigation system would prevent potentially unsafe exposures to building occupants.
3) Implement institutional controls included in the 2005 ROD
EPA was unable to implement an Environmental Covenant at the Site because the property has been abandoned and has no owner to execute this type of institutional control. The July 24, 2013 ESD expanded the types of institutional controls that may be used to implement the land and groundwater use restrictions selected in the OU2/4 ROD. EPA is currently in discussion with State and local officials in effort to post a notice of land use restrictions. In recognition that the Site had been abandoned, pursuant to Virginia Code § 10.1-1406.1, the Circuit Court of Albemarle County granted access to VDEQ under Court Order (Case No.: CL12000268-00) for the purpose of performing remediation at the Site. VADEP representatives are on the Site operating the water treatment plant on a daily basis. No activities have been observed that would violate the institutional controls. The subject property is fenced and the gate is locked each night and weekend. Institutional controls are not yet in place.

Table 6
Site Discharge Limits Comparison Pre-2009 vs Current

PARAMETER	Pre-2009 DMR QUALITY or CONCENTRATION			EPA Calculated Limit	Calculated Limit Based Upon Aquatic Protection	Calculated Limit Based Upon Human Health	2009 VADEQ Revised Limit	2009 Informal Performance Goal	EPA Monitoring Frequency
	Minimum	Maximum Continuous	Units						
Inorganics									
pH	6	9	SU	6.0 to 9.0	Y		6 to 9	6 to 9	M
ALUMINUM, TOTAL RECOVERABLE	NA	87	ug/L	87 [1]			NR	NA	NR [2]
CADMIUM, DISSOLVED	NA	1	ug/L	1.1	Y		NR	NA	NR [2]
CHROMIUM, DISSOLVED TRIVALENT	NA	171.6	ug/L	69	Y		NR	NA	NR [2]
CHROMIUM, DISSOLVED HEXAVALENT	NA	16	ug/L	11	Y		NR	NA	NR [2]
COPPER, DISSOLVED	NA	9.2	ug/L	8.3	Y		NR	NA	NR [2]
CYANIDE	NA	7.6	ug/L	5.2	Y		7.2	7.2	M
LEAD	NA	1.9	ug/L	12	Y	Y	NR	NA	NR [2]
MERCURY, DISSOLVED	NA	0.018	ug/L	0.051		Y	NR	NA	NR [2]
NICKEL, DISSOLVED	NA	128.3	ug/L	19	Y		NR	19	M
ZINC, DISSOLVED	NA	65	ug/L	110	Y		NR	NA	NR [2]
Toxicity									
ACUTE WHOLE EFFL TOXICITY (NOAEC%)	100	NA	NOAEC	100	Y		1 TUa	1 TUa	Q
CHRONIC WHOLE EFFL TOXICITY (TUc)	NA	1	TUc	1	Y		1.4 TUc	1.4 TUc	Q
Organics									
BENZENE	NA	77.5	ug/L	71		Y	NR	71	M
BIS-2-CHLOROETHYL ETHER	NA	1.4	ug/L	1.4		Y	NR	1.4	Q
BIS-2-ETHYLHEXL PHTHALATE	NA	R	ug/L	59		Y	NR	NA	NR [3]
CARBON TETRACHLORIDE	NA	90.8	ug/L	44		Y	NR	44	M
CHLOROBENZENE	NA	21000	ug/L	21,000		Y	NR	NA	NR [4]
CHLOROFORM	NA	R	ug/L	2,900		Y	NR	NA	NR [4]
1,2-DICHLOROBENZENE	NA	R	ug/L	1,700		Y	NR	NA	NR [3]
1,2-DICHLOROETHANE	NA	R	ug/L	990		Y	NR	990	Q
METHYLENE CHLORIDE	NA	1600	ug/L	1,600		Y	NR	NA	NR [4]
NAPHTHALENE	NA	90.7	ug/L	90.7 [1]		Y	NR	NA	NR [3]
TETRACHLORO-ETHYLENE	NA	R	ug/L	89		Y	NR	89	M
TRICHLOROETHENE	NA	R	ug/L	810		Y	NR	810	M
TOLUENE	NA	256	ug/L	256		Y	NR	NA	NR [4]
VINYL CHLORIDE	NA	NA	ug/L	5,300		Y	NR	5,300	M

Table Abbreviations
- M- Monthly
- NOAEC%- No observed adverse effect concentration
- NA- Not applicable
- NR- Not required
- Q- Quarterly
- R- Report only, no limit established
- SU- Standard units
- TUa- Toxicity Units, Acute
- TUc- Toxicity Units, Chronic
- ug/L- Micrograms per liter
- Y- Yes

Notes
1. Analyte not listed on the 2008 Piedmont Region Water Quality spreadsheet. EA proposed retaining the previous value for continuity purposes
2. Sampling not required for DMR/Informal Performance Goals; however, this analyte is included in monthly TAL metals sampling used to evaluate Site treatment plant performance
3. Sampling not required for DMR/Informal Performance Goals; however, this analyte is included in quarterly SVOC sampling used to evaluate Site groundwater quality
4. Sampling not required for DMR/Informal Performance Goals; however, this analyte is included in monthly VOC sampling used to evaluate Site treatment plant performance

TABLE 7 TREATMENT PLANT INFLUENT CONCENTRATIONS AND POUNDS OF CONTAMINANTS REMVED ANNUALLY

Month	CCl_4 (µg/L)	BCEE (µg/L)	Others (µg/L)	Total Org (µg/L)	Influent Flow (gallons)	Mass Removed (pounds) [1]	Annual Total (pounds)
Mar-02	207	23.5	106.1	336 6	327,184	0.9	
Apr-02	197	29	116	342	322,741	0.9	
May-02	210	27	176	413	327,458	1.1	
Jun-02	270	27	240	537	397,374	1.8	
Jul-02	400	46	222	668	541,603	3.0	
Aug-02	190	35	221	446	563,167	2.1	18.5
Sep-02	250	47	276	573	453,346	2.2	
Oct-02	410	48	423	881	434,044	3.2	
Nov-02	250	46	246	542	490,304	2.2	
Dec-02	130	22	85.4	237.4	530,810	1.1	
Jan-03	72	45	126.7	243.7	519,089	1.1	
Feb-03	470	21	303.7	794.7	459,077	3.0	
Mar-03	0	20	138	158	504,799	0.7	
Apr-03	83	12	53.5	148.5	412,636	0.5	
May-03	190	13	90.4	293.4	509,022	1.2	
Jun-03	210	22	240	472	541,938	2.1	
Jul-03	320	24	197.2	541.2	538,729	2.4	25.2
Aug-03	330	24	173.8	527.8	614,305	2.7	
Sep-03	400	25	287	712	501,655	3.0	
Oct-03	220	13	114.2	347.2	635,084	1.8	
Nov-03	510	24	314.6	848.6	688,806	4.9	
Dec-03	250	22	164.4	436.4	466,984	1.7	
Jan-04	360	24	219.1	603.1	911,079	4.6	
Feb-04	100	27	101.91	228.91	775,940	1.5	
Mar-04	250	15	572.8	837.8	734,302	5.1	
Apr-04	440	17	218.1	675.1	672,508	3.8	
May-04	140	17	154.7	311.7	661,850	1.7	
Jun-04	460	22	266.4	748.4	624,352	3.9	
Jul-04	220	21	189.9	430.9	534,085	1.9	39.7
Aug-04	350	16	239	605	538,252	2.7	
Sep-04	180	11	115.3	306.3	606,336	1.5	
Oct-04	210	7.4	159.7	377.1	807,601	2.5	
Nov-04	490	23	225.9	738.9	1,406,220	8.7	
Dec-04	260	15	154.56	429.56	490,187	1.8	

TABLE 7 TREATMENT PLANT INFLUENT CONCENTRATIONS AND POUNDS OF CONTAMINANTS REMVED ANNUALLY

Month	CCl_4 (µg/L)	BCEE (µg/L)	Others (µg/L)	Total Org (µg/L)	Influent Flow (gallons)	Mass Removed (pounds) [1]	Annual Total (pounds)
Jan-05	140	18	93.2	254.4	463,888	1 0	27.9
Feb-05	310	18	219	554.2	480,857	2.2	
Mar-05	460	20	213.9	703	627,217	3.7	
Apr-05	460	15	269.15	744.15	417,367	2.6	
May-05	410	6.8 J	257.5	667.5	556,098	3.1	
Jun-05	260	23	186.2	469.2	475,376	1.9	
Jul-05	280	15.5	126.7	422.2	503,597	1.8	
Aug-05	245	21.25	107.8375	374.0875	506,351	1.6	
Sep-05	190.2	9.24	113.864	313.304	452,948	1.2	
Oct-05	98	17	127.9	242.9	489,829	1.0	
Nov-05	740	19	489.6	1248.6	192,608	2.0	
Dec-05	130	11	309.2	450.2	1,583,054	5.9	
Jan-06	140	11	216	367	1,407,803	4.3	75.8
Feb-06	130	8.3	259.6	397.9	1,350,960	4.5	
Mar-06	140	15	271.8	426.8	1,433,760	5.1	
Apr-06	280	12	380.1	672.1	1,225,250	6.9	
May-06	240	12	284.2	536.2	1,187,577	5.3	
Jun-06	210	14	264	488	1,352,785	5.5	
Jul-06	300	13	325.6	638.6	1,639,485	8.7	
Aug-06	280	11	373.1	664.1	1,612,527	8.9	
Sep-06	290	13	382.9	685.9	1,384,525	7.9	
Oct-06	200	7.7	267.5	475.2	1,411,204	5.6	
Nov-06	210	13	281.9	504.9	1,491,593	6.3	
Dec-06	200	3.2	261.9	465.1	1,747,054	6.8	
Jan-07	120	7.4	168.2	295.6	1,734,053	4.3	56.0
Feb-07	110	12	177.1	299.1	1,497,348	3.7	
Mar-07	130	5.8	187.8	323.6	1,357,745	3.7	
Apr-07	220	5	191.4	416.4	1,558,601	5.4	
May-07	230	9.6	201.9	441.5	1,601,221	5.9	
Jun-07	320	11	248	579	1,265,251	6.1	
Jul-07	160	10	150.8	320.8	1,636,007	4.4	
Aug-07	190	5.4	117.7	313.1	1,597,163	4.2	
Sep-07	380	7.5	217.4	604.9	1,791,013	9.0	
Oct-07	120	8.5	217.5	346	1,485,646	4.3	
Nov-07	20	1.8	38.9	60.7	1,660,671	0.8	
Dec-07	130	9.2	188.4	327.6	1,545,735	4.2	

TABLE 7 TREATMENT PLANT INFLUENT CONCENTRATIONS AND POUNDS OF CONTAMINANTS REMVED ANNUALLY

Month	CCl_4 (µg/L)	BCEE (µg/L)	Others (µg/L)	Total Org (µg/L)	Influent Flow (gallons)	Mass Removed (pounds) [1]	Annual Total (pounds)
Jan-08	240	5.9	286.1	532	2,010,607	8.9	74.3
Feb-08	245	5.8	197.9	448.7	1,839,200	6.9	
Mar-08	250	5.7	109.7	365.4	1,562,871	4.8	
Apr-08	130	8	156.2	294.2	1,640,741	4.0	
May-08	190	8.7	243.7	442.4	1,686,810	6.2	
Jun-08	280	6.1	157.8	443.9	1,393,427	5.2	
Jul-08	300	9.7	194.7	504.4	1,648,660	6.9	
Aug-08	290	10	209.3	509.3	1,518,133	6.4	
Sep-08	340	6.7	212.8	559.5	1,258,913	5.9	
Oct-08	360	5.4	231.3	596.7	1,677,727	8.3	
Nov-08	280	5.7	207.2	492.9	1,224,931	5.0	
Dec-08	230	6	168.2	404.2	1,683,776	5.7	
Jan-09	260	7.6	203.46	471.06	1,612,580	6.3	65.8
Feb-09	99	9.1	157.4	265.5	1,438,436	3.2	
Mar-09	180	ns	218.81	398.81	1,671,821	5.6	
Apr-09	160	6.4	273.71	440.11	1,672,789	6.1	
May-09	370	ns	245.72	615.72	1,490,294	7.7	
Jun-09	240	ns	154.45	394.45	1,459,671	4.8	
Jul-09	240	5.1	158.27	403.37	1,713,926	5.8	
Aug-09	350	ns	210.45	560.45	1,668,457	7.8	
Sep-09	270	ns	134.52	404.52	1,532,196	5.2	
Oct-09	330	6.3	274.89	611.19	1,580,667	8.1	
Nov-09	79	7.7	72.5	159.2	1,726,326	2.3	
Dec-09	130	ns	132.37	262.37	1,407,162	3.1	
Jan-10	260	ns	145.1	405.1	1,565,549	5.3	72.4
Feb-10	210	2.5 J	132.9	345.4	1,598,412	4.6	
Mar-10	140	ns	90	230	1,737,301	3.3	
Apr-10	180	ns	129.4	309.4	1,569,676	4.1	
May-10	270 E	6.3 E	160.9	437.2	1,574,334	5.7	
Jun-10	390	ns	194.5	584.5	1,443,807	7.0	
Jul-10 [2]	0.23 J	ns	UL	0.23	1,659,556	0.0	
Aug-10	410	7.4 E	234.6	652	1,780,193	9.7	
Sep-10	220	ns	145.9	365.9	1,582,260	4.8	
Oct-10	380	ns	937.7	1317.7	1,536,527	16.9	
Nov-10	220	nd	177.7	397.7	1,639,390	5.4	
Dec-10	250	ns	146.9	396.9	1,652,934	5.5	

TABLE 7 TREATMENT PLANT INFLUENT CONCENTRATIONS AND POUNDS OF CONTAMINANTS REMVED ANNUALLY

Month	CCl_4 (µg/L)	BCEE (µg/L)	Others (µg/L)	Total Org (µg/L)	Influent Flow (gallons)	Mass Removed (pounds) [1]	Annual Total (pounds)
Jan-11	180 +	ns	168.9	348.9	1,428,788	4.2	55.6
Feb-11	300 +	7.5	188.4	495.9	1,300,455	5.4	
Mar-11	88 +	ns	99.5	187.5	1,753,447	2.7	
Apr-11	150 +	3.6 J	133.2	286.8	1,780,020	4.3	
May-11	190 +	ns	186.3	376.3	1,920,276	6.0	
Jun-11	180 L	ns	167.9	347.9	1,395,817	4.1	
Jul-11	130 +	nd	117.8	247.8	1,852,948	3.8	
Aug-11	220 +	ns	187.5	407.5	1,835,454	6.2	
Sep-11	330 +	ns	207.0	537.0	1,507,956	6.8	
Oct-11	210 +	5.9	128.2	344.1	975,035	2.8	
Nov-11	100 +L	ns	62.2	162.2	1,535,090	2.1	
Dec-11	290 +J	ns	153.3	443.3	1,959,229	7.2	
1Q 2012	220	3	170.0	445.2	4,335,125	16.1	69.8
2Q 2012	195	2.1	175.0	583.0	4,365,123	21.2	
3Q 2012	191	2.2	165.0	543.0	4,315,435	19.6	
4Q 2012	192 +J	2.1	153.3	355.0	4,345,327	12.9	
						Total mass removed since 2002 (lbs)	581.0

Notes:

1 Mass removed is based on calculations using monthly concentrations from the SL-1 sampling port (equalization tank).

2 The samples arrived at the lab > 4°F and many data were UL qualified.

Acronyms:

BCEE-Bis(2-chloroethyl) Ether

CCl_4 - carbon tetrachloride

nd - not detected above quantitation limit

ns - not sampled for analyte

Data Qualifiers:

E - Estimated

J - Analyte present. Value may not be accurate or precise.

L-Analyte present.Actual value is expected to be higher.

UL - Not detected. Quantitation limit is probably higher.

+ - sample was diluted

TABLE 9
COMPARISON OF TOXICITY VALUES
GREENWOOD CHEMICAL SITE

Chemical of Concern	2005 RBRGs[1]				2013 RBRGs[2]			
	Carcinogenic Toxicity Value		Non-Carcinogenic Toxicity Value		Carcinogenic Toxicity Value		Non-Carcinogenic Toxicity Value	
	Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Reference Dose (mg/kg-day)	Reference Concentration (mg/m^3)	Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Reference Dose (mg/kg-day)	Reference Concentration (mg/m^3)
Bis(2-Chloroethyl)Ether	1.1E+00	3.3E-04	--	--	1.1E+00	3.3E-04	--	--
Carbon Tetrachloride	1.3E-01	1.5E-05	7.0E-04	2.0E-03	7.0E-02	6.0E-06	4.0E-03	1.0E-01
1,2-Dichloroethane	9.1E-02	2.6E-05	2.0E-02	4.9E-03	9.1E-02	2.6E-05	6.0E-03	7.0E-03
Tetrachloroethene	5.4E-01	--[3]	1.0E-02	4.9E-01	2.1E-03	2.6E-07	6.0E-03	4.0E-02
Trichloroethene	4.0E-01	--[3]	3.0E-04	4.0E-02	4.6E-02	4.1E-06	5.0E-04	2.0E-03
Vinyl Chloride	7.2E-01	4.4E-06	3.0E-03	1.0E-01	7.2E-01	4.4E-06	3.0E-03	1.0E-01

RBRGs = Risk-Based Remedial Goals
-- = No toxicity values available

1) 2005 RBRGs toxicity values taken from TetraTech/Black & Veatch, 2005, *Final Ground-Water Investigation and Focused Feasibility Study Report, Green Chemical Site, Greenwood, Albemarle County, Virginia*. June.
2) 2013 RBRGs toxicity values taken from USEPA Regional Screening Level Summary Table, May 2013, for resident adult and child eposure to tap water, available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm.
3) Inhalation unit risks were extrapolated based upon the oral slope factor.

TABLE 10
COMPARISON OF RISK-BASED REMEDIAL GOALS (RBRGs)
GREENWOOD CHEMICAL SITE

Chemical of Concern	MCL (mg/L)	2005 RBRGs[1]			2013 Revised RBRGs[2]			
					without adult dermal		with adult dermal	
		Carcinogenic[3] (mg/L)	Non-Carcinogenic[4] (mg/L)	Final RBRG (mg/L)	Carcinogenic[3] (mg/L)	Non-Carcinogenic[4] (mg/L)	Carcinogenic[3] (mg/L)	Non-Carcinogenic[4] (mg/L)
Bis(2-Chloroethyl)Ether	NA	0.0005	--	0.0005	0.0006	--	0.0006	--
Carbon Tetrachloride	0.005	0.004	0.008	0.004	0.009	0.05	0.008	0.05
1,2-Dichloroethane	0.005	0.006	0.1	0.005 (MCL)	0.007	0.08	0.007	0.08
Tetrachloroethene	0.005	0.0008	0.1	0.0008	0.3	0.07	0.2	0.07
Trichloroethene	0.005	0.001	0.004	0.001	0.004	0.007	0.004	0.007
Vinyl Chloride	0.002	0.0001	0.04	0.0005 (CRQL)	0.0001	0.04	0.0001	0.04

RBRGs = Risk-Based Remedial Goals
MCL = Maximum Contaminant Level
NA = Not Available
-- = No toxicity values available

1) 2005 RBRGs taken from TetraTech/Black & Veatch, 2005, *Final Ground-Water Investigation and Focused Feasibility Study Report, Green Chemical Site, Greenwood, Albemarle County, Virginia*. June.

2) 2013 RBRGs calculated using USEPA Screening Level calculator, available at: http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search, assuming resident adult and child exposure to tap water.

3) Carcinogenic RBRGs are based upon a carcinogenic risk level of 10^{-5}.

4) Non-carcinogenic RBRGs are based upon a hazard quotient of 1.

ATTACHMENTS

ATTACHMENT A: List of Documents Reviewed

Record of Decision [OU1], Greenwood Chemical, Albemarle County, Newtown, VA, dated December 29, 1989

Record of Decision [Interim OU2], Greenwood Chemical, Albemarle County, Newtown, VA, dated December 31, 1990

Explanation of Significant Differences, Greenwood Chemical, Albemarle County, Newtown, VA, dated July 17, 1991

Explanation of Significant Differences, Greenwood Chemical, Albemarle County, Newtown, VA, dated March 24, 1994

Record of Decision [final OU2 and OU4], Greenwood Chemical, Albemarle County, Newtown, VA, dated September 22, 2005

Third Five-Year Review Report, Greenwood Chemical, Newtown, VA, September 2008

Annual Operations and Maintenance Report for 2007, March 2008

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2008, May 2008

Quarterly Operations and Ground Water Monitoring Report, 2nd Quarter, 2008, October 2008

Greenwood Chemical Effluent Limits and Monitoring Requirements Fact Sheet, October 2008

Technical Memorandum, VDEQ/EA Discharge Limits Comparison Discussion, Greenwood Chemical Site, Operable Unit (OU) -2 and OU-4, Greenwood, Albemarle County, Virginia, December 2008

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2008, January 2009

Annual Long Term Monitoring Report for 2008, February 2009

Annual Operations and Maintenance Report for 2008, March 2009

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2009, June 2009

Quarterly Operations and Ground Water Monitoring Report, 2nd Quarter, 2009, October 2009

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2009, Dec 2009

Annual Long Term Monitoring Report for 2009, April 2010

Annual Operations and Maintenance Report for 2009, April 2010

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2010, July 2010

Quarterly Operations and Ground Water Monitoring Report, 2nd Quarter, 2010, August 2010

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2010, Jan 2011

Annual Long Term Monitoring Report for 2010, May 2011

Annual Operations and Maintenance Report for 2010, May 2011

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2011, July 2011

Quarterly Operations and Ground Water Monitoring Report, 2nd Quarter, 2011, August 2011

Quarterly Operations and Ground Water Monitoring Report, 3rd Quarter, 2011, Dec 2011

Annual Long Term Monitoring Report for 2011, April 2012

Annual Operations and Maintenance Report for 2011, March 2012

Quarterly Operations and Ground Water Monitoring Report, 1st Quarter, 2012, May 2012

Annual Operations and Maintenance Report for 2012, March 2013

EPA Risk Based Screening Tables, May 2013

Explanation of Significant Differences, Record of Decision [final OU2 and OU4], Greenwood Chemical, Albemarle County, Newtown, VA, dated July 24, 2013