URS DIAMOND

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REMEDIAL INVESTIGATION AND RISK ASSESSMENT REPORT ADDENDUM

HAY ROAD SLUDGE DRYING SITE (DE-024) WILMINGTON, DELAWARE

Draft Submission: September 12, 2008
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CORPORATE REMEDIATION GROUP
An Alliance between
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Acronym	Definition
AF1	ratio of the concentration in pore water/leachate to the concentration in groundwater at the point of surface water discharge
AF2	ratio of the concentration in groundwater at the point of surface water discharge to the concentration in surface water prior to exposure
AWQC	Ambient Water Quality Criteria
ASTM	American Society for Testing and Materials
BGS	Background Standard
cfs	cubic feet per second
cm/sec	centimeters per second
COCs	constituents of concern
CRG	Corporate Remediation Group
CSL_L	Closure Screening Levels for leachate
CSL_S	Closure Screening Levels for solids
CSM	conceptual site model
DDR	DuPont Data Review
DGS	Delaware Geological Survey
DM	Dredge Material
DM:LPU	Dredge Material: Low-Permeability Unit
DM:WBZ	Dredge Material: Water-Bearing Zone
DNREC	Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
DSWA	Delaware Solid Waste Authority
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FFS	Focused Feasibility Study
GMZ	groundwater management zone
HI	hazard index
HSCA	Hazardous Substances Control Act
HxBC	Hexahlorobiphenyls
HxCDD	1,2,3,7,8,9-hexachlorodibenzo-p-dioxin
Staged IRM	Staged Iron-Rich Material
MCL	Maximum contaminant level
mg/L	Milligrams per liter
mg/kg	Milligrams per kilogram
MS/MSD	matrix spike/matrix spike duplicate
NAVD	North American Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NSWMC	Northern Solid Waste Management Center
OCDF	octachlorodibenzofuran
OCDD	octachlorodibenzo-p-dioxin
OH	Organic Silts and Clays of Medium to High Plasticity
OL	Organic Silts and Clays of Low Plasticity
PBT	Persistent, bioaccumulative, and toxic
PCBs	polychlorinated biphenyls
PeBC	Pentachlorobiphenyls
pg/L	picograms per liter
PID	photo ionization detector
PPRA	Proposed Plan of Remedial Action
QA/QC	quality assurance/quality control
RAOs	remedial action objectives

Acronym	Definition
RAIS	Risk Assessment Information System
RCRA	Resource Conservation and Recovery Act
RI/RA	Remedial Investigation/Risk Assessment
SI	Supplemental Investigation
SL	Screening level
SPLP	synthetic precipitation leaching procedure
SSL	soil screening level
SSS	Site-Specific Standard
SU	standard units
SVOCs	semi-volatile organic compounds
SWPF	Surface Water Protection Factor
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TRI	Toxic Release Inventory
µg/L	micrograms per liter
URS	Uniform Risk-Based Standard
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VCP	Voluntary Cleanup Program
VOCs	volatile organic compounds
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

This document, the *Remedial Investigation and Risk Assessment Report Addendum* (Addendum), presents the results and evaluation of additional technical information collected at the request of the Delaware Department of Natural Resources and Environmental Control following an independent third-party evaluation as requested by House Concurrent Resolution No. 22 (HCR 22). The new data were integrated with previously collected data and used to update the site-specific exposure and risk evaluation. This report, responding to Delaware Department of Natural Resources and Environmental Control and public comments and to those comments raised by the third-party evaluation of the Staged Iron-Rich Material at the Hay Road Sludge Drying Site, is provided to complete the administrative record and furnish Delaware Department of Natural Resources and Environmental Control with a sufficient technical basis for the final disposition of the Staged Iron-Rich Material. The updated evaluation demonstrates that implementation of a cap-in-place remedy for the Staged Iron-Rich Material is appropriate for the final disposition of this material, as it is protective of human health and the environment. As noted in Delaware Department of Natural Resources and Environmental Control's proposed remedy for the site, post closure monitoring shall be recommended to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity for further action.

Background

The Hay Road Sludge Drying Site is a 23-acre parcel contained within the 108-acre E.I. du Pont de Nemours and Company (DuPont) Cherry Island property. Beginning in 1997 and continuing to mid-2001, the DuPont Edge Moor Plant generated approximately 500,000 tons of Staged Iron-Rich Material, which was transported as a saleable product and stored in a product staging area at the Sludge Drying Site. In mid-2001, DuPont discontinued marketing the product and ceased sending materials to the Sludge Drying Site.

DuPont entered into a Delaware Department of Natural Resources and Environmental Control Voluntary Cleanup Program Agreement on September 11, 2002 to select a remedial alternative for the Staged Iron-Rich Material at the Sludge Drying Site. To comply with the Voluntary Cleanup Program Agreement, DuPont completed and Delaware Department of Natural Resources and Environmental Control approved the Remedial Investigation/Risk Assessment and Focused Feasibility Study reports in 2004. Delaware Department of Natural Resources and Environmental Control then prepared and published a Proposed Plan of Remedial Action on December 14, 2004, which presented the cap-in-place remedial option (combined with institutional/engineering controls) as the preferred cleanup alternative for the Sludge Drying Site. In the Voluntary Cleanup Program Agreement, the nature and extent of contamination were defined by the chemical properties and areal extent (e.g., footprint) of the Staged Iron-Rich Material Pile.

In response to public comments to the Proposed Plan of Remedial Action, HCR 22 was passed in June 2005 by the 143rd General Assembly of the House of Representatives.

Following the request of HCR 22, Delaware Department of Natural Resources and Environmental Control engaged an independent engineering firm, Schnabel Engineering, to complete a review of the existing data that was used to support the Proposed Plan of Remedial Action. Schnabel Engineering recommended in their December 2006 report that additional technical data be obtained to more fully support Delaware Department of Natural Resources and Environmental Control's selection of a final remedial alternative. DuPont agreed to collect the additional information.

Supplemental Investigation

In August 2007, DuPont submitted and Delaware Department of Natural Resources and Environmental Control approved the *Supplemental Investigation Work Plan*, which presented the details of a comprehensive field program to collect the additional requested site data. The *Supplemental Investigation Work Plan* included collecting and analyzing samples from all relevant environmental media at the site [e.g., Staged Iron-Rich Material and Dredge Material solids and groundwater], as well as surface water and sediment samples from within Shellpot Creek. Supplemental Investigation sample collection was completed in February 2008, and final validated analytical data were received in June 2008.

In addition to the Supplemental Investigation scope of work, a groundwater flow evaluation was completed in June 2008 to measure the primary flow path of shallow groundwater within the Dredge Material: Water Bearing Zone underlying the Sludge Drying Site. Also in June 2008, a review of historical records and aerial photographs was completed to better understand past site operational history and to complement the evaluation of the Supplemental Investigation technical data. The results of this review are summarized as follows:

- The entire Hay Road Sludge Drying Site is underlain, not by native soils, but by placed dredge and fill materials. Historical records demonstrate that in 1927 a seawall was constructed parallel to and approximately 2,300 feet east of the then-existing shoreline. Between 1927 and the late 1940s, Dredge Material originating from the Delaware and Christina Rivers was pumped behind the seawall to create new land (Cherry Island). The 1927 seawall forms the current boundary/shoreline of the Delaware River shoreline.
- The historical dredge and fill materials contain distinct chemical characteristics that are indicative of regional impacts to the river sediments prior to Dredge Material emplacement behind the 1927 seawall and to DuPont purchasing the Sludge Drying Site in 1956.
- DuPont and the City of Wilmington were co-permitted by Delaware Department of Natural Resources and Environmental Control to air-dry sludges from the DuPont Edge Moor Plant and the City of Wilmington Wastewater Treatment Plant (hence the name Sludge Drying Site) prior to DuPont using the property to store Staged Iron-Rich Material. Such dewatering and sludge drying activities may have impacted the chemical nature of the Dredge Material: Low Permeability Unit and groundwater.

Conclusions

Based on the evaluation of all available data for the Sludge Drying Site, including original information as well as that collected during the Supplemental Investigation, the following conclusions can be drawn:

- Analytical data collected during the Supplemental Investigation are consistent with data collected previously.
- All requests by Delaware Department of Natural Resources and Environmental Control for additional technical information, in response to public comments to the Proposed Plan of Remedial Action and to HCR 22, have been met. Sufficient data exist to decide the final disposition of the Staged Iron-Rich Material.
- The updated exposure and risk evaluation and pile-specific transport modeling supports a cap-in-place remedy for the Staged Iron-Rich Material as fully protective of human health and the environment from exposure to the staged materials.
- Current subsurface conditions of the Dredge Material: Low Permeability Unit and Dredge Material: Water-Bearing Zone may have been influenced by historic Dredge Material placement and possibly by past site operational practices prior to DuPont storing Staged Iron-Rich Material at the site. Additional assessment of these units is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the Dredge Material: Low Permeability Unit and Dredge Material: Water-Bearing Zone and the potential interaction of these units with the surrounding environment.

1.0 INTRODUCTION

This document, the *Remedial Investigation and Risk Assessment (RI/RA) Report Addendum* (Addendum), presents the results and evaluation of additional technical information collected at the request of the Delaware Department of Natural Resources and Environmental Control (DNREC) following an independent third-party evaluation as requested by House Concurrent Resolution No. 22 (HCR 22). The new data were integrated with previously collected data and used to update the site-specific exposure and risk evaluation originally presented in the DNREC-approved 2004 *Final Remedial Investigation/Risk Assessment Report* (2004 RI/RA report; DuPont, 2004a). The 2004 RI/RA report and subsequent *Focused Feasibility Study* (FFS; DuPont, 2004b) supported selection of a cap-in-place remedy for the Staged Iron-Rich Material (Staged IRM) at the Hay Road Sludge Drying Site.

This report, responding to DNREC and public comments and to those comments raised by the third-party evaluation of the Staged IRM, is provided to complete the administrative record and furnish DNREC with a sufficient technical basis for the final disposition of the Staged IRM.

1.1 DuPont Property Location and Description

DuPont owns 108 acres of property (DuPont Property) on Cherry Island in Wilmington, Delaware, as shown in Figure 1-1. The closed Hay Road Landfill, formerly known as the Cherry Island Landfill, occupies approximately 30 acres of the DuPont Property. The Sludge Drying Site [naming convention as defined in the Voluntary Cleanup Program (VCP) Agreement] occupies approximately 23 acres of the DuPont Property. Undeveloped, unused land comprises the remaining 55 acres. The Sludge Drying Site boundary is shown in Figure 1-2.

The Sludge Drying Site is bordered by Shellpot Creek to the north, the Delaware River to the east, the 12th Street Extension to the south, and the closed Hay Road Landfill to the west (see Figures 1-1 and 1-2). The DuPont Edge Moor Plant (Plant) is located one mile north (see Figure 1-1) of the DuPont Property.

1.2 DuPont Property Operational History

A timeline for the DuPont Property operational history is provided in Figures 1-3a, 1-3b, and 1-3c and described in this section. Prior to 1927, the present-day Sludge Drying Site and most of the DuPont Property was submerged and part of the Delaware River (see historical photographs in Appendix B). Historical records document that around 1927 a seawall was constructed parallel to and approximately 2,300 feet east of the then-existing shoreline (see Figure 1-2). DM originating from the Delaware and Christina Rivers was pumped by the United States Army Corps of Engineers (USACE) between the shoreline and the constructed seawall to create new land (i.e., Cherry Island). DM placement in this area ceased around 1946 or shortly thereafter, as vegetation appears to exist on the 1945 aerial photograph (see Figure 5 in Appendix B) and is well established on the 1954

aerial photograph (see Figure 6 in Appendix B). The 1927 seawall forms the current Delaware River shoreline.

DuPont purchased the 108-acre property parcel from the American Dredge Company in 1956. A portion of the DuPont Property is native land, and the remainder is a man-made land feature created by the historic dredging activities (see Appendix B photographs). From 1958 to 1996, DuPont operated an industrial solid waste landfill (the Hay Road Landfill) for the disposal of solid waste byproducts generated by the Plant. Landfill operations were conducted within the northwestern portion of the DuPont Property (area nearest to Hay Road as shown in Figure 1-2) in an area underlain by both native soils and made-land. The first state-issued landfill permit was received in October 1968. In 1993, landfill closure was initiated under DNREC Permit SW-93/01. Closure entailed installing a multi-layer geosynthetic cap over the landfill to inhibit precipitation infiltration. Closure was completed in 1996 and approved by DNREC in 1997. Post-closure care and monitoring of the closed landfill is currently conducted under DNREC Post-Closure Permit SW-93/01. A DNREC-approved National Pollutant Discharge Elimination System (NPDES) permit was issued for the DuPont Property in 1976 and remained in place until the Hay Road Landfill was closed in 1996.

1.3 Sludge Drying Site Background and Regulatory History

Adjacent to the closed landfill is a 23-acre parcel of land known as the Hay Road Sludge Drying Site (DE-0024). A site map is presented in Figure 1-2. The entire Hay Road Sludge Drying Site is underlain by made-land created by the USACE river dredging activities. Beginning in the early 1980s and continuing through 1996, waste sludge from the Plant was placed within bermed drying beds to dewater the solids prior to stabilization and disposal in the adjacent landfill, hence, the name “Sludge Drying Site.” During this time period, DuPont and the City of Wilmington were co-permitted by DNREC (Solid Waste Permit SW-83/23) to air-dry sludges from both the DuPont Edge Moor Plant and the City of Wilmington Wastewater Treatment Plant (WWTP) at the Sludge Drying Site. Sludge drying activities ceased in 1996 when the solid waste landfill was closed. During the landfill closure, the sludge drying beds were cleaned out and the excavated, dewatered solids were stabilized and placed in the landfill for final disposal.

Beginning in 1997 and continuing to mid-2001, the Plant generated approximately 500,000 tons of Staged IRM, which was transported as a saleable product and stored in a staging area at the Sludge Drying Site in preparation for sale as a soil substitute. Appendix C contains five maps (one for each year of product staging at the Sludge Drying Site) showing the limits of the Staged IRM for a given year. Based on site topography, historical photographs, and product production rates, the areal extent of Staged IRM at the Sludge Drying Site grew to approximately 23 acres by 2001. In mid-2001, DuPont discontinued marketing the product and ceased sending materials to the Sludge Drying Site. Since that time, the Plant has disposed of all IRM at industrial waste landfills.

DuPont conducted a DNREC-approved interim measure in 2002 to consolidate the areal extent of the Staged IRM from 22.7 acres to 15.9 acres (see Figure 1-2). The interim measure also involved the application of various coatings to cover the staged materials

and minimize potential water infiltration and airborne particle generation. Additional coatings have been applied to the Staged IRM on an as-needed basis, based on observations during monthly inspections. In 2007, DNREC approved a change in the coating material from the polymer (Soil Sement®) to fiber-reinforced cement (Posi-Shell®). A second Posi-Shell application was completed in the spring of 2008. DuPont conducts monthly inspections to monitor the continued integrity of the Posi-Shell coating and the effectiveness of the surrounding sediment and erosion control measures. The Posi-Shell covering continues to minimize potential human and ecological exposures to the Staged IRM.

In 2001, DuPont agreed to enter into the DNREC Division of Air and Waste Management's Site Investigation and Remediation Branch's VCP. The Sludge Drying Site was accepted into the VCP on September 11, 2002 to select a remedial alternative for the Staged IRM at the Sludge Drying Site. Consistent with the scope of work attached to the VCP documents, DuPont completed and submitted a *Final RI/RA Report* to DNREC on May 14, 2004. The report and remedial action objectives (RAOs) were approved on May 20, 2004, and a FFS was submitted to DNREC on June 18, 2004. DNREC subsequently approved the FFS. The purpose of the FFS was to develop and evaluate a limited range of remedial alternatives that meet the Sludge Drying Site RAOs and select the appropriate remedial plan.

DNREC prepared a Proposed Plan of Remedial Action (PPRA), which presented the cap-in-place remedy for the staged materials with institutional/engineering controls as the preferred remedial alternative for the Sludge Drying Site (DNREC, 2004). The VCP Agreement defined the nature and extent of contamination by the chemical properties and areal extent (e.g., footprint) of the Staged IRM Pile.

In response to public comments to the PPRA, HCR 22 was passed in June 2005 by the 143rd General Assembly of the House of Representatives. Following the request of HCR 22, DNREC engaged an independent engineering firm, Schnabel Engineering, to complete a review of the existing data that was used to support the PPRA. Schnabel Engineering recommended in their December 2006 report that additional technical data be obtained to more fully support DNREC's selection of a final remedial alternative. DuPont agreed to collect the information recommended by Schnabel Engineering, plus some additional data requested by DNREC.

1.4 Supplemental Investigation Scope of Work

A *Supplemental Investigation (SI) Work Plan* was submitted to DNREC on August 6, 2007, and later approved by DNREC on September 10, 2007. The SI scope of work presented the details of a comprehensive field program to collect the additional requested site data. The SI Work Plan included collecting and analyzing samples from all relevant environmental media at the site (e.g., Staged IRM and DM solids and groundwater), as well as surface water and sediment samples from Shellpot Creek. The SI was initiated in October 2007, and sample collection was completed in February 2008. Final validated analytical data were received in June 2008. A detailed discussion of the methodologies used to accomplish the SI tasks is presented in Section 2.0 and in the SI Work Plan, presented as Appendix A. The SI scope of work, as requested by

DNREC/Schnabel, and the additional work DuPont undertook, is summarized in the following discussion.

Six soil borings (PILE-1 through PILE-6) were advanced through or adjacent to the Staged IRM Pile (see Figure 1-4). Two samples were collected (one each from the upper and lower portions) from the Staged IRM at three locations. Twelve samples were collected from the Dredge Material: Low Permeability Unit (DM:LPU) to provide a vertical profile of constituents. Samples were analyzed for an extensive list of chemical constituents and to characterize geotechnical properties.

Three permanent monitoring wells (MW-71 through MW-73) and one temporary monitoring well (PILE-1) were constructed. One round of groundwater samples was obtained from the new monitoring wells and one existing monitoring well (MW-36A). All of these monitoring wells are screened within a water-bearing zone contained within the DMs [Dredge Material: Water-Bearing Zone (DM:WBZ)]. Two sediment samples (SC-1 and SC-2) and one surface water sample (SC-2) were collected from Shellpot Creek. Groundwater, surface water, and sediment samples were analyzed for an extensive list of chemical constituents.

In addition to the SI scope of work, a groundwater flow evaluation was completed in June 2008 to measure the primary flow path of shallow groundwater within the DM:WBZ. The evaluation included slug tests and a tidal study, using groundwater monitoring wells within and adjacent to the Sludge Drying Site, to obtain a more extensive understanding of the groundwater elevation and movement. Also in June 2008, a review of historical records and aerial photographs was completed to better understand past site operational history and to complement the evaluation of the SI technical data.

DNREC collected a total of 10 split samples from the media investigated (Staged IRM, DM:LPU, groundwater, surface water, and sediment) during the SI. DNREC also independently collected two Delaware River surface water and sediment samples (SC-3 and SC-4; see Figure 1-4). This report includes and presents both DuPont and DNREC analytical results.

1.5 Addendum Purpose and Organization

This Addendum documents work conducted at the Sludge Drying Site in accordance with the approved scope of work presented in the SI Work Plan (DuPont, 2007a). In addition, this Addendum includes an evaluation of migration and exposure pathways, a site-specific risk evaluation, and updates the findings previously presented in the 2004 RI/RA report to further demonstrate that the PPRA for the Iron Rich Staging Area is fully protective of human health and the environment from exposure to the staged materials.

This Addendum follows the general format of the previously submitted 2004 RI/RA report and is consistent with DNREC guidance "*Delaware Regulations Governing Hazardous Substance Cleanup*" (last revision February 2002) and the "*Hazardous Substance Cleanup Act (HSCA) Guidance Manual*" (last revision October 1994). This revised Addendum is organized into the following sections:

- Section 1.0 presents the report purpose, provides a brief discussion of the Sludge Drying Site background and regulatory history, and describes the SI scope of work. Additional information is presented in the 2004 RI/RA report.
- Section 2.0 is a description of the field investigation methods, the geotechnical testing, and the results from these activities.
- Section 3.0 provides information about the geology, hydrogeology, surface water hydrology and storm water runoff, meteorology, demography and land use, and ecological setting.
- Section 4.0 provides an identification of constituents of concern (COCs) and screening criteria and presents the analytical results from the SI.
- Section 5.0 identifies potential migration and exposure pathways for COCs contained within the Staged IRM.
- Section 6.0 presents the results of a generic risk evaluation, completed following DNREC guidance. In addition, this section details updates to the 2004 site–specific risk evaluation developed for the potentially complete exposure pathways identified in Section 5.0.
- Section 7.0 contains the summary, conclusions, and recommendations.
- Section 8.0 contains the references cited in this report.

2.0 SUPPLEMENTAL INVESTIGATION FIELD ACTIVITIES

The SI Work Plan (see Appendix A) included soil borings, groundwater sampling, surface water, and sediment sampling. This section describes the means and methods used in the implementation of the work plan. The field data, which are also presented in this section, are interpreted in subsequent sections of this report.

Activities performed at the Sludge Drying Site during the SI include the following:

- Advancement of borings and logging the resulting information.
- Collection and testing of samples for geotechnical and analytical properties.
- Installation of four monitoring wells (three permanent and one temporary) within the DM:WBZ.
- Evaluation of groundwater quality in the DM:WBZ.
- Sampling of surface water and sediments in Shellpot Creek.
- Slug testing to determine horizontal hydraulic conductivities.
- Completion of a tidal study and evaluation of groundwater flow.

2.1 Soil Borings

2.1.1 Field Methodology

Eight borings (PILE-1 through PILE-5, PILE-6/MW-71, MW-72, and MW-73) were advanced during the SI to develop a greater understanding of the site geology and nature of the subsurface conditions. The regional geology near the site is discussed in Section 2.2 of the 2004 RI/RA report, included as Appendix D. A more detailed discussion of the site geology is presented in Section 3.0 of this Addendum, which incorporates the findings of this field investigation. A Spider 5 sonic drilling rig was used to advance the borings because this drilling technology is capable of providing continuous, relatively undisturbed core samples through highly variable subsurface conditions. This method provides high quality and accurate subsurface information. To prevent the potential for cross contamination, a 6-inch steel casing was installed at each boring, keyed into the DM:LPU, and grouted in place to seal off the upper zones (Staged IRM or fill), prior to advancing the borehole through the DM:LPU. The boring locations are shown in Figure 1-4.

All cores obtained from all boreholes were visually classified, by the same field geologist, according to the Unified Soil Classification System (USCS). Use of this system ensures accurate and consistent descriptions of lithology. In addition, continuous screening of the cores was performed with a Mini RAE 2000 photo ionization detector (PID) equipped with a 10.6 electron Volt bulb. This screening allows for the detection of organic vapors in the core. All information was recorded in a field log book by the field geologist. After drilling, soil boring locations were surveyed by a professional land

surveyor for coordinates in the State Plane Coordinate System (NAD 83) and elevations in the North American Vertical Datum (NAVD 88).

2.1.2 Field Results

Soil borings were terminated at depths of 20 to 60 feet below ground surface (see Appendix E for boring logs). A thorough re-evaluation of available boring logs was conducted to confirm site geology and re-classify wells, where needed. A cross section location map and geological cross sections through the Sludge Drying Site are presented in Figures 2-1 and 2-2, respectively. Figure 2-3 and 2-4 present geological fence diagrams. The Staged IRM was placed on top of the DM, which forms the ground surface at the site and along most of Cherry Island. The DM unit is comprised of two distinct zones, DM:LPU and DM:WBZ. The geologic units present beneath the Sludge Drying Site can be generalized from top to bottom as follows:

- DM:LPU
- DM:WBZ
- Marsh Deposits
- First Aquifer
- Potomac Clay
- Bedrock

A detailed description of the lithology encountered is shown on the boring logs in Appendix E and is discussed in Section 3.0 of this Addendum. During drilling, saturated soils were encountered at elevations of -6 to +9 feet above sea level (NAVD 88).

2.1.3 Materials Testing

Field Methodology

DuPont collected geotechnical samples from the Sludge Drying Site soil borings to provide data for determining the hydrogeologic characteristics of the Staged IRM and DM:LPU. These samples were collected by drilling to depth as described in the previous section and then advancing a thin-walled Shelby tube. All geotechnical samples were collected in accordance with the *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes* [American Society for Testing and Materials (ASTM) D 1587-08]. For the Staged IRM, samples were collected from intervals near the pile surface (2 to 4 feet below the top of the pile) and near the base of the Staged IRM but above the transition zone to DM:LPU at the ground surface.

In addition to the geotechnical testing, Synthetic Precipitation Leaching Procedure (SPLP) tests for metals were performed. These tests were performed on two sample intervals from each of the three boring locations (PILE-1, PILE-2, and PILE-3) within the Staged IRM footprint. Samples were collected from the base of the Staged IRM and from the upper zone of the DM:LPU (e.g., just below the effective ground surface) to evaluate the leaching potential of metals from the Staged IRM.

Geotechnical Laboratory Results

A total of 22 samples were collected and submitted to the URS Totowa, New Jersey geotechnical laboratory for testing. Complete materials testing results for Staged IRM and DM:LPU samples, along with the ASTM methods used for the analysis, are presented in Appendix N. A summary of the measured hydraulic conductivities is presented in Table 2, and a summary of all measured parameters is presented in Table 3.

Grain size distribution results from the Staged IRM samples indicate a fine grained material with 63.7% to 90.1% of the sample particles passing a No. 200 sieve. The laboratory classified the Staged IRM as Organic Silts and Clays of Medium to High Plasticity (OH) according to the USCS. Measured hydraulic conductivity values range from 10^{-5} to 10^{-7} centimeters per second (cm/sec).

DM:LPU sample results indicate that 81.5% to 98.9% of the sample particles passed the No.200 sieve. The laboratory classified DM:LPU as Organic Silts and Clays of Low Plasticity (OL) and OH according to the USCS. Measured hydraulic conductivity values range from 10^{-4} to 10^{-8} cm/sec. The sample result of 10^{-4} cm/sec is an outlier and is not representative since organic material and roots were present in the sample.

A comparison of the fine grained fraction of the Staged IRM, DM:LPU, and DM:WBZ are presented in Figure 2-5. The objective of this figure is to depict variables in percentages of fines relative to location and depth. Samples for SPLP metals tests were collected in accordance with the work plan. The results are presented in Appendix I.

2.1.4 Monitoring Well Installations

Field Methodology

Three permanent groundwater monitoring wells (MW-71, MW-72, and MW-73) and one temporary well (PILE-1) were installed in the DM:WBZ beneath and adjacent to the Staged IRM. The purpose of these wells is to monitor the groundwater quality and conduct in-situ hydraulic tests. The monitoring wells were installed in the boreholes that were drilled as discussed above.

After borehole completion, wells were constructed with 5-foot lengths of 2-inch poly vinyl chloride (PVC), a 0.010-inch slot screen, and a 2-inch PVC riser. The screen intervals that were selected were based on the lithology that was logged during the borehole drilling. After completion, the wells were developed by alternately surging and purging the groundwater with a submersible pump. The wells were then completed with a stickup casing and were surveyed by a professional land surveyor in NAD 83 and NAVD 88 coordinate systems.

Field Results

The monitoring wells were installed at the locations shown in Figure 2-6. This figure also indicates which unit all Sludge Drying Site wells are screened in. Top of well screen elevations ranged from +7.53 feet to -2.2 feet. Bottom of well screen elevations ranged from +2.53 feet to -7.37 feet. Water elevations after development ranged from +5 feet to -2 feet. These levels indicate a potentiometric surface that (under confined conditions) rises above the confining layer. See Table 1 for a summary of monitoring well

information. Well construction diagrams are included in Appendix E with the borehole logs.

2.1.5 Groundwater Sampling

Field Methodology

Following monitoring well installation, and after an equilibration period to allow the groundwater to return to ambient conditions, groundwater samples were collected from each of the newly installed wells (MW-71, MW-72, and MW-73) and from the temporary well (PILE-1). Additionally, a groundwater sample was collected from existing monitoring well MW-36A. Water levels for all Sludge Drying Site monitoring wells were measured prior to sampling, and samples were collected using low-flow methodology. The samples were then submitted for laboratory analysis for dioxins, furans, metals, polychlorinated biphenyls (PCBs), pH, semi-volatile organic compounds (SVOCs), and volatile organic compounds (VOCs) in accordance with the work plan.

Groundwater Analytical Results and data Validation

Complete analytical results are presented in Appendix K. Dioxin and Furan, 1613 and 209 PCBs, and HR-PCB/1668A results were sent to Environmental Standards, located in Valley Forge, Pennsylvania, for third-party data validation. The results of the validation are included in Appendix K. Based on the validation, results were qualified due to blank contamination, out-of-criteria ion ratios, field duplicate contamination, quantitation below the practical quantitation limit (PQL), and reporting conventions for PCBs and polychlorinated dibenzodioxin (PCDDs)/polychlorinated dibenzofuran (PCDFs). These data may be used with an understanding of limitations of the qualified results. A deviation from the work plan resulted in octochlorostyrene not being analyzed by the lab. Analytical results for this compound are available from the DNREC split sample data.

2.1.6 Surface Water and Sediment

Field Methodology

During the SI, one surface water sample (SC-2) and two sediment samples (SC-1 and SC-2) were collected from Shellpot Creek. Only one surface water sample could be collected due to tidal conditions. This change in sample collection scope was approved by DNREC in the field. The sample locations are located upstream of the Staged IRM (SC-1) and near the southern shoreline of the Delaware River (SC-2). The sample locations are shown in Figure 1-4. The surface water sample was collected first from the base of the water column (taking care not to disturb the creek bed). The surface water sample collection was followed by collection of a sediment sample from the same location, utilizing current sediment sampling protocol.

Surface Water and Sediment Results

Both surface water and sediment samples were collected in accordance with the work plan. The analytical results are presented in Table 5 of Appendix I. Complete laboratory analytical results are presented in Appendix K along with the data validation report.

2.1.7 Slug Tests

Field Methodology

To aid the hydrogeologic evaluation of the site, in-situ hydraulic conductivity tests (i.e., slug tests) were performed. Tests were conducted on the four newly installed wells (MW-71, MW-72, MW-73, and PILE-1) as well as two previously existing wells (MW-33R and MW-35). Tests were conducted by placing a Model 500 pressure transducer/data logger into the well and allowing the water level to equilibrate. A slug was then lowered into the well to displace the water. The data logger continuously recorded the water level as it decreased during the falling head test. After equilibrium was reached, the slug was withdrawn, and the water level was again recorded as it rebounded.

Data logging equipment used consisted of sixteen Level Troll Model 700, ten Mini Troll-Pro and nine Levelogger L13001 transducers. The raw data from each of the slug tests and each well used in the tidal study is found in Appendix H. The data sheets list the serial number of each pressure transducer used.

Slug test data were analyzed using the Bouwer-Rice method to derive a value for hydraulic conductivity. These calculations were performed using the computer application Isoaqx, developed by Hydralogic, Inc.

Field Results

The calculated hydraulic conductivity values determined by the slug tests ranged from 10^{-3} to 10^{-5} cm/sec. The results of the slug testing are presented in Table 2. As can be observed, slug tests were conducted on four wells screened in the DM:WBZ. The geometric average of these four test results (8.42×10^{-4} cm/sec or 2.76×10^{-5} feet/sec) is representative of the hydraulic conductivity for the DM:WBZ.

2.1.8 Groundwater Flow Evaluation of DM:LPU

Field Methodology

A groundwater flow evaluation and tidal study were conducted to better understand the connectivity of the DM:LPU with Shellpot Creek and the Delaware River. The results from this evaluation were used to confirm the hydrogeologic characteristics of the shallow groundwater beneath the Sludge Drying Site and determine the primary flow path/direction.

Pressure transducers were installed in wells completed within the DM:WBZ, in existing monitoring wells screened in the First Aquifer Zone, and in the surrounding surface water bodies (i.e., Shellpot Creek and the Delaware River). Depth of water over each transducer was recorded at 1 minute intervals and was corrected to the site vertical datum (feet NAVD 88). No corrections were made for density differences because the salt line of the Delaware River does not extend significantly north (upriver) from the Delaware Memorial Bridge during the time of year when the study was conducted [Delaware River Basin Commission (DRBC), 2008; Cohen and McCarthy, 1963]. The tidal study was conducted from mid-May through early June. All data are provided in Appendix H. Table 1 provides information for Sludge Drying Site wells.

Field Results

Hydrographs illustrating the recorded water level data for the DM:WBZ wells and surface water bodies are shown in Figures 2-7a and 2-7b. The water level measured at the tide gate in Shellpot Creek and precipitation data recorded at the Delaware Solid Waste Authority (DSWA) Cherry Island municipal landfill [Northern Solid Waste Management Center (NSWMC)-2] are also included on the hydrographs. Two populations of data can be observed within these hydrographs: wells that exhibit a high correlation to the surface water tidal cycles and wells that have little or no tidal influence.

The two wells with the greatest tidal influence (MW-34A and MW-73) are the DM:WBZ wells that are closest to Shellpot Creek. DM:WBZ wells MW-35 and MW-72, which are similarly close to the Delaware River, showed minimal tidal influence (see Figure 2-7b). Well MW-36A, located directly adjacent to well MW-35, but screened slightly deeper within the DM:WBZ, displayed some tidal fluctuation.

3.0 SLUDGE DRYING SITE CHARACTERISTICS

This section presents a discussion of the physical characteristics of the site. In 1988 and 1989, the Sludge Drying Site was thoroughly investigated as a proposed expansion area for the Hay Road solid waste landfill (Cells 1-3). The results of these investigations were documented in the *Geotechnical Investigation Proposed Cell No. 4 Cherry Island Landfill Report* (Woodward-Clyde Consultants, 1990) and were summarized in the *Final RI/RA Report* (included herein as Appendix D). A total of 46 borings were drilled in the vicinity of the Sludge Drying Site prior to the SI (see Figure 3-1). Eight additional borings were advanced during the SI (see Appendix E for boring logs). The interpretation of the geology and hydrogeology described herein are based upon the 54 borings advanced at the 23-acre site. A discussion of the physical characteristics for the Staged IRM is also included, even though this material is not considered a site geologic unit.

3.1 Staged IRM

The Staged IRM sits directly on top of the DM:LPU, rises to almost 48 feet NAVD88, and covers approximately 16 acres. This material was brought to the site as a saleable product and stored while potential markets were being developed. The total volume of material is estimated to be 410,000 cubic yards (500,000 tons). Three borings, PILE-1 through PILE-3, were advanced during the SI through the Staged IRM. A description of field methodology has been previously described in Section 2.0.

The Staged IRM is described as red (when oxidized and dry) to a black or brown, silty clay textural consistency with medium plasticity. Minor intervals of poorly sorted silty sand and gravel were present from 18 feet to 25 feet deep in one boring (PILE-2). In two of the borings (PILE-2 and PILE-3), a transition zone was noted near the base of the pile, wherein Staged IRM and the underlying DM:LPU were commingled. The material was further described in the boring logs as moist, but not saturated, with no evidence of pooled water (or any other liquid) observed in any of the borings.

Results of geotechnical analysis of Staged IRM are presented in Table 3. This data indicates the fine-grained nature of the Staged IRM, with generally more than 80% of its mass consisting of silt or clay-size particles. The laboratory generally classified the Staged IRM as OH according to the USCS (see Appendix N). Correspondingly, the measured hydraulic conductivity values ranged from 10^{-5} to 10^{-7}cm/sec, which is characteristic of silty clays and clayey silts. Figure 2-5 illustrates the distribution of geotechnical analysis results, showing the percentage of mass of each sample that passed a No. 200 sieve (i.e., percent fines results). Grain-size distribution curves are presented in Appendix F.

3.2 Site Geology

The regional geology near the Sludge Drying Site was previously presented in Section 2.2 of the 2004 RI/RA report contained in Appendix D. Locally, the geology has been

influenced by the placement of dredged river sediments by the USACE. For purposes of discussion, the artificially emplaced DM is included as a geologic unit. From shallow to deep, the geologic units underlying the Sludge Drying Site are generalized as follows:

- DM:LPU
- DM:WBZ
- Marsh Deposits
- First Aquifer
- Potomac Clay
- Bedrock

These units are depicted on cross sections which are presented in Figures 2-1 and 2-2. Below are descriptions of the geologic units at the Sludge Drying Site. These unit designations do not necessarily represent the comprehensive characteristics or the material origin of the unit (e.g., the Marsh Deposits may include non-marsh materials, and the Potomac Clay includes beds of other grain sizes).

3.2.1 Dredge Material

The DM was placed at the Sludge Drying Site between 1927 and 1946. These materials were hydraulically dredged from the Delaware and Christina Rivers, transported by barge, and hydraulically transferred into an area behind the seawall and berms constructed adjacent to the Delaware River and Shellpot Creek. This mode of transfer resulted in variable deposition of the sluiced materials (e.g., a preferential settling of coarse-grained constituents adjacent to the discharge location and the deposition of finer fractions elsewhere). Subsequently, the DM unit, which forms the ground surface at the site, is comprised of two distinct zones, the DM:LPU and the coarser grained DM:WBZ.

DM:LPU

Eight borings, PILE-1 through PILE-5, PILE-6/MW-71, MW-72, and MW-73 were advanced through the DM:LPU during the SI. Based on historical investigation and SI results, the DM:LPU ranges from 8 to 21 feet thick with an average thickness of 15 feet.

The DM:LPU is described as a moist dark gray to black silty clay to elastic silt with discontinuous gray sand lenses. Organic material, including root fibers, is present in portions of the DM:LPU. Thin sand intervals were observed during drilling, but were not correlative between adjacent, closely-spaced boring logs. The presence of these sand lenses are depicted in the SI boring logs presented in Appendix E. These sand lenses are also depicted in the historical boring logs in Appendix F. Thin, discontinuous sand lenses were also visually observed in the cut face of the DM along the Delaware River. However, field data indicates that there is no continuity between these lenses, and the sandy intervals were not observed to be saturated during investigatory drilling. The DM:LPU did not display saturated conditions during installation of the SI borings, even within the discontinuous sand lenses.

DM:LPU samples were collected during the SI using thin-walled Shelby tubes and submitted for analysis of geotechnical parameters by ASTM International methods.

Results are provided in Appendices F and N and summarized in Tables 2 and 3 and Figure 3-6. The DM:LPU is fine-grained, generally consisting of more than 90% silt and clay-sized particles. The laboratory classified DM:LPU as OL and OH according to USCS.

The harmonic mean of measured DM:LPU vertical hydraulic conductivity values under the footprint of the Staged IRM Pile ranges from 10^{-7} to 10^{-8} cm/sec. These values are within the published range of clays and silty clays (Domenico and Schwartz, 1990). A slug test of MW-33R (located outside of the Staged IRM Pile footprint) was completed to obtain the horizontal hydraulic conductivity from an existing monitoring well screened in the DM:LPU. The resulting horizontal hydraulic conductivity of MW-33R was 2.60 x 10^{-5} cm/sec (see Table 2 and Figure 3-6). In layered sediments, horizontal hydraulic conductivity values typically exceed vertical hydraulic conductivity values by one or more orders of magnitude.

The DSWA intentionally located its nearby municipal solid waste landfills (NSWMC-1 at Pigeon Point and NSWMC-2 at Cherry Island) on dredge material because of the fine-grained nature, low hydraulic conductivity, and excellent confining properties (McCabe & Associates, 2005). The DM:LPU acts as a confining unit restricting vertical flow into the underlying DM:WBZ.

DM:WBZ

The DM:WBZ is a sandy unit that is consistently found beneath the DM:LPU at the Sludge Drying Site. This unit ranges from well to poorly graded sand with gravel and varying amounts of silt. The DM:WBZ is generally thinner to the west (see Figure 2-2). Although previous investigation reports did not identify the DM:WBZ in the western portion of the Sludge Drying Site, borings advanced during the SI encountered a thin layer of this sandy unit. The SI borings were terminated within or beneath the DM:WBZ.

On average, the DM:WBZ is estimated to be approximately 10 to 11 feet thick (see Figures 2-1 trough 2-4). The unit is thickest along the Delaware River berm, where it is almost 30 feet thick, and thinnest near the southwestern portion of the Sludge Drying Site, where it is approximately 1 foot thick.

3.2.2 Marsh Deposits

Based on investigations completed prior to the SI (Woodward-Clyde, 1979 and 1990; DuPont, 2004a), a Marsh Deposits unit (thick sequence of organic silty clay with organic matter, likely of Holocene age) underlies the DM: WBZ. Minor intervals of sand have been observed occasionally within the unit. This unit is not a significant component of the shallow hydrologic system.

This unit is thicker in the eastern portion of the site (i.e., thickest in the area of the Shellpot Creek and Delaware River confluence; see Figure 2-2). The lower portion of the Marsh Deposits unit contains more vegetation than the upper portion. Thus, it is possible that some upper portion of the unit consists of initially emplaced DM, and only the lower portion represents natural river-bottom or marsh deposits.

The Marsh Deposits act as an aquitard to isolate the overlying DM:WBZ from the underlying First Aquifer Zone. Boring logs and cross-sections completed during the

Geotechnical Investigation of Proposed Cell No. 4 Cherry Island Landfill (Woodward-Clyde, 1990) show that this unit ranges from approximately 20 feet thick in the western portion of the site to approximately 60 feet thick in the eastern portion of the site. The thickening of the Marsh Deposits in the area of the Staged IRM Pile serves to further isolate the underlying First Aquifer Zone in this area. Therefore, the DM:WBZ is the water-bearing zone of interest for the Sludge Drying Site.

3.2.3 First Aquifer Zone

Based on investigations completed prior to the SI, the First Aquifer Zone is generally dense to very dense silty sand and gravel (classified as SM/SW according to USCS). The First Aquifer Zone underlies the Marsh Deposits. The unit name is based upon historical usage and is not meant to imply that the unit is a productive water source. The First Aquifer Zone is not a significant component of the shallow hydrologic system.

The First Aquifer Zone likely represents a remnant of the Delaware Bay Group, although it could be part of the Columbia Formation (Ramsey, 2005). The unit is considered to be a relatively thin remnant locally and is located near the Fall Line between the Piedmont and Atlantic Coastal Plain physiographic provinces.

3.2.4 Potomac Clay

The Potomac Clay underlies the First Aquifer Zone. It consists primarily of red to varicolored (e.g., red, white, and yellow) clays to sandy clay from the upper portion of the Potomac Formation (Ramsey, 2005; Scott and Sugarman, 2006; Scott, 2006).

3.2.5 Bedrock

The bedrock underlying the Sludge Drying Site is described by others as consisting of banded gneisses that are part of the Wilmington Complex (Ward, 1959; Ramsey, 2005).

3.3 Hydrogeology

The hydrogeology was evaluated using published information, historical site information, and SI results. A discussion of this evaluation is provided in the subsections below.

3.3.1 Regional Hydrogeology

The regional hydrogeologic units of northern New Castle County, southeast of the Fall Line, are generally comprised of two distinct water-bearing units: the sandy Columbia Formation and sands of the underlying Potomac Formation. These units are generally separated by clays of the Potomac Formation. In the extreme northern reaches of New Castle County where the Hay Road Sludge Drying Site is located, the Fall Line is close to the Delaware River. Thus, depth-to-bedrock is much shallower near the Fall Line as compared to the Coastal Plain deposits of Delaware and New Jersey southeast of the site. At the Sludge Drying Site, the Columbia Formation is absent and replaced by a remnant of the more recent Delaware Bay Group. The regional Delaware

Bay Group and sandy units of the Potomac Formation are isolated from the shallower local site units by less permeable fine-grained materials (e.g., the Potomac Clays).

Delaware Geological Survey (DGS) hydrogeologic maps do not depict groundwater levels in the crystalline rocks of the Wilmington/New Castle area north of the Delaware Memorial Bridge.

3.3.2 Sludge Drying Site Hydrogeology

Most of the precipitation falling onto the Staged IRM Pile runs off the pile due to the temporary Posi-Shell® cover material. The limited amount of water that may pass through the cover material percolates down through the fine-grained Staged IRM and potentially through the fine-grained DM:LPU to the DM:WBZ. During the drilling of the PILE-1, PILE-2, and PILE-3 borings through the Staged IRM, saturated conditions were not encountered until depths of 32 to 48 feet below the surface (e.g., below top of pile). These depths are consistent with when the DM:WBZ was encountered in the respective borings. After the completion of the PILE-1 temporary well, which is screened in the DM:WBZ, the water level was allowed to equilibrate with atmospheric conditions and then rose to an elevation above the DM:LPU. The water levels in wells screened in the DM:WBZ rise to a level above the Staged IRM and DM:LPU interface, which indicates a semi-confining condition.

The relevant hydrogeologic flow system at the site is horizontal groundwater flow through the DM:WBZ toward Shellpot Creek. The Marsh Deposits unit acts as an aquitard, providing isolation of this flow system from the underlying First Aquifer Zone, Potomac Clay, and Bedrock. Groundwater elevation measurements and permeability testing in the primary hydraulic units support that the DM:WBZ and First Aquifer Zone are isolated from one another by the silty clay Marsh Deposits aquitard.

DM:WBZ

The permeability and consistent occurrence of this unit below the relatively impermeable DM:LPU aquitard defines the DM:WBZ as the first (i.e., shallowest) continuous unit capable of storing and yielding water within the Sludge Drying Site. The flow within the DM:WBZ is predominantly horizontal, as groundwater discharges primarily to Shellpot Creek with a minor component of flow going to the Delaware River.

Prior to the SI, one well (MW-36A) was identified as being screened in the DM:WBZ. During the SI, four wells (PILE-1, MW-71, MW-72, and MW-73) were installed and screened in the upper portion of this unit. Additional activities associated with the SI included resurveying, benchmark confirmation, and re-evaluation of historical boring logs. The data were used to refine the subsurface conceptual model, resulting in the assignment of wells MW-34A, MW-35, and MW-41A to the DM:WBZ.

Lithologic data from the DM:WBZ wells indicate that the unit as a well to poorly-graded sand with gravel. However, the log recorded at PILE-1 describes the DM:WBZ as silty fine sand with trace amounts of organics. Thus, the unit permeability characteristics will vary from location to location. The range in hydraulic conductivity for this unit is 2.10×10^{-4} to 4.23×10^{-3} cm/sec, with a geometric mean of 8.42×10^{-4} cm/sec.

First Aquifer Zone

The overlying Marsh Deposits aquitard isolates the semi-confined to confined First Aquifer Zone from the shallow DM:WBZ local flow system. Two wells (MW-37 and MW-40) are believed to be screened within the First Aquifer Zone. The screen depth of MW-40 is approximately -20 feet to -25 feet NAVD88. The screen depth of MW-37 is -61 feet to -67 feet NAVD88, which is deeper than MW-40. A review of the lithologic log at MW-37 reveals that the -61 feet sand layer is the first permeable zone below the DM:WBZ. The fluctuations in water levels observed at MW-37 during the tidal study are consistent with those measured within the Delaware River. This indicates that the First Aquifer Zone in the area of MW-37 is in good hydraulic connection to the Delaware River.

Groundwater Flow Evaluation and Tidal Study

A groundwater flow evaluation and tidal study were conducted to better understand the hydrogeologic conditions at the site and to understand the connectivity of the site subsurface geologic units with Shellpot Creek and the Delaware River. Results from this evaluation confirmed the hydrogeologic characteristics of the shallow flow system and provided a refined understanding of groundwater flow beneath the Sludge Drying Site.

Water level data recorded in DM:WBZ monitoring wells are shown in Figures 2-7a and 2-7b. Local precipitation data obtained from the DSWA Cherry Island municipal landfill, the Shellpot Creek tide gate water level data, and the Delaware River water level data are also included on the hydrographs. Two populations of data can be observed within these hydrographs: wells that exhibit a high correlation to the surface water tidal cycles and wells that have little or no tidal influence.

The two wells with the greatest tidal influence (MW-34A and MW-73) are the DM:WBZ wells that are closest to Shellpot Creek. Wells MW-73 and MW-34A are located approximately 115 feet and 260 feet, respectively, from Shellpot Creek. DM:WBZ wells MW-35 and MW-72, which are similarly close to the Delaware River, showed minimal tidal influence (see Figure 2-7a). DM:WBZ well MW-36A, located directly adjacent to well MW-35 but screened slightly deeper within the DM:WBZ, displays some tidal fluctuation.

Three water level data sets representing high tide, mid-tide (falling tide), and low tide were extracted from the data stream for each DM:WBZ well. These data were contoured to create representative potentiometric surface maps as shown in Figures 3-2, 3-3, and 3-4. Each of these maps indicates that the prevailing hydraulic gradient is from the southwestern portion of the property near MW-41A to the northeast and near MW-73 and Shellpot Creek. This interpretation is consistent with the observation that wells MW-34A and MW-73 have a high degree of connection with Shellpot Creek. Based on this data set, it is likely that groundwater upgradient of and beneath the Staged IRM Pile flows toward and discharges into Shellpot Creek in the area near MW-34A and MW-73. Similarly, groundwater at MW-71 (on the southeastern edge of the Staged IRM Pile) follows a flow path that discharges to Shellpot Creek.

The highest water level elevation is consistently measured in monitoring well MW-41A, although the DM:WBZ thins in this area and there is a thick layer of DM:LPU in this region. The data suggest there is a source of water (e.g., groundwater recharge) to the

DM:WBZ in this area, possibly from the large wastewater finishing ponds or from the 12th Street Extension sewer pipe. This hypothesis is supported by several head anomalies observed in the hydrograph for MW-41A. The shapes of the anomalies suggest the apparent influence of off-site pumping on the water level measurements for the well. As seen in the Figure 2-7a hydrograph, three periods of "drawdown" occur at about 20:00 hours on May 27, 18:00 hours on June 1, and 01:00 hours on June 3. These "drawdown" periods are not observed in any of the other hydrographs and do not coincide with any known work that was being conducted at the Sludge Drying Site. The shape of the observed head responses suggest the "drawdown" periods may be related to possible sump dewatering along the sewer line.

Additional observations include the following:

- A steep horizontal hydraulic gradient is evident in the DM:WBZ near the Delaware River shoreline, as would be expected if the seawall is impeding direct communication with the river.
- Although tidal influence is prominent in the wells adjacent to Shellpot Creek, little change in hydraulic gradient is observed across much of the central and southwestern portions of the Sludge Drying Site throughout the tidal cycle. Measurements and observations showed that materials under the Staged IRM Pile are less permeable than materials in the subsurface along Shellpot Creek.
- Minimal flow is directed from beneath the site towards the Delaware River during all phases of the tidal cycle, and little to no flow originates or passes under the Staged IRM footprint and discharges to the Delaware River.
- The potentiometric head in the PILE-1 well is not influenced by precipitation events, indicating a lack of percolation through the temporary cover, the Staged IRM, and the DM:LPU during rain events. This finding suggests precipitation is not a major contributor of water to groundwater in the DM:WBZ.
- Water temperature measurements in well MW-73 fluctuated in direct correlation with the tidal cycle, indicating physical mixing of water from Shellpot Creek with groundwater in the DM:WBZ under this portion of the Sludge Drying Site (see Figure 3-5).

Potentiometric surface maps were used to calculate a seepage velocity and time of travel from near the center of the Sludge Drying Site to the discharge area along Shellpot Creek. The following equation and representative estimates of the site conditions were used to calculate the advective seepage velocity:

$$v = ki/n, \text{ where:}$$

- $k = (8.42 \times 10^{-4}$ cm/sec) $(3.281 \times 10^{-2}$ feet/cm) $= 2.76 \times 10^{-5}$ feet/sec
- i = A horizontal hydraulic gradient (i) of 0.005 measured from MW-41A to MW-73
- n = effective porosity of 15%

$v = (2.76 \times 10^{-5}$ feet/sec) (0.005 feet/feet)/0.15 $= 9.20 \times 10^{-7}$ feet/sec = 29 feet/year

The resulting advective seepage velocity was calculated as approximately 29 feet per year. The calculated seepage velocity and advective travel time estimate the rate of groundwater flow, but do not necessarily represent potential travel times for individual constituents. Transport of individual chemical constituents may be slower than that of the groundwater due to physical and chemical interactions with the aquifer matrix (e.g., sorption, dispersion, abiotic and biotic degradation processes, etc.).

3.4 Surface Water Hydrology and Storm Water Runoff

The Sludge Drying Site is bound on the north by Shellpot Creek and the east by the Delaware River. The Delaware River and Shellpot Creek are located at approximately 300 feet and 200 feet, respectively, from the edge of the Staged IRM Pile. Both Shellpot Creek and the Delaware River are tidally influenced. The mean high tide in the Delaware River in the area of the Sludge Drying Site is typically +6.5 feet NAVD88 and the low tide is approximately –1.0 NAVD88.

As noted previously, the Sludge Drying Site and the current Staged IRM Pile are located on made-land, created by DM emplacement between the late 1920s and 1940s within the historical footprint of the Delaware River channel. On the current DuPont parcel, berms were constructed, and the DM was impounded to an elevation of approximately 22 feet NAVD88. Hay Road currently has an elevation of 14 feet NAVD88 at its intersection with the 12th Street Extension and an elevation of 12 feet NAVD88 at the bridge crossing Shellpot Creek.

The Sludge Drying Site is surrounded by a berm made of low permeability silts/clays, probably from historical DM:LPU or clayey/silt river deposits. The berm elevations along both water bodies range from approximately 20 feet to 25 feet NAVD88. The 100-year floodplain elevation level is 8.9 feet NAVD88. According to the Federal Emergency Management Agency (FEMA) Flood Insurance Map (#10003C0160 G, effective date October 6, 2000), the entire DuPont Property, City of Wilmington, and DSWA properties are Zone X. Zone X is defined on the map as follows: “areas determined to be outside of 500-year floodplain” (FEMA, 2000).

All surface water drainage is controlled by the perimeter berms. All storm water runoff exits the Sludge Drying Site to the Delaware River at the southeastern corner of the site after passing through sediment control devices. The water quality of the storm water runoff is monitored at Outfall D-002 as part of the Solid Waste Landfill Post-Closure Care Permit. Results from this monitoring program are submitted annually to DNREC and are summarized in the *2007 Annual Hydrogeological Report* (DuPont, 2008) for the Hay Road Landfill. No exceedances of Uniform Risk-Based Standard (URS) values for surface water were noted in the most recent monitoring event reported (June 2006). Storm water samples were not collected in 2007 because there were no qualifying storm events. As concluded in the report, storm water concentration trends over time are generally stable.

The annual mean stream flow in Shellpot Creek is measured at a U.S. Geological Survey (USGS) gaging station located on Philadelphia Pike. Data have been collected from 1946 to the present. Unfortunately, this gaging station is too far upstream of the Sludge Drying Site and the Shellpot Creek tidal gate to accurately reflect the volume of surface water

flowing past the site. Because the Sludge Drying Site is located at the confluence of Shellpot Creek and the Delaware River and below the Shellpot Creek tidal gate structure, a large amount of water exists in Shellpot Creek next to the site relative to the stream flows recorded upstream at the gaging station. The measured annual mean stream flow in Shellpot Creek at the gaging station ranged from a low of 5.31 cubic feet per second (cfs) in 1954 to a high of 19.1 cfs in 1996. The data for this stream gage are provided at http://nwis.waterdata.usgs.gov (USGS, 2008). However, DNREC communication suggests a critical low flow (e.g., 7Q10) value of 0.29 cfs and a long-term median flow of 3.77 cfs at the mouth of Shellpot Creek. DuPont believes a value of 10 cfs (24,468,480 liters per day) is considered representative for a conservative long-term average flow past the Sludge Drying Site Delaware River surface-water flow is monitored at a gaging station located in Trenton, New Jersey. This gaging station is far upstream of the Sludge Drying Site and represents a lower base flow than what actually flows past the site. This gaging station is used by the DRBC and DNREC for their work on the Delaware River and will be used in this Addendum as a conservative value for Delaware River flow volumes at the Sludge Drying Site. The measured mean harmonic flow for the river is 7,402 cfs at this measurement station.

3.5 Regional Water Use

Regional water use was investigated by reviewing DGS geological boring logs that identify installed water wells; requesting a well radius search from the DNREC Division of Water Resources, Water Supply Section; and interviewing the local water company. Well searches of DNREC records were conducted in 2000 (radius search) and again in 2007 (local parcel search) to identify local water use. Results for 2000 are presented as part of the 2004 RI/RA report (see Appendix D); 2007 results are provided in Appendix G. None of the wells identified by the well search were described as drinking water supply wells. The lack of potable wells in this area is evidence that the Sludge Drying Site is not located over a viable potable water aquifer. Water quality data collected from the Hay Road Landfill monitoring program confirm that naturally occurring chlorides, iron, and manganese render the groundwater unsuitable for potable purposes. Based on this information, no consumptive use of water occurs within 3 miles of the Sludge Drying Site.

Additionally, the Sludge Drying Site is located within the boundaries of the City of Wilmington groundwater management zone (GMZ), which was established by DNREC in August 2001 to prevent the installation of water supply wells in this area (DNREC, 2001).

3.6 Meteorology

The Sludge Drying Site is located approximately 6.2 miles from the Greater Wilmington New Castle County Airport. Additional meteorological information is provided in Section 2.5 of the 2004 RI/RA report (see Appendix D).

3.7 Demography and Land Use

A summary of demographic and land use information is provided in Section 2.6 of the 2004 RI/RA report (see Appendix D).

3.8 Ecological Setting

The existing temporary Posi-Shell® cover over the IRM Pile effectively mitigates the potential for exposure by wildlife. Direct exposures to wildlife are, thus, expected to be minimal. In addition, the Posi-Shell® cover system also limits the amount of vegetation that could grow on the Staged IRM.

The Delaware River and Shellpot Creek are located adjacent to the Sludge Drying Site. While both of these water bodies support various types of aquatic life (including fish such as channel catfish, striped bass, and white perch), they are located in an area that is highly industrialized.

Numerous studies have been and continue to be performed on the impact of industry on the Delaware River. For example, DNREC has collected fish tissue samples in response to several regulatory programs including total maximum daily load evaluations, fish advisories, waste site cleanup, and natural resource damage assessment. A study of Shellpot Creek was completed by various industry parties (e.g., Amtrak, DuPont, and ATU) in 2007 and submitted to DNREC for review. DuPont is in the process of incorporating site-specific information into the Regional Risk Model as part of the Delaware River Initiative. These studies can be used to provide perspective as part of a holistic approach to addressing the potential impact of the Sludge Drying Site.

4.0 NATURE AND EXTENT OF COCS

This section updates the nature and extent of COCs, previously presented in Section 3.0 of the 2004 RI/RA report (see Appendix D), by incorporating the additional information from the SI. The additional data support the original conclusions regarding source and identification of COCs, as discussed below.

The section follows DNREC's VCP Agreement process for identifying COCs that are then carried through a generic risk assessment evaluation. The first step involves comparison to DNREC's URS. Human health risk-based screening at this point corresponds to a risk level of 10^{-6} and a hazard quotient of 0.1. However, DNREC's decisions for remedial action are set at 10^{-5} and HQ of 1 (EPA, 1996). The ten-fold difference is built into the process to account for potential cumulative risk. Those constituents that failed the URS screen for human health are carried forward to a cumulative risk evaluation.

In addition to the generic risk assessment, an updated site-specific exposure evaluation was also performed to evaluate potential risks following capping of the Staged IRM. In this evaluation (see Appendix M), the COCs were defined using site-specific information as well as the Region III screening levels for the leaching to groundwater pathway. Thus, the site specific exposure evaluation results in an expanded list of COCs that is different from the COCs determined from the VCP Agreement process.

Regardless of how the COCs were defined (either via the VCP Agreement or the site-specific exposure evaluation), all detected constituents were evaluated and cumulative risk is taken into account.

The analysis of the nature and extent of COCs is an essential step in the development of a Conceptual Site Model (CSM) and, ultimately, for developing RAOs for unacceptable exposure pathways. For the Sludge Drying Site, the CSM was developed using information on potential sources, physiochemical characteristics, potential constituent release mechanisms, potential environmental pathways, and potential receptors. Previous components of the CSM were presented in the 2004 RI/RA report (see Appendix D). The CSM presented here incorporates the SI results to provide an updated and refined version of the CSM presented in the 2004 RI/RA report.

The CSM for the Sludge Drying Site was developed to evaluate the potential for the Staged IRM to impact human health and the environment. The CSM includes the following four primary components:

1) Identification and characterization of known and potential source areas
2) Preliminary identification of COCs
3) Definition of primary transport mechanisms
4) Identification of potential receptors and exposure points

This section presents the first two components listed above. Components three and four are discussed in Section 5.0. The identification of COCs in this section and migration

and exposure pathways in Section 5.0 serve as a basis for the risk evaluation presented in Section 6.0.

4.1 Identification of COCs and Screening Criteria

The U.S. Environmental Protection Agency (EPA) identified the five metals listed below as major COCs in its groundwater risk assessment for IRM (EPA, 2000). The risk assessment served as the basis for the EPA's September 14, 2000, proposal to list certain wastes from the titanium dioxide, chloride-illmenite manufacturing process as Resource Conservation and Recovery Act (RCRA) hazardous waste (EPA, 2001).

- Antimony
- Arsenic
- Iron (identified based on DuPont process knowledge)
- Manganese
- Thallium

In addition to the metals identified by the EPA (2001), chemical analyses conducted by DuPont and process knowledge indicated that the following persistent, bioaccumulative, and toxic (PBT) compounds may also be present in the Staged IRM:

- Hexachlorobenzene
- Hexachlorobutadiene
- Octachlorostyrene
- Pentachlorobenzene
- PCBs (primarily as PCB 209)
- Chlorinated dioxins and furans [primarily as octachlorodibenzofuran (OCDF)]

The five metals identified by the EPA and the above PBT compounds identified by DuPont are subsequently referred to as the primary COCs associated with the Staged IRM.

While the focus of the discussion below is on the primary COCs identified above, all detected constituents were screened against the applicable URS screening criteria, consistent with the DNREC VCP Agreement guidance. Those constituents that failed the screening were retained as COCs. In addition, octachlorostyrene, which does not have DNREC URS values, was retained as a COC.

The screening levels for Staged IRM, DM:LPU, groundwater, surface water, and sediment are as follows:

- Staged IRM and DM:LPU
  Constituents detected in Staged IRM and DM:LPU were compared to the DNREC Non-Critical Area Restricted Surface and Subsurface Soil URS values for protection of human health. The soil URS values reflect a combination of standards, including EPA soil screening levels (SSLs) for compounds with

inhalation concerns, other miscellaneous guidelines, and risk-based values based on an excess cancer risk of 1 in 1,000,000 (10^{-6}) and a hazard quotient of 0.1.

- Groundwater
  Constituents detected in groundwater were compared to the DNREC generic groundwater URS values for protection of human health. Groundwater URS values reflect a combination of standards, predominantly including EPA maximum contaminant levels (MCLs), health advisory limits, other miscellaneous guidelines, and risk-based values derived to reflect a carcinogenic risk of 10^{-6} and a non-carcinogenic hazard quotient of 0.1.
- Surface Water and Sediment
  Constituents detected in surface water and sediment were compared to the DNREC generic URS values for protection of the environment. Surface water and sediment URS values are derived to evaluate potential ecological receptors and, similar to those above, reflect a combination of standards, including Delaware and federal water quality standards protective of aquatic life, EPA Ecotox Threshold Benchmark Values, and other ecological screening benchmarks.

Exceedances of the generic URS screening levels do not in themselves indicate either a confirmed release from the Sludge Drying Site or an unacceptable exposure. Rather, the screening levels serve to indicate potential concerns for human and ecological exposure. A discussion of primary COCs identified in each of the media investigated is presented in the subsections below and summarized in Table 4 and Figure 4-1. Additional constituents detected above screening levels in each of the media investigated are also presented in the subsections below and are included in the Risk Assessment Information System (RAIS) cumulative calculations. The analytical results from the historical characterization and more recent SI samples and DNREC split sample results are presented in Appendix I.

4.2 Staged Iron-Rich Material

The SI analytical results for Staged IRM are similar to historical analytical results. Prior to the SI, characterization of the Staged IRM was based upon samples collected before the material was placed in the staging area. During the SI, additional Staged IRM samples were collected from borings PILE-1, PILE-2, and PILE-3 installed within the footprint of the Staged IRM Pile (see Figure 1-4). At each of these three locations, one sample was collected from near the surface of the pile (i.e., top), and a second sample was collected from near the base of the pile (i.e., above the DM:LPU interface/ground surface). The analytical results from the historical characterization and more recent SI samples are summarized in Table 4 and presented in their entirety in Table 1 of Appendix I.

4.2.1 Comparison of Metal COCs to Screening Criteria

Of the five primary metal COCs (antimony, arsenic, iron, manganese, and thallium) identified in Section 4.1, only three (arsenic, iron, and manganese) were detected at concentrations that exceed the soil URS values in at least one Staged IRM sample. As

shown in Table 1 of Appendix I, arsenic was detected in one 1999 characterization sample (#91941001) at a concentration of 14.5 milligrams per kilogram (mg/kg), just slightly greater than the URS value of 11 mg/kg. Arsenic was not detected above the URS in any of the other characterization or SI samples. Iron and manganese concentrations exceeded URS values in all nine Staged IRM samples where these constituents were analyzed. Iron concentrations ranged from 91,600 mg/kg (2001 characterization sample DPE-SO-1) to 332,000 mg/kg (SI sample PILE-1-IRM-BASE) versus. the 61,000 mg/kg URS value. Manganese concentrations ranged from 10,300 mg/kg (1999 characterization sample #91941001) to 36,000 mg/kg (SI sample PILE-1-IRM-NEAR_SURFACE) versus the 4,100 mg/kg URS value.

In addition to the primary metal COCs detected above soil URS values, vanadium was also detected at concentrations above soil URS values in Staged IRM samples collected during the SI (see Table 1 of Appendix I). All three samples collected from the base of the Staged IRM Pile contained vanadium concentrations greater than the 1,400 mg/kg URS value.

4.2.2 Comparison of Organic COCs to Screening Criteria

Primary organic COCs include four SVOCs as well as PCBs and chlorinated dioxin/furans. Of the SVOCs, one constituent (hexachlorobenzene) was detected at concentrations that exceed the soil URS values. As shown in Table 1 of Appendix I, hexachlorobenzene exceeded the 3.6 mg/kg URS value in both the historical characterization and current SI samples. Hexachlorobenzene was detected above the URS value in 10 out of 14 Staged IRM samples, with a maximum detected concentration of approximately 55 mg/kg observed in characterization sample EM-IR-S07. The maximum detected concentration observed in the SI samples was 19 mg/kg. No free-phase hexachlorobenzene was observed during visual logging of the pile area borings during the SI field effort. Hexachlorobenzene concentrations measured during the SI were lower than those used previously to calculate the potential volume of free-phase hexachlorobenzene in the Staged IRM Pile, which indicated the hexachlorobenzene is not present in significant amounts as a separate pure phase, either as a dense nonaqueous phase liquid or as a solid organic compound (DuPont, 2007b).

Octachlorostyrene was analyzed by DNREC in split samples collected during the SI. Hexachlorobutadiene was analyzed by both DuPont and DNREC. Neither of these compounds was detected in any of the samples. Pentachlorobenzene was not scheduled for analysis in the approved SI work plan (see Appendix A). However, available data collected by the Plant for Toxic Release Inventory reporting indicate pentachlorobenzene concentrations in the material are below URS values (see Appendix J).

Seventeen chlorinated dioxin/furan congeners, including OCDD and OCDF, were analyzed in the SI Staged IRM samples (see Table 1 of Appendix I). Of these 17 congeners, soil URS values are available for two congeners: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin (HxCDD). Neither TCDD nor HxCDD was detected in the SI Staged IRM samples.

High-resolution analytical methodology was employed to analyze samples for individual PCB congener concentrations. Although some pairs of PCBs coelute during analysis and

cannot be separated, this high-resolution method allows calculation of precise total PCB concentrations. Total PCBs were calculated by summing the 209 individual PCB congener concentrations analyzed and reported by the laboratory. One-half of the detection limit was used in the summation calculation for individual congeners that were not detected in the sample. The calculated total PCB concentrations were compared to the 1 mg/kg total PCB soil URS value. None of the calculated total PCB concentrations exceeded the soil URS in the SI samples collected by DuPont (see Table 1 of Appendix I). However, total PCB concentrations slightly exceeded the soil URS value in split samples collected by DNREC. As shown in Table 1 of Appendix I, concentrations of PCB 209 measured in the DNREC split samples were approximately two times greater than PCB 209 concentrations measured in the DuPont SI samples.

Analytical characterization data show Staged IRM has a distinct distribution pattern (or "fingerprint") of both dioxin/furan and PCB congeners.

- More than 90% of the furans in Staged IRM are OCDF.
- OCDF concentrations are generally three to four orders of magnitude higher in concentration than OCDD concentrations.
- The PCB 209 congener accounts for greater than 90% of the total PCB congeners present by mass.

4.2.3 Additional Observations

Characterization data collected during the SI demonstrate the chemical stability of Staged IRM for most measured parameters. The pH measured in the Staged IRM was approximately 7 to 8 standard units (SU) regardless of the sample depth. Results from the SPLP indicated that manganese was the only primary metal COC that was detected in the SPLP sample at concentrations above groundwater URS values (see Table 2 of Appendix I). Test results showed iron was not detected in the SPLP leachate with a detection limit of 0.052 mg/L. Measured SPLP concentrations were actually less than concentrations observed in upgradient groundwater monitoring locations (see Tables 2 and 4 in Appendix I).

Chloride concentrations ranged from 116 mg/kg (sample PILE-1-IRM-NEAR_SURFACE) in the top 2 to 4 feet of the pile to 80,600 mg/kg (sample PILE-2-IRM-BASE) near the bottom 27 to 29 feet of the pile (see Table 1 of Appendix I). No soil URS value exists for chloride. These concentrations are not attributable to the dissolution and leaching of ferric chloride, but can be explained by the Staged IRM physical properties and chemical composition (see Appendix O for more information). When it was emplaced, the filtered product consisted of approximately 48 wt% metal oxide/hydroxide solids, approximately 6 wt% calcium chloride (in solution), and the remaining 46 wt% was water. Calcium chloride is highly soluble in water and would be expected to migrate from top to bottom of the Staged IRM Pile as rain water percolated downward through the pile prior to implementation of the temporary cover interim measure.

4.3 DM:LPU

DM:LPU samples were previously collected in 2002 from three locations (DM-2, DM-9, and DM-14) and during the SI from six locations (PILE-1 through PILE-6). Sample locations are shown in Figure 1-4. The 2002 historical samples were collected from near the surface of the DM:LPU (i.e., ground surface) in areas that had been previously covered by the IRM Pile. The SI samples were collected from boring locations adjacent to the pile and through the pile, with vertical profiling at two locations (PILE-1 and PILE-5). Depth ranges for DM:LPU samples indicate the interval of sampling as measured from the top of DM:LPU or ground surface. The analytical results from the historical characterization and more recent SI samples are summarized in Table 4 and presented in their entirety in Table 3 of Appendix I.

4.3.1 Comparison of Metal COCs to Screening Criteria

Of the five primary metal COCs (antimony, arsenic, iron, manganese, and thallium) identified in Section 4.1, only three (arsenic, iron, and manganese) were detected (in at least one DM sample) at concentrations that exceed the soil URS values. As shown in Table 3 of Appendix I, arsenic concentrations ranged from 11.5 mg/kg (sample PILE-2-DM) to 49.7 mg/kg (sample PILE-5-DM) vs. the 11 mg/kg soil URS value. Arsenic was not detected above the soil URS value in any of the 2002 DM:LPU samples. Conversely, iron and manganese exceedances of soil URS values were noted in the 2002 DM:LPU samples but not the SI samples.

4.3.2 Comparison of Organic COCs to Screening Criteria

The only primary organic COC that exceeded the soil URS values was total PCBs. The two samples (PILE-1 and PILE-5) that exceeded the soil URS value were collected from a depth approximately 10 feet below the Staged IRM/DM:LPU interface. None of the shallow DM:LPU soil samples exceeded the URS screening criteria for organic compounds. Total PCB concentrations in PILE-1 and PILE-5 samples were 1.2 and 1.1 mg/kg, respectively, just slightly above the 1 mg/kg soil URS value. Other primary organic COCs were either not detected (octachlorostyrene) or were detected below soil URS values (hexachlorobenzene, hexachlorobutadiene, and dioxins/furans). Estimated concentrations of TCDD and HxCDD were below soil URS values.

A detailed evaluation of the total PCB and dioxin/furan chemical composition showed that the individual PCB congener and dioxin/furan distribution pattern in the DM:LPU is different from the Staged IRM “fingerprint” pattern as defined in Section 4.2.2. For example, OCDF concentrations were typically less than OCDD concentrations in the DM:LPU SI samples, but OCDF concentrations are 1,000 to 10,000 greater than OCDD concentrations in the Staged IRM. Similarly, PCB 209 concentrations in the DM:LPU represent less than 20% of the total measured PCB concentrations, whereas PCB 209 concentrations in Staged IRM represent greater than 90% of the total measured PCB concentrations. Furthermore, TCDD was detected in DM:LPU but not detected in Staged IRM. These findings show a different “fingerprint” for the organic detections at depth in the DM:LPU and suggest the source is not due to the Staged IRM.

The lowest measured dioxin and furan concentrations are observed in the shallowest SI samples just below the surface of the DM:LPU, near the interface with the Staged IRM. Estimated (J-value) concentrations of dioxins and furans increase with depth through the DM, with the highest concentrations detected approximately 8 to 10 feet below the top of the DM:LPU. The vertical distribution and chemical composition of chlorinated dioxin/furan and PCB congener constituents in the DM:LPU, indicate the Staged IRM Pile is not the source of these compounds in the DM:LPU. Both advective (e.g., leaching) and diffusive transport of these compounds from the Staged IRM to the DM:LPU would result in concentration profiles with the highest concentrations observed at the interface of the two units and then decreasing with depth or distance from the interface. The opposite pattern is observed in the SI data, suggesting the measured peak constituent concentrations at 8 to 10 feet below the interface are not due to migration from the Staged IRM.

A likely explanation for the constituent distribution in the DM:LPU is that river sediments were impacted prior to emplacement and creation of the Sludge Drying Site. The deeper layers of the DM:LPU would have been emplaced first, as the made-land was built up, and would have been sourced from younger river channel sediments that would have been most impacted by the increased industrial activities of the 1920s, 1930s, and 1940s. These sediments could have contained chemical constituents from potentially thousands of regional industrial, municipal, and agricultural sources. As the dredging advanced deeper into the river channel sediments, older, less impacted material would have been recovered and placed onto the Sludge Drying Site, burying the more impacted material.

4.3.3 Additional Observations

Of the primary metal COCs analyzed using SPLP, arsenic, iron, and manganese were detected at concentrations above groundwater URS values (see Table 2 of Appendix I). Aluminum was also detected in the SPLP samples above groundwater URS values. However, similar to Staged IRM SPLP results, the measured DM:LPU SPLP leachate concentrations are less than the concentrations observed in groundwater monitoring locations upgradient of the Staged IRM Pile (see Tables 2 and 4 in Appendix I).

Measured chloride concentrations in the DM:LPU are lower than concentrations measured in the overlying Staged IRM (see Table 3 of Appendix I). Similarly, the pH values measured in the DM:LPU were 5 to 6 SUs, approximately two whole standard units lower than pH values measured in the Staged IRM. These results indicate limited vertical leaching and migration from the Staged IRM down into the underlying DM:LPU.

4.4 Groundwater

Available information regarding the DM:WBZ was enhanced by the installation and sampling of three monitoring wells (MW-71, MW-72, and MW-73) and one temporary monitoring well (PILE-1) during the SI. Each of these wells was screened in the upper portion of the DM:WBZ to characterize groundwater immediately beneath the DM:LPU. In addition, existing monitoring well MW-36A, located between the Staged IRM Pile and the Delaware River, was sampled. This well was re-classified during the SI as being

screened in the DM:WBZ. The results from these five samples were combined with groundwater data from wells associated with the adjacent Hay Road Landfill (MW–34A, MW-35, and MW-41A). The analytical results from the historical characterization and more recent SI samples are summarized in Table 4 and presented in their entirety in Table 4 of Appendix I.

During the SI, both unfiltered and filtered samples were collected and analyzed to obtain total and dissolved fractions of metals. Samples from MW-71 and MW-72 exhibited high turbidity; therefore, analyses for PCBs and dioxin/furan congeners were conducted on filtered samples from these locations in addition to the unfiltered samples.

4.4.1 Comparison of Metal COCs to Screening Criteria

Each of the five primary metal COCs (antimony, arsenic, iron, manganese, and thallium) identified in Section 4.1 were detected at concentrations that exceed the groundwater URS values in one or more of the SI monitoring locations (MW-36A, MW-71, MW-72, MW-73, and PILE-1) and landfill locations (MW-34A, MW-35, and MW-41A). As shown in Table 4 of Appendix I, total arsenic concentrations above the 10 micrograms per liter (µg/L) URS value ranged from 19.4 µg/L in location MW-36A to 84.2 µg/L in location MW-72. Dissolved arsenic concentrations also exceeded the groundwater URS values in four out of five SI sample locations and in upgradient monitoring location MW-41A (see Table 4 of Appendix I).

Total and dissolved iron and manganese exceeded groundwater URS values in each of the five SI locations. Total iron concentrations ranged from 153 milligrams per liter (mg/L) in location MW-72 to 1,140 mg/L in location MW-71 (above the 0.3 mg/L groundwater URS value). Total manganese concentrations ranged from 10.6 mg/L in location MW-72 to 113 mg/L in location MW-73 (above the 0.050 mg/L groundwater URS value). Total and dissolved iron and manganese concentrations were similar in magnitude. Total and dissolved iron and manganese concentrations in upgradient location MW-41A and landfill locations MW-34A and MW-35 also exceeded groundwater URS values. Historical DM placement in this area has likely impacted the groundwater quality both upgradient and throughout the Sludge Drying Site (DuPont, 2004a). Additional information discussing the geochemical conditions and water quality of the DM:WBZ is contained in Appendix O.

In the SI samples, dissolved antimony and thallium were also detected above groundwater URS values. However, total antimony and thallium were either not detected or below groundwater URS values. In addition to the primary metal COCs detected above groundwater URS values, total aluminum, total and dissolved barium, total and dissolved cadmium, and dissolved vanadium were also detected above URS values in groundwater collected from one or more of the monitoring locations (see Table 4 of Appendix I).

4.4.2 Comparison of Organic COCs to Screening Criteria

Primary organic COCs analyzed during the SI were either not detected (hexachlorobenzene and hexachlorobutadiene) or detected below groundwater URS values (total PCBs). Octachlorostyrene was not detected in the DNREC split sample for

location MW-73. Concentrations of PCB and dioxin/furan congeners were significantly lower in filtered samples than in the corresponding unfiltered samples, indicating that these compounds are associated with or sorbed to solid-phase particles rather than dissolved in the groundwater.

In addition to the primary organic COCs discussed above, acetone was detected in one sample (MW-71) during the SI at an estimated concentration of 69 µg/L (vs. the 61 µg/L groundwater URS value). Acetone is a common laboratory contaminant and is not an expected COC at the Sludge Drying Site. Therefore, this detection is likely anomalous. No other detections for acetone were observed in the SI samples.

4.4.3 Additional Observations

Chloride was observed in each of the five SI monitoring locations above the National Secondary Drinking Water Standard of 250 mg/L. (Chloride does not have a groundwater URS value.) Chloride concentrations in the SI samples ranged from 2,210 mg/L at location MW-72 to 36,700 mg/L at location MW-73. Chloride concentrations in upgradient location MW-41A and landfill locations MW-34A and MW-35 were also above the screening value of 250 mg/L.

Chloride was observed at a concentration of 36,700 mg/L in SI location MW-73, which is located between the Staged IRM Pile and Shellpot Creek. This value is higher than concentrations measured during previous monitoring events at the landfill and at upgradient locations (see Table 4 of Appendix I). However, chloride concentrations in DM:WBZ groundwater directly beneath the IRM Pile (sample PILE-1) are much lower (9,220 mg/L). The observed concentrations in the DM:WBZ may be the result of additive contributions from the DM:LPU as well as the Staged IRM. Appendix O provides additional discussion.

4.5 Surface Water

The Sludge Drying Site is bordered to the North by Shellpot Creek and to the East by the Delaware River. The condition of surface water in Shellpot Creek at its confluence with the Delaware River is assessed twice per year by surface water sampling at two locations as required by the DNREC Solid Waste Permit for the adjacent Hay Road Landfill. One location in Shellpot Creek is upstream of the landfill, west of the Hay Road Bridge. The other location is downstream of the landfill at the confluence of Shellpot Creek and the Delaware River. These locations are currently analyzed for chloride and metals (arsenic, cadmium, chromium, copper, iron, lead, and selenium).

Appendix P contains a historic data summary table for the landfill permit Shellpot Creek surface water quality sampling. This table was originally found in the "2007 Annual Hydrogeological Report for the Hay Road Landfill, DuPont Edge Moor Plant, Edgemoor, Delaware". The surface water sampling spans 14 years, from May, 1993 to October, 2007 and has 30 individual sampling events. The data documents that both the upstream and downstream water quality in Shellpot Creek is very poor. For example, all but one sample result for total iron exceeds the DNREC SWQS and EPA Ambient Water Quality Criteria (AWQC) of 1.0 mg/L at the upstream location; with values ranging from 0.928 mg/L to 2,910 mg/L. At the downstream location total iron ranges from 0.6 mg/L to 62.9

mg/L. Upstream surface water samples values for lead arsenic, cadmium and chromium have also exceeded their respective DNREC SWQS and EPA AWQC. Although analysis of PCBs in surface water is not required by the DNREC Solid Waste Permit, sampling of sediments for PCBs is required. The upstream sediment samples for the PCBs show detections of various congeners. Shellpot Creek receives run off from several potential sources of contamination located upstream of the site in the watershed. These include:

- An industrialized area of the City of Wilmington;
- Route I-495;
- Wilmington Maintenance Facility (Amtrak rail-yard);
- DP&L Ash Landfill; and
- City of Wilmington Sludge Drying/Processing beds.

For PCBs in particular, the most important upstream source is the Wilmington Maintenance Facility. This 110 acre site, operated from 1940 to late 1970's, was used for equipment maintenance and disposed of PCB laden transformer oil. A 1981 investigation report by Woodward-Clyde Consultants, found in DNREC SIRB's on-line data base reported soil sample results for PCBs that were as high as 894 mg/kg. The entire 110 acre site drains into the Shellpot Creek basin.

During the SI, one surface water sample was collected from Shellpot Creek (SC-2) near the southern shoreline. The surface water sample location is shown in Figure 1-4. In addition, DNREC independently collected samples at several locations in Shellpot Creek, and data from two of these locations, in the vicinity of the Sludge Drying Site. These samples (shown in Figure 4-2) were collected at locations upstream of the site (I-495 to Wires) and just upstream of the IRM Pile and SI location SC-2 (between Tide Gate and Mouth). Independent of the SI, DNREC also collected surface water samples from two locations along the Delaware River: one sample upstream (SC-3) and one sample downstream (SC-4) of the Sludge Drying Site (see Figure 4-2). Analytical results from historical data, the more recent SI sample SC-2, and the DNREC samples are summarized in Table 4 and presented in their entirety in Table 5 of Appendix I.

4.5.1 Comparison of Metal COCs to Screening Criteria

Of the five primary metal COCs (antimony, arsenic, iron, manganese, and thallium) identified in Section 4.1, only iron (total) and manganese (total and dissolved) were detected in SI sample SC-2 at concentrations that exceeded the URS values for surface water.

The data shown in Table 5 of Appendix I, illustrate an increasing concentration trend for total iron from upstream to downstream locations. Total iron concentrations ranged from 518 mg/L at the upstream location to 7.370 mg/L at location SC-2 to a concentration of 12.9 mg/L at the downstream location. However, dissolved iron was not detected above the URS value at SC-2. The URS value for iron in surface water is 1.0 mg/L. Conversely, a decreasing concentration trend was noted for manganese concentrations. Total manganese concentrations ranged from 0.865 mg/L at the upstream location to

0.845 mg/L at location SC-2 to a concentration of 0.482 mg/L at the downstream location. The URS value for manganese in surface water is 0.080 mg/L.

Iron and manganese also exceeded the URS values for surface water in the DNREC samples collected from the Delaware River (SC-3 and SC-4). For each exceedance, concentrations observed upstream of the Sludge Drying Site (SC-3) were slightly higher than concentrations observed downstream of the Sludge Drying Site.

4.5.2 Comparison of Organic COCs to Screening Criteria

Of the primary organic COCs, only total PCBs exceeded the surface water URS value in both the DNREC and DuPont sample locations (see Table 5 of Appendix I). Total PCB concentrations ranged from 24,700 picograms per liter (pg/L) upstream of the Sludge Drying Site (DNREC location I-495 to Wires) to 11,708 pg/L (DuPont SI location SC-2). In each of the DNREC samples, PCB 209 concentrations, in addition to several other PCB congeners, were qualified with a B indicating blank contamination.

A detailed evaluation of the total PCB and dioxin/furan chemical composition showed that the individual PCB congener and dioxin/furan distribution pattern in the surface water is different from the Staged IRM “fingerprint” pattern as defined in Section 4.2.2. For example, OCDF concentrations were typically less than OCDD concentrations in the surface water samples, but OCDF concentrations are 1,000 to 10,000 greater than OCDD concentrations in the Staged IRM. Similarly, PCB 209 concentrations in the surface water represent less than 15% of the total measured PCB concentrations, whereas PCB 209 concentrations in Staged IRM represent greater than 90% of the total measured PCB concentrations. These findings show a different “fingerprint” for the organic detections in the surface water relative to the observed “fingerprint” for Staged IRM.

Lighter, less-chlorinated homologues surrounding the Pentachlorobiphenyls (PeBC) and Hexahlorobiphenyls (HxBC) were also evident in the samples collected. This distribution is similar in pattern to commercial PCB blends sold by several manufacturers under various trade names (Monsanto's "Aroclor" blends being the most common in the U.S.) from the 1930s until their ban in the 1970s (Fiedler, 1997; Frame, 1999) and used by upstream potential sources along Shellpot Creek. IRM does not contain appreciable concentrations of these lighter, less chlorinated homologues. Therefore, PCB congener and dioxin/furan distribution patterns observed in the surface water samples are considered representative of contributions from a mixture of different source materials.

Total PCBs also exceeded the URS value for surface water in river locations SC-3 and SC-4. Similar to the metal COC exceedances noted earlier, concentrations observed upstream were slightly higher than concentrations observed downstream, and the PCB congener and dioxin/furan distribution patterns observed in the samples are representative of contributions from a mixture of different source materials.

In general, the pattern of PBTs observed in surface water is consistent with results observed in a previous surface water evaluation of Shellpot Creek (DuPont, 2002). The conclusions of the Shellpot Creek screening assessment were as follows:

- IRM has a distinct distribution pattern of both PCBs and dioxin/furan congeners.

- Principal sources of both PCBs and dioxins are present along Shellpot Creek above Hay Road.
- The data suggest that IRM may have contributed to the PCB 209 concentrations in lower Shellpot Creek.
- The data suggest that IRM may have contributed to the OCDF concentrations in lower Shellpot Creek.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further study. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, Shellpot Creek surface water and sediment data collected upstream of the DuPont Property and the tide gate (as part of the Hay Road Landfill Post Closure Care monitoring permit) document historical and current upstream exceedances for PCBs and metals (including iron).

4.5.3 Additional Observations

In addition to the COCs identified in sample SC-2, total lead slightly exceeded the URS value of 3.2 µg/L. Total lead was present at an estimated concentration of 10.3 µg/L in the field duplicate sample but was nondetect in the parent sample. Dissolved selenium was present at an estimated concentration of 9.5 µg/L, exceeding the URS value of 0.4 µg/L. However, total selenium was nondetect, at a detection limit of 9.4 µg/L (above the URS value). Chloride was detected but does not have a URS value.

4.6 Groundwater to Surface Water Discharge

Results for the groundwater flow evaluation and potentiometric surface contours (see Figures 3-2, 3-3, and 3-4) demonstrate that groundwater in the DM:WBZ beneath the Staged IRM primarily follows a flow path to Shellpot Creek and not the Delaware River. For this reason, the evaluation below will focus on Shellpot Creek.

The volume of groundwater discharge to Shellpot Creek from the DM:WBZ is calculated in the following manner: **Q=kia**, where **Q** equals the volume discharged in gallons per day, **k** is the hydraulic conductivity in feet per day, **i** is the hydraulic gradient, and **a** is the cross sectional area along the Creek Bank/DM:WBZ interface. Representative values used in the calculations are defined below.

k = 8.42E-04 cm/sec, for the DM:WBZ (see Table 5 in Appendix M) = 2.38 ft/day.

i = 0.005, calculated from the hydraulic head difference between wells MW-41A and MW-73 and a separation distance equal to 1,461 feet (see Figure 3-3).

a = (768 ft x 10 ft), the pile is approximately 768 feet wide along Shellpot Creek (see Figure 1-2) and the bank/saturated zone is 10 feet thick (see Table 7 in Appendix M).

Using the above parameter values, the number of gallons of DM:WBZ groundwater discharging into Shellpot Creek per day is as follows:

Q = (2.38 ft/day)(0.005)(768 ft x 10 ft)= 91 cubic feet of water per day (or 2,577 liters per day).

To calculate the mass loading of a particular contaminant, the concentration of that contaminant in the groundwater must be multiplied by the flow, Q. Using the recent iron (1,220 mg/L) and for manganese (117 mg/L) results for well MW-73, which is near the bank of Shellpot Creek and between the Staged IRM Pile and Shellpot Creek, gives the following mass load:

Iron: (1,220 mg/L)(2,577 l/day) = 3,143,940 mg/day. However, due to the flow in Shellpot Creek, this mass load is mixed with 9,224,617 liters per day (i.e., 3.77 cfs, the DNREC suggested long-term median flow, see Section 3.4 above). This results in a true average surface water concentration in Shellpot Creek of 0.34 mg/L for iron using the concept of a Surface Water Protection Factor (SWPF) as described below.

The SWPF is calculated by dividing the Shellpot Creek surface water flow (9,224,617 liters per day) by the water discharged through the DM:WBZ (2,577 liters per day):

(9,224,617 l/d) / (2,577 l/d) = 3,580 SWPF.

The protection factor can then be divided into a groundwater analyte concentration to calculate the concentration of that analyte in the river due to the groundwater discharge. Using the MW-73 iron example above gives the following:

(1,220 mg per liter)/(3,580 SWPF) = 0.34 mg per liter.

Using the SWPF and the highest iron concentration measured in well MW-34A (220 mg/L on April 9, 2001, see Appendix D), which, like MW-73, is also located near the bank of Shellpot Creek, results in the following surface water concentration:

(220 mg/L)/(3,580 SWPF) = 0.06 mg/L.

Both calculated potential surface water concentrations are less than the DNREC SWQS/EPA AWQC for iron, which is 1.0 mg/L (found in Table 3b of Appendix M).

Manganese: (117 mg/L)(2,577 l/day) = 301,509 mg/day. However, due to the flow in Shellpot Creek, this mass load is mixed with 9,224,617 liters per day (i.e., 3.77 cfs, the DNREC suggested long-term median flow, see Section 3.4 above). This results in a true average surface water concentration in Shellpot Creek of 0.033 mg/L for manganese.

Using the SWPF and the highest manganese concentration measured in well MW-34A (4.81 mg/L on April 9, 2001, see Appendix D), which, like MW-73, is also located near the bank of Shellpot Creek, results in the following surface water concentration:

(4.81 mg/L)/(3,580 SWPF) = 0.0013 mg/L.

Both calculated potential surface water concentrations are less than the DNREC URS criteria for surface water for manganese, which is 0.080 mg/L (see Table 4).

Based on the above calculations, the groundwater discharge (represented by the water quality in wells MW-73 and MW-34A) to Shellpot Creek has no adverse impact for both iron and manganese, given the low mass load and large degree of mixing the groundwater receives. A similar analysis for groundwater discharge to the Delaware River using groundwater concentrations in Well MW-35, MW-36A, or MW-72 would show an even lower impact, given the even larger flow (i.e., higher protection factor) in the Delaware River. This evaluation of COCs already present in the groundwater excludes any attenuation of metals by the clayey silt spoils material due to sorptive or other geochemical/biological retardation mechanisms. Therefore, site COCs in groundwater at their present concentrations at the Shellpot Creek Bank/DM:WBZ interface do not present any unacceptable risk to either Shellpot Creek or the Delaware River.

The maximum concentration of Iron that can be present in groundwater without having an exceedance of the DNREC SWQS/EPA AWQC of 1.0 mg/L in Shellpot Creek can be calculated by the following formula:

$$C_{gwmax} = (C_{surfacewaterAWQC})(Q_{surfacewater})/Q_{gw}$$

Where C is concentration in mg/L and Q is discharge in liter per day.

For iron, this gives C_{gwmax} = (1.0 mg/L)(9,224,617 l/day)/2,577 l/day = 3,580 mg/L. This is the calculated maximum concentration of iron that could be present in groundwater that discharges to Shell Pot Creek without creating an exceedance of the DNREC SWQS/EPA AWQC for iron. As shown above, the iron concentrations in groundwater discharging to Shellpot Creek are below this value.

For manganese, this gives C_{gwmax} = (0.080 mg/L)(9,224,617 l/day)/2,577 l/day = 286 mg/L. This is the calculated maximum concentration of manganese that could be present in groundwater that discharges to Shell Pot Creek without creating an exceedance of the DNREC URS standard for manganese. As shown above, the manganese concentrations in groundwater discharging to Shellpot Creek are below this value.

4.7 Sediment

The sediment erosion control structure at Outfall D002 consists of a concrete box (installed December 2001) preceded by a sediment-settling area. The erosion control structure essentially prevents off-site sediment discharge. The concrete box has a valve/pipe combination weir for overflow and a French drain filtered underdrain system. Another (even larger) concrete box was installed during the closure of the Hay Road Landfill in 1996. This older concrete box, in conjunction with the settling pond, minimized sediment migration to the Delaware River prior to 2001.

DuPont semi-annually collects sediment samples from two locations within Shellpot Creek (upstream and downstream) as part of the Hay Road Landfill monitoring program. Before 2001, these sediment samples were analyzed only for metals. PCB and dioxin/furan analyses were added in October 2001. Typically, the results indicate no impact to sediments from the landfill. The upstream samples usually contain higher levels of inorganic and organic constituents than the downstream samples. The data are submitted annually to DNREC.

During the SI, sediment samples were collected from two locations in Shellpot Creek (see Figure 1-4). One location was collected upstream of the IRM Pile (SC-1), and one location was collected near the southern shoreline of the Delaware River (SC-2).

DNREC independently collected sediment samples at several locations in Shellpot Creek; data from two of these samples, located in the vicinity of the Sludge Drying Site, are also included in the tables. These locations, which are detailed in Figure 4-2, were collected upstream of the Sludge Drying Site (I-495 to Wires) and just upstream of the IRM Pile and near the SI location SC-1 (between Tide Gate and Mouth). DNREC also collected sediment samples from two locations along the Delaware River: one upstream sample (SC-3) and one downstream sample (SC-4) (see Figure 1- 4). Analytical results from historical data, the more recent SI samples, and DNREC samples are summarized in Table 4 and presented in Table 6 of Appendix I.

4.7.1 Comparison of Metal COCs to Screening Criteria

Of the five primary metal COCs (antimony, arsenic, iron, manganese, and thallium) identified in Section 4.1, only arsenic was detected in samples from locations SC-1 and SC-2 at concentrations that exceed the URS values for sediment. Iron, manganese, and thallium were also detected, but do not have sediment URS values. Similar to surface water, an overall decreasing concentration trend was noted for iron and manganese between upstream and downstream locations in Shellpot Creek.

Arsenic also exceeded sediment URS values in the DNREC samples collected from the Delaware River (SC-3 and SC-4). Iron and manganese were also detected, but no sediment URS values exist for these metals.

4.7.2 Comparison of Organic COCs to Screening Criteria

Similar to the surface water results, of the primary organic COCs, only total PCBs exceeded the sediment URS value in both the DNREC and DuPont sample locations (see Table 6 of Appendix I). A decreasing total PCB concentration trend was noted between upstream and downstream sample locations. In addition, similar to surface water, the individual PCB congener and dioxin/furan distribution pattern in the sediment is different from the Staged IRM “fingerprint” pattern as defined in Section 4.2.2. For example, OCDF concentrations were typically less than OCDD concentrations in the sediment samples, but OCDF concentrations are 1,000 to 10,000 greater than OCDD concentrations in the Staged IRM. Similarly, PCB 209 concentrations in the sediment samples represent less than 12% of the total measured PCB concentrations, whereas PCB 209 concentrations in Staged IRM represent greater than 90% of the total measured PCB concentrations. These findings show a different “fingerprint” for the organic detections in the sediment relative to the observed “fingerprint” for Staged IRM.

Total PCBs also exceeded the sediment URS values in DNREC samples from river locations SC-3 and SC-4, with concentrations observed upstream being slightly higher than concentrations observed downstream. In addition, PCB congener and dioxin/furan distribution patterns observed in the samples are considered representative of contributions from a mixture of different source materials.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further study. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, Shellpot Creek surface water and sediment data collected upstream of the DuPont Property and the tide gate (as part of the Hay Road Landfill Post Closure Care monitoring permit) document historical and current upstream exceedances for PCBs and metals (including iron).

4.7.3 Additional Observations

In addition to the primary metal COCs identified earlier, the following seven additional constituents were detected in the SI Shellpot Creek samples at concentrations above sediment URS values: barium, copper, lead, mercury, nickel, silver, and zinc. Chloride, which does not have a sediment URS value, was also detected in the sediment samples.

Two additional constituents (nickel and zinc) also exceeded sediment URS values in samples collected from river locations SC-3 and SC-4 (but not in Shellpot Creek samples). In addition, barium was detected at concentrations above the URS values but was qualified by DNREC as being detected in the associated method blank. As stated previously, chloride does not have a sediment URS value.

4.8 Air

Since 2001, temporary cover materials have been applied to the Staged IRM Pile surface to minimize and/or eliminate the potential for airborne Staged IRM dusts and particles. Soil-Sement (a polymer-based material) was applied from 2001 through 2006. In 2007, a fiber-reinforced, cement temporary cover (Posi-Shell®) was applied for the first time on the Staged IRM Pile. Both temporary cover materials are effective in minimizing the potential for airborne particles from the Staged IRM Pile, but the use of Posi-Shell® has the following advantages:

- Posi-Shell® is gray in color after drying, which contrasts the red-brown Staged IRM color. As a result, any area of the Staged IRM Pile not covered by Posi-Shell® can be easily identified and repaired. Soil-Sement dries clear and blends with the Staged IRM color.
- Posi-Shell® is applied to a measurable thickness of approximately ¼ inch. Soil-Sement is partially absorbed into the Staged IRM, and its thickness cannot be readily measured.

4.9 Biota

The Sludge Drying Site does not support significant vegetation; therefore, it is not a likely source of food for birds or burrowing animals. Small mammals may track across the site but are not likely to linger. In addition, the existing temporary cover over the

Staged IRM Pile effectively mitigates the potential for exposure by wildlife. Direct exposures to terrestrial wildlife are, thus, expected to be minimal.

As reported in the Shellpot Creek Assessment (DuPont, 2002), fish tissue data was collected by DNREC for an evaluation of PCB and dioxin/furan profiles that might be expected in Shellpot Creek. DNREC conducted another fish tissue evaluation in October 2007 to support several regulatory programs including: total maximum daily load evaluations, fish advisories, waste site cleanup, and natural resource damage assessment. Additional information regarding sample locations, sampling methodology, and analytical parameters can be found on the DNREC website: (http://www.dnrec.state.de.us/DNREC2000/Library/Water/swmonpro.pdf).

Although COCs have been detected in fish tissues in the tidal portion of Shellpot Creek adjacent to the site, the low proportion of site-related to non-site related constituents present indicates that these constituents are related not only the site but to regional sources as well. Tidal water from the Delaware River that mixes with the water from Shellpot Creek along with potential upstream sources in Shellpot Creek may be responsible for the presence of constituents not found in IRM. However, at this time, the relative significance of these detections is unclear and warrants further study.

4.10 Data Usability

Analytical data reported in this section were reviewed in accordance with the DuPont Data Review (DDR) process to determine data usability. The in-house DDR consisted of an evaluation of the data based on hold times, blank contamination, matrix spike/matrix spike duplicate (MS/MSD) recoveries, MS/MSD relative percent differences, laboratory control spike/control spike duplicate recoveries, laboratory control spike/control spike duplicate relative percent differences, and surrogate recoveries. Based on the review of the quality assurance/quality control (QA/QC) data for the sampling events, the results for the samples reported in Appendices I and K were considered usable for the project objectives with some qualifications added during the data review. Additional information regarding these qualifications is contained in the DDR Narrative Report(s) included with the analytical data in Appendix K.

Samples for dioxin/furan and PCB analysis were also evaluated by a third party (Environmental Standards, Inc.). Findings of the data validation are provided in Appendix K. Qualifiers applied during the validation process were added to the DuPont Corporate Remediation Group (CRG) Envista database along with those applied during the DDR process.

5.0 POTENTIAL MIGRATION AND EXPOSURE PATHWAYS

In the 2004 RI/RA report, potential migration and exposure pathways for COCs in environmental media at the Sludge Drying Site were identified and evaluated (in Section 4.0 "Contaminant Fate and Transport"). The evaluation used existing information regarding current conditions at the Sludge Drying Site and information regarding human and environmental populations.

The evaluation included the following potential migration pathways and exposures:

- Direct contact to workers and trespassers
- Inhalation of air/wind-blown materials by workers and off-site human and ecological receptors
- Ingestion of groundwater. (Note: Groundwater use at the site as a drinking water source is prohibited per the Wilmington GMZ as shown in the Memorandum of Agreement, DNREC, Between: Division of Air and Waste Management and Division of Water Resources, For: City of Wilmington, August 2001.)
- Leaching of materials from Staged IRM and migration to site groundwater
- Groundwater to surface water migration and subsequent exposures to off-site human and ecological receptors in surface water
- Wind-blown deposition and storm water runoff to surface water

The 2004 RI/RA exposure evaluation results indicated the following:

- Exposures via direct contact with the Staged IRM Pile were minimal because the site is fenced, and worker activity is monitored.
- There was some historic potential for wind-dispersed material to be deposited in the nearby surface water bodies, the Delaware River, and Shellpot Creek. An evaluation was performed to assess the potential impact of both windblown deposition and surface runoff (Cherry Island Staging Area Potential Historic Release Assessment, DuPont, Nov. 2001, Sept. 2002, Dec. 2003). The conclusions were as follows:
  - Resulting exposures to surface water and sediment receptors were possible but were unlikely to be significant. A Posi-Shell cover has been applied to the Staged IRM Pile to limit wind and surface water erosion and rain water infiltration.
  - Estimated concentrations in the Delaware River and Shellpot Creek did not exceed AWQC.
  - Using "reasonable worst-case assumptions," cumulative risks of PBTs (resulting from potential historic wind-blown deposition and surface runoff of Staged IRM materials to surface water) were expected to be approximately an order of magnitude below *de minimus* levels (less than 1×10^{-6} risk).

- Leaching to groundwater was possible but likely to be minimal because of the 10-foot layer of low permeability dredged soils below the Staged IRM Pile. However, groundwater in this area is not used, and no exposures were expected.
- Exposure evaluations of the groundwater to surface water pathway indicated that the Staged IRM Pile would not present an unacceptable exposure to human health or ecological receptors—either with or without a cap.

Details of the evaluation are provided in Sections 4.0 and 5.0 of the 2004 RI/RA report, which is included in Appendix D. The 2004 RA evaluation concluded that groundwater to surface water interactions were the only potentially complete "exposure pathway" for the evaluation of potential risk from the Staged IRM Pile.

Data from the SI were incorporated into the CSM and used to update the exposure evaluation for COCs in environmental media at the Sludge Drying Site. Based on this re-evaluation, the potential migration pathways and receptor exposures are expected to be limited as described below.

- The Staged IRM Pile has been consolidated and covered with polymer and fiber reinforced cement covers. Therefore, surface runoff, airborne transport, and exposures via direct contact with the Staged IRM are minimal. These pathways are not considered potentially complete exposure pathways.
- Leaching to groundwater is possible but likely to be minimal due to the 10-foot layer of low permeability Dredge Material below the Staged IRM and the limited infiltration through the Posi-Shell cover. Groundwater use in this area is restricted by the GMZ and human ingestion exposures are not expected.
- Impacted groundwater may discharge to surface water bodies, including the Delaware River and Shellpot Creek.

Per DRBC regulations (Delaware River Basin Commission, Administrative Manual-Part III, Water Quality Regulations, September 2006, Section 3.30.5), the site falls within Zone 5. Delaware River water in Zone 5 is not designated for drinking water purposes. Because river water and groundwater sources are restricted by regulation, there is no drinking water source in the vicinity of the Staged IRM Pile. Consequently, potential receptors are limited to recreational users of the Delaware River and Shellpot Creek and aquatic organisms. Consistent with Section 4.0 of the 2004 RI/RA report (see Appendix D), potentially complete exposure pathways for the Staged IRM Pile may include the following:

- Recreational Users of the Delaware River and Shellpot Creek – Incidental ingestion of and dermal contact with surface water while fishing and ingestion of harvested fish from the creek/river
- Ecological Receptors of the Delaware River and Shellpot Creek – Ingestion of and direct contact with surface water and direct ingestion of biota with accumulated constituents

Section 6.0 presents further evaluation of these potentially complete exposure pathways using site-specific transport modeling to evaluate the potential human health and ecological risks due to groundwater discharge to surface water.

6.0 RISK EVALUATION

In accordance with VCP Agreement guidance (DNREC Hazardous Substance Cleanup Act Guidance Manual, October 1994), DNREC requires a conservative baseline risk evaluation of current site conditions. Hence, consistent with the 2004 RI/RA report, constituents detected in Staged IRM, DM:LPU, groundwater, surface water, and sediment samples collected during the SI were compared to generic URS values for protection of human health and the environment. As previously discussed in Section 4.0 and summarized in Table 4, some constituents exceeded their screening criteria. However, these exceedances do not necessarily indicate an actual risk from exposure.

Constituents in Staged IRM, DM:LPU, and groundwater samples that were detected above the generic URS values for protection of human health were further evaluated using a risk calculator. The 2004 RI/RA report used the DNREC risk calculator to evaluate potential risk to human health; however, recent guidance from DNREC required the use of the RAIS website (http://rais.ornl.gov/prg/ for_sel_data.shtml) for evaluating the potential risk to human health. The generic URS values for surface water and sediments are based on protection of the environment. Thus, these constituents/media were not evaluated with the RAIS but were retained for further site-specific evaluation (see Section 6.2).

Overall, the generic baseline risk evaluation is intended to serve as a conservative evaluation to determine the need for remedial actions and help define the RAOs. However, this protocol does not consider site-specific elements to help determine actual risk (DNREC, 1999). Therefore, in addition to the generic evaluation required by the VCP Agreement, DuPont has performed a number of site-specific evaluations over the past several years (2001 to 2005) to define the actual potential risk from Staged IRM that has been stored at the Sludge Drying Site and to determine the most protective remedy for closure. As part of an effort to address the potential impact of Staged IRM on the environment, DuPont has undertaken the following activities:

- *Cherry Island Staging Area, Potential Historic Release Assessment* (DuPont, 2003)
- *Screening Assessment of Shellpot Creek* (DuPont, 2002)
- *Staging Area Material Exposure and Risk Evaluation, DuPont Cherry Island Facility* (ENVIRON, 2003)
- *Updated Remedy Implementation Risk Evaluation, Hay Street Iron-Rich Staging Area* (ENVIRON, 2005)
- *Final Remedial Investigation/Risk Assessment Report, Cherry Island Landfill — Iron Rich Staging Area/Hay Street Sludge Drying Site (DE-024), Wilmington, Delaware* (DuPont, 2004a)

A summary of the above listed risk evaluation studies is provided in Appendix L. These evaluations concluded that impact from the Staged IRM on human health and the environment is minimal. The studies demonstrated that the groundwater to surface water pathway is the only critical potential exposure pathway for the evaluation of risk from the

Staged IRM Pile. An evaluation of this pathway in the 2004 RI/RA report indicated that the Staged IRM Pile would not present an unacceptable exposure to human health or ecological receptors, even without a cap. An update of this site-specific exposure and risk evaluation for the cap in place remedy for the Staged IRM Pile at the Sludge Drying Site is presented to address groundwater to surface water migration and exposures to human and ecological receptors in the adjacent water bodies.

6.1 DNREC Remediation Standard Evaluation

As outlined in DNREC VCP Agreement guidance, determining the most appropriate remediation approach to address or manage risk to human health and the environment includes the establishment of acceptable remediation standards. Three remediation standard options are available in the VCP Agreement: Background Standard (BGS), URS, and Site-Specific Standard (SSS). In addition, DNREC requested that DuPont also use the RAIS risk calculator to evaluate potential risk to human health from COCs detected above generic URS values in Staged IRM, DM:LPU, and groundwater sampled during the SI.

The RAIS risk calculator is a tool for calculating cumulative cancer risk estimates and non-cancer hazards from multiple analytes. For this evaluation, the calculator used the following default exposure assumptions:

- Non-residential (i.e., industrial) direct contact for soils with exposures of 8 hours per day, 250 days per year for 25 years
- Human consumption of water (e.g., drinking water consumption)
- Recreational direct contact for surface water and sediment
- Maximum observed constituent concentrations (per DNREC's request)

It should be noted that these assumptions do not accurately reflect actual potential exposure pathways at the Sludge Drying Site (i.e., default exposure assumptions are highly conservative). Groundwater is not a source of drinking water on or near the Sludge Drying Site. Institutional controls (GMZ; DRBC regulations) that restrict the use of site groundwater and adjacent surface water for human consumption are in place. In addition, the site is not an active, operating facility. Hence, on-site worker activity is infrequent and monitored, and direct contact with Staged IRM is limited by the presence of the temporary pile cover and by the site fence. Furthermore, central tendency estimates (average/upper confidence level) of concentrations, not the maximum observed concentrations, are typically used to evaluate potential risks due to chronic exposures to provide a better estimate of average lifetime exposure concentrations.

The RAIS risk calculator results are presented in Table 5. Results presented in the table were compared to the DNREC target cumulative cancer risk level of 1 in 100,000 (1×10^{-5}) and a hazard index (HI) of 1 for groups of toxicants that effect the same target organ (DNREC, 1999). Total HIs did not exceed the DNREC target non-cancer effects level of 1 in either the Staged IRM or DM:LPU. Using conservative maximum detected concentrations, the Staged IRM results indicate a calculated cumulative cancer risk of 3×10^{-5} from direct exposure over 25 years. For the DM:LPU, the calculated cumulative cancer risk is 1×10^{-5} (see Table 5). However, if average concentration values are used

(as is typical practice), the calculated cumulative cancer risk would be at or less than 1 x 10^{-5} for these media (see Table 5).

The same cumulative risk analysis was repeated for the groundwater, even though groundwater used for drinking water is prohibited at the site by the GMZ and DRBC regulations.

Cumulative cancer risk estimates exceeded the DNREC risk level of 1 x 10^{-5} for the DM:WBZ (see Table 5). Similar to Staged IRM and DM:LPU, maximum detected values were used in the evaluation as a conservative measure. Arsenic was the primary risk driver in the evaluation. However, upgradient groundwater appears to be the source of arsenic, with higher levels detected in upgradient monitoring location MW-41A than those measured at the Sludge Drying Site (see Table 4 of Appendix I). The total HI exceeded the DNREC target non-cancer effects level of 1 in groundwater. As shown in Table 5, non-cancer hazards were driven primarily by iron and manganese. However, no potentially complete exposure pathways exist for groundwater ingestion. As previously discussed, groundwater is not a source of drinking water on or near the Sludge Drying Site.

6.2 Estimated Concentration of Iron in Surface Water

Per DNREC's request, an evaluation of the potential incremental contribution, from the Staged IRM Pile, to iron concentrations in surface water is presented. The analysis assumes that, under current conditions, iron is present in leachate below the Staged IRM and will ultimately migrate and discharge to Shellpot Creek.

Estimates of the potential maximum incremental iron concentrations in Shellpot Creek, resulting from this transport pathway, were calculated. A goal of the evaluation was to determine if under current, uncapped conditions potential leachate would generate an unacceptable concentration level in Shellpot Creek. The evaluation used the SI SPLP results from Staged IRM samples to determine constituent concentrations in leachate. Since the SPLP results were non-detect for iron, the iron leachate concentration was conservatively set equal to 0.052 mg/L (the SPLP detection limit for iron). Using this initial concentration, estimates of potential incremental iron concentrations in Shellpot Creek were calculated under two scenarios: 1) for a transport time equal to 11 years to reflect the actual time period Staged IRM has been stored on the Sludge Drying Site, and 2) for steady state conditions (10,000 years) to reflect the ultimate incremental impact to Shellpot Creek if the material was left uncapped.

A second goal of the evaluation was to determine if under capped conditions potential leachate would generate an unacceptable concentration level in Shellpot Creek. Similar to the above simulations, the iron leachate concentration was conservatively set equal to 0.052 mg/L (the SPLP detection limit for iron). Using this initial concentration, estimates of potential incremental iron concentrations in Shellpot Creek were calculated for the following scenarios: 1) for a transport time equal to 30 years to reflect the typical post-closure care monitoring period following remedy implementation; 2) for 1,000 years; and 3) for steady state conditions (10,000 years) to reflect the ultimate incremental impact to Shellpot Creek following implementation of a cap.

Predicted iron concentrations in Shellpot Creek were modeled using the U.S. EPA's HELP model for vertical migration through the Staged IRM and unsaturated DM:LPU zone and an analytical horizontal transport groundwater model that accounts for advection and dispersion during transport in the saturated DM:WBZ. Results are summarized below. The evaluation was performed by ENVIRON, and details regarding input parameters and modeling assumptions are provided in Appendix M-1.

6.2.1 Baseline Simulations

Estimates of potential incremental iron concentrations in Shellpot Creek, under current, uncapped conditions, were calculated for two scenarios: 1) a transport time equal to 11 years and 2) steady state conditions. The iron concentration in the DM:WBZ beneath the Staged IRM Pile, after mixing of leachate and groundwater, is estimated to be 0.052 mg/L. After 11 years, the model estimates that the incremental contribution, from the Staged IRM Pile to iron concentrations in Shellpot Creek, is approximately zero. The steady state model simulation estimates the incremental increase in iron concentration in Shellpot Creek would be 0.0052 mg/L. Both results are well below the 1 mg/L EPA National Recommended Water Quality Interview for iron for protection of aquatic life (EPA, 2006). Iron concentrations in Shellpot Creek are plotted vs. time in Figure 1 in Appendix M-1. These results suggest that the groundwater to surface water exposure pathway for the Staged IRM has a negligible impact on water quality in both the DM:WBZ and in Shellpot Creek.

6.2.2 Cap-in-Place Remedy Simulations

Estimates of potential incremental iron concentrations in Shellpot Creek, following a cap-in-place remedy for the Staged IRM Pile, were calculated for the following scenarios: 1) a transport time equal to 30 years; 2) a transport time of 1,000 years; and 3) steady state conditions. The iron concentration in the DM:WBZ beneath the Staged IRM Pile after mixing of leachate and groundwater is estimated to be 1.84E-05 mg/L. This is less than the estimated concentration under the uncapped scenario conditions because the cap limits infiltrating precipitation, thus significantly reducing leachate volume. After 30 years of travel time, the model estimates that the incremental contribution, from the Staged IRM Pile to iron concentrations in Shellpot Creek, is approximately zero. After 1,000 and 10,000 years, incremental iron concentrations in Shellpot Creek are predicted to be 1.55E-06 and 1.84E-06 mg/L, respectively. These concentrations are also well below the 1.0 mg/L surface water quality screening level for protection of aquatic life. Iron concentrations in Shellpot Creek are plotted vs. time for the cap-in-place remedy in Figure 1 in Appendix M-1. These results demonstrate that implementation of a cap over the Staged IRM will reduce potential leaching and migration of iron from the material to Shellpot Creek by approximately three orders of magnitude. However, it is important to note that under both scenarios simulated (baseline and cap-in-place remedy), the groundwater to surface water exposure pathway for the Staged IRM has a negligible impact on water quality in both the DM:WBZ and in Shellpot Creek.

6.3 Site-Specific Groundwater to Surface Water Evaluation

Consistent with the restrictions on land and groundwater use at the Sludge Drying Site, groundwater to surface water interactions are considered the critical "pathway" for evaluation of potential risk from the Staged IRM Pile. To evaluate the potential human health and ecological risks due to groundwater discharge to surface water, site-specific transport modeling was performed by ENVIRON. This modeling was updated from the previous version (ENVIRON, 2003) presented in the 2004 RI/RA report (see Appendix D) to include the SI results and evaluate potential exposures to Staged IRM constituents, following implementation of a cap-in-place remedy for the Staged IRM.

6.3.1 Maximum Theoretical Screening Levels

Maximum theoretical screening levels for Staged IRM and Staged IRM pore water/leachate were back-calculated from the AWQC. The specific steps in this process were as follows:

- AWQC for the protection of both human health and aquatic species were obtained for all COCs using DNREC, the DRBC, and the EPA as sources. The AWQC were used as target concentrations or screening level (SL) values in the surface water. For protection of human health, criteria based on both fish ingestion and recreational swimming scenarios were considered. A summary of the derived AWQC is presented in Tables 3a through 3c of Appendix M.
- An attenuation factor (AF2) was calculated to account for dilution in the surface water between the point of groundwater discharge into surface water and the point of exposure. Specifically, AF2 was the ratio of the concentration in groundwater at the point of surface water discharge to the concentration in surface water prior to exposure. The SL value for a constituent in surface water was multiplied by the AF2 value to calculate the maximum concentration in groundwater discharging to surface water that would meet the surface water quality criteria for protection of human health and aquatic species. In evaluating the protection of human health, AF2 was estimated as the ratio of the surface water flow to the groundwater flow. In evaluating aquatic species, AF2 was conservatively set equal to 10 because some species may be exposed after only limited mixing of groundwater and surface water.
- An attenuation factor (AF1) was calculated to account for constituent attenuation during migration from the Staged IRM to the point of groundwater discharge into surface water. Specifically, AF1 was equal to the ratio of the concentration in Staged IRM pore water/leachate to the concentration in groundwater at the point of surface water discharge. Chemical-specific values for AF1 were estimated using the EPA HELP model to assess conservative vertical migration through the Staged IRM material and unsaturated zone DM:LPU and an analytical solution that accounts for advective, dispersive, and reactive (e.g., linear sorption) transport in the DM:WBZ. AF1 values for each COC were calculated for time periods of 30 and 1,000 years and until maximum steady-state conditions were reached. The modeling timeframes were selected to represent the typical

monitoring time for waste units after closure (30 years), a maximum "lifetime" for the system (1,000 years), and equilibrium conditions.

- Multiplying the surface water constituent SL values by both the AF1 value and the AF2 value resulted in the maximum COC concentrations in Staged IRM pore water/leachate that would not result in exceedance of surface water quality criteria. These concentrations in Staged IRM pore water/leachate are termed Closure Screening Levels for leachate (CSL_L) (see Table 6).
- COC concentrations in the Staged IRM solids that correspond to the CSL_L values were estimated by multiplying the CSL_L values by equilibrium partitioning coefficients. These concentrations in the Staged IRM are termed Closure Screening Levels for solids (CSL_S) (see Table 6).

COC concentrations measured in the Staged IRM solids and Staged IRM leachate (from the SPLP analysis) were compared to site-specific closure screening levels derived using the process described above. If measured concentrations are below corresponding closure screening levels (CSL_S and CSL_L), then risks to human health and ecological receptors are predicted to be below levels of concern. The most stringent CSL_L and CSL_S values were calculated for a time period of 10,000 years, which represents the approximate time to reach maximum steady-state conditions assuming an infinite source.

The results of the comparison demonstrate that a cap-in-place remedy would prevent COCs in the Staged IRM Pile from leaching and migrating into the Delaware River or Shellpot Creek at appreciable concentrations for at least 1,000 years. These conclusions are based on overall modeling exposure assessment methodologies and assumptions that are conservative (i.e., likely to overstate rather than understate actual risks). Additional details regarding the methodologies and assumptions used in the evaluation are presented in Appendix M.

6.4 Summary

In summary, the 2004 RI/RA report concluded that, due to restrictions that prevent development of the Sludge Drying Site for residential, recreational, or commercial use, leaching to groundwater is the only significant pathway for constituent migration from Staged IRM. While use of groundwater at the Sludge Drying site is not expected, potentially impacted groundwater may ultimately discharge to Shellpot Creek and the Delaware River. Consistent with the restrictions on land and groundwater use at the Sludge Drying Site, groundwater to surface water interactions are considered the critical "pathway" for evaluation of potential risk from the Staged IRM Pile. Data collected in the SI continue to support these conclusions. The baseline risk evaluation suggests the need for some form of remedial action because of exceedances of generic screening levels. A site-specific exposure and risk evaluation indicates that a cap-in-place remedy would be protective of human health and the environment.

Per DNREC's request, an evaluation of the potential incremental contribution, from the Staged IRM Pile to iron concentrations in surface water, was conducted. The analysis assumed that under current conditions, iron is present in leachate below the Staged IRM and will ultimately migrate and discharge to Shellpot Creek. Estimated incremental

increases in iron concentrations for both the current conditions (no cap) and the cap-in-place remedy are well below the ecological threshold for iron. These results demonstrate that the groundwater to surface water exposure pathway for the Staged IRM has a negligible impact on water quality in both the DM:WBZ and in Shellpot Creek.

7.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

7.1 Summary

In 1956, DuPont purchased a 108-acre parcel of land on Cherry Island in Wilmington, Delaware. The Hay Road Sludge Drying Site (DE-0024) is a 23-acre parcel contained within the larger 108-acre parcel. The entire Sludge Drying Site is underlain, not by native soils, but by placed dredge and fill materials. Historical records demonstrate that in 1927, a seawall was constructed parallel to and approximately 2,300 feet east of the then-existing shoreline. From approximately 1927 to 1946, DM originating from the Delaware and Christina Rivers was pumped between the shoreline and seawall to create new land (Cherry Island). The dredged river sediments contain distinct chemical characteristics that are indicative of regional impacts to the river sediments prior to dredging and emplacement behind the 1927 seawall and to DuPont purchasing the Sludge Drying Site in 1956. The 1927 seawall forms the current boundary of the Delaware River shoreline.

Beginning in the early 1980s and continuing through 1996, sludges from the DuPont Edge Moor Plant were placed within bermed drying beds to dewater the solids prior to stabilization and disposal in the now closed Hay Road Landfill, hence, the name "Sludge Drying Site." During this time period, DuPont and the City of Wilmington were co-permitted by DNREC (Permit SW-83/23) to air-dry sludges, from both the Plant and the City of Wilmington WWTP, at the Site. All sludge drying activities ceased in 1996 when the solid waste landfill was closed. During the landfill closure, the sludge drying beds were cleaned out, and the excavated, dewatered solids were stabilized and placed in the landfill for final disposal.

Beginning in 1997 and continuing through mid-2001, the Plant generated approximately 500,000 tons of "Iron-Rich Material", which was transported as a saleable product and stored in a staging area at the Sludge Drying Site in preparation for sale as a soil substitute. In mid-2001, DuPont discontinued marketing the product and ceased sending materials to the Site. DuPont entered into a DNREC VCP Agreement on September 11, 2002 to select a remedial alternative for the Staged IRM at the Sludge Drying Site. To comply with the VCP, DuPont completed and DNREC approved the RI/RA and FFS reports in 2004. DNREC then prepared and published a PPRA on December 14, 2004, which presented the cap-in-place remedial option (combined with institutional/ engineering controls) as the preferred remedial alternative for the Sludge Drying Site. In the VCP Agreement, the nature and extent of contamination were defined by the chemical properties and areal extent (e.g., footprint) of the Staged IRM Pile.

In response to public comments to the PPRA, HCR 22 was passed in June 2005, by the 143rd General Assembly of the House of Representatives. Following the request of HCR 22, DNREC engaged an independent engineering firm, Schnabel Engineering, to complete a review of the existing data that was used to support the PPRA. Schnabel Engineering recommended in their December 2006 report that additional technical data

be obtained to more fully support DNREC's selection of a final remedial alternative. DuPont agreed to collect the additional information.

In August 2007, DuPont submitted and DNREC approved a SI work plan which presented the details of a comprehensive field program to collect the additional requested site data (DuPont, 2007a). The SI was initiated in October 2007 and sample collection was completed in February 2008. Final validated analytical data were received in June 2008. A groundwater flow evaluation was completed in June 2008 to measure the primary flow path of shallow groundwater within the DM:WBZ. Also in June 2008, a review of historical records and aerial photographs was completed to better understand past site operational history.

The new data were integrated with previously collected data and used to update the site-specific exposure and risk evaluation originally presented in the DNREC approved 2004 Final RI/RA report (DuPont, 2004a). The 2004 RI/RA report and subsequent FFS (DuPont, 2004b) supported selection of a cap-in-place remedy for the Staged IRM at the Site. This report, responding to DNREC and public comments and to those comments raised by the third-party evaluation of the Staged IRM, is provided to complete the requirements of HCR 22 and furnish the DNREC with a sufficient technical basis for the final disposition of the Staged IRM.

7.1.1 Nature and Extent

The SI work plan included collecting and analyzing samples from all relevant environmental media at the site (e.g., Staged IRM and DM solids and groundwater), as well as surface water and sediment samples within Shellpot Creek. Six soil boring locations were advanced through or adjacent to the Staged IRM Pile, and samples were collected from the Staged IRM and DM:LPU. In addition, three permanent monitoring wells and one temporary monitoring well were constructed. One round of groundwater samples was obtained from the DM:WBZ monitoring wells. Two sediment samples and one surface water sample were collected from within Shellpot Creek. Collected samples were subjected to comprehensive analytical and geotechnical testing as appropriate.

The new SI data were integrated with the previously collected data presented in the 2004 RI/RA report (DuPont, 2004a). In addition, data collected by DNREC during the SI is presented in this report and was included in the evaluation. The unique visual characteristics of the Staged IRM, the operational history of the Staged IRM Pile, and sampling results were used to define the chemical properties and areal extent of the Staged IRM. The nature and extent of the Staged IRM source material are known (15.9 acres), and the site is well characterized. The analytical, geotechnical, and hydrogeological data used to develop the CSM are fairly extensive and of good quality.

The SI data indicate that current subsurface conditions of the DM:LPU and DM:WBZ may have been influenced by historic DM placement and possibly past site operational practices prior to DuPont storing Staged IRM at the site. Constituents detected above generic URS screening criteria in the DM:WBZ include various metals, such as iron and manganese. Site-related organic constituents were either not detected or were detected below applicable generic screening criteria. Comparison of filtered and unfiltered sample

results demonstrated that these compounds are associated with or sorbed to solid-phase particles rather than dissolved in the groundwater. The 2004 RI/RA report site-specific groundwater screening criteria (quantitative ROAs) were updated for iron and manganese using the DNREC SWQS for iron and the DNREC URS surface water screening criteria for manganese (there is currently no DNREC SWQS or EPA AWQC for manganese). A site-specific screening criteria was not developed for hexachlorobenzene because no site-related organic constituents, including hexachlorobenzene, were detected in groundwater.

SI data from Shellpot Creek surface water and sediments indicate the presence of site-related compounds in addition to many non-site related COCs. Iron, manganese, and total PCBs were detected above generic URS screening criteria for surface water. Total PCBs were also detected above generic URS screening criteria for sediment. Samples collected upstream of the site contained higher concentrations in both surface water and in sediment for total PCBs and manganese than did samples collected downstream of the site. A comparison of filtered and unfiltered sample results demonstrated that iron concentrations are associated with or sorbed to solid-phase particles rather than dissolved in the groundwater. Dissolved iron concentrations were below the generic surface water quality screening criteria.

The significance of current detections in Shellpot Creek, relative to the Sludge Drying Site, is unclear at this time and warrants further study. The site is located at the confluence of Shellpot Creek and the Delaware River, and both water bodies experience tidal ingress and egress behavior with water freely mixing between the two surface water bodies. Organic constituents detected in Shellpot Creek are also detected in the Delaware River, where multiple different sources may have contributed the same compounds. Furthermore, Shellpot Creek surface water and sediment data collected upstream of the DuPont Property and the tide gate (as part of the Hay Road Landfill Post Closure Care monitoring permit) document historical and current upstream exceedances for PCBs and metals (including iron).

7.1.2 Pathways and Receptors

In the 2004 RI/RA report, potential migration and exposure pathways at the Sludge Drying Site were identified and evaluated based on site conditions, existing data, and readily available information regarding human and environmental populations. This evaluation was updated using the SI data and current site conditions that reflect interim measure activities (e.g., Staged IRM Pile consolidation and Posi-Shell cover application). Based on this updated evaluation, the only potentially complete migration pathway, for constituents in the Staged IRM, is leaching to groundwater with subsequent discharge to surface water and exposure of surface water to human recreational users and ecological receptors of the Delaware River and Shellpot Creek. All other potential migration and exposure pathways are incomplete as a result of Interim Measure activities and existing institutional controls at the site.

7.1.3 Risk Evaluation

In accordance with VCP guidance, DNREC requires a conservative baseline risk evaluation using current site conditions to help determine the need for remedial actions and define the RAOs. Consistent with the 2004 RI/RA report, constituents detected in Staged IRM, DM:LPU, groundwater, surface water, and sediment samples collected during the SI were compared to generic URS screening values for protection of human health and the environment. As discussed in Section 4.0, some constituents exceeded their respective URS screening criteria. However, these exceedances do not necessarily indicate an actual risk from exposure because they do not consider site-specific exposure mechanisms (DNREC, 1999). Staged IRM, DM:LPU, and groundwater constituents detected above generic URS values for protection of human health were further evaluated using the DNREC required RAIS risk calculator.

The baseline risk evaluation suggests the need for some form of remedial action because of exceedances of generic screening levels, particularly for human health for direct contact with Staged IRM. However, this generic evaluation does not consider site-specific elements to determine actual risk (DNREC, 1999). Therefore, site-specific transport modeling was performed to evaluate the potential human health and ecological risks from groundwater discharge to surface water, the only significant potentially complete exposure pathway for the Sludge Drying Site. Transport modeling for simulating iron migration from the Staged IRM to Shellpot Creek was conducted for current baseline conditions and for a cap-in-place remedy. In addition, the site-specific exposure analysis used results from the SI to update the previous model (presented in the 2004 RI/RA report) for evaluating actual potential exposures to Staged IRM constituents. Modeling results demonstrated that, for both the uncapped baseline condition and for the cap-in-place remedial option, leaching and migration of Staged IRM constituents from the pile to the nearby surface water bodies would not occur at potentially significant concentrations. Thus, the site-specific exposure and risk evaluation supports a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials.

7.2 Conclusions

Based on the review and analysis of SI data, the following conclusions have been drawn:

- Analytical data collected during the SI are consistent with data collected previously. All requests by DNREC for additional technical information, in response to public comments to the PPRA and to HCR 22, have been met. Sufficient data exist to decide the final disposition of the Staged IRM.
- Current subsurface conditions of the DM:LPU and the DM:WBZ may have been influenced by historic dredge material placement and possibly by past site operational practices prior to DuPont storing Staged IRM at the site. Additional assessment is recommended as part of the monitoring phase of the remedial action to understand the hydrologic and geochemical nature of the DM:LPU and the DM:WBZ and the potential interaction of these units with the surrounding environment.

- The updated exposure and risk evaluation and site-specific transport modeling support a cap-in-place remedy for the Staged IRM as fully protective of human health and the environment from exposure to the staged materials.

7.3 Recommendations

DuPont recommends initiation of activities to implement the PPRA, a cap-in-place remedy for the Staged IRM combined with institutional controls. As noted in PPRA, groundwater monitoring shall be proposed to monitor the effectiveness of the remedy and to address any additional remedial activity should such monitoring demonstrate the necessity of further action.

7.3.1 Remedial Action Objectives

DuPont recommends the following qualitative RAOs for the Sludge Drying Site, consistent with the RAOs presented in the DNREC PPRA:

- Minimize human and ecological exposure to the Staged IRM and historic dredge spoils.
- Minimize migration of the Staged IRM constituents to air, surface water, and sediments by wind transport, storm water runoff, and/or groundwater/surface water interaction.
- Minimize further migration of iron and/or any other COC present in the Staged IRM from the staged materials to the groundwater.
- Continue the prohibition of the withdrawal of groundwater for potable use and limit withdrawal and use consistent with current restrictions on groundwater use in the area (GMZ, DRBC regulations).
- Prohibit residential or unrestricted use of the property.

Based upon the qualitative RAOs, the following quantitative RAOs are recommended:

- Minimize human exposure to the Staged IRM that would result in a carcinogenic risk exceeding $1x10^{-5}$ or a hazard index of 1.0.
- Maintain adequate storm water controls in the storm water retention area adjacent to the Iron Rich Pile to minimize human and ecological exposure to the historic dredge spoils.
- Minimize discharge of Staged IRM into Shellpot Creek and the Delaware River above the EPA AWQC.
- Place a deed restriction on the property prohibiting residential or unrestricted use and for limiting groundwater use.
- Develop a groundwater monitoring program to monitor for compliance with EPA AWQC for Shellpot Creek or the Delaware River. The maximum concentrations allowed in groundwater monitoring wells on the bank of Shellpot Creek will be 3,580 mg/L for iron and 286 mg/L for manganese.

These RAOs are protective of human health and the environment and are consistent with the current and future land use of the site as commercial in an urban setting (per New Castle County zoning policies and state regulations governing water supply and worker health and safety).

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