Evaluating the Potential for Vapor Intrusion at Superfund Sites in North Carolina Contaminated with Volatile Organic Compounds

by

Kristin Nicole Smith

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Approved by advisory committee:

Committee Chair - Dr. Elizabeth Nichols

Committee Member - Linda Taylor

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Abstract

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Vapor intrusion is the migration of volatile chemicals into overlying buildings. While vapor intrusion has been a known pathway for many years, there is concern that some sites may still be at risk for human exposure. The purpose of this project was to evaluate the potential for vapor intrusion at a subset of Superfund sites in North Carolina. The primary constituents of concern for this project were volatile organic compounds. Twenty-seven sites contaminated with volatile organic compounds were evaluated using the United States Environmental Protection Agency's Office of Solid Waste and Emergency Response Technical Guidance documents as a starting point for site criteria. These documents detail the U.S. EPA's approach for assessing and mitigating vapor intrusion at sites.

For this project, a site calculator was developed to create a consistent risk-ranking system for vapor intrusion potential. The site calculator uses a set of possible inputs and scores for each criteria along with a "weight of importance" to create a risk score, zero to five, with five being the highest risk. Of the twenty-seven sites assessed, twenty-four resulted in a risk score of one or zero indicating little to no risk for vapor intrusion. Two sites resulted in a moderate risk score of two. The highest risk score from the sites in North Carolina was a three, which is still considered a moderate risk. This paper demonstrates the effectiveness of the site calculator tool in evaluating the potential for vapor intrusion.

Biography

Kristin Smith is an Environmental Scientist with RTI International in Research Triangle Park, North Carolina. Ms. Smith has practiced environmental consulting for federal and commercial clients since 2011. Her project involvement consists of conducting risk assessments, literature reviews, data gathering, and report writing. Ms. Smith is also a certified ISO 9001:2008 Lead Auditor and has experience conducting internal audits and creating quality assurance programs within RTI.

Ms. Smith received her Bachelors of Science degree in Environmental Technology and Management and Certificate in Geographic Information Systems from North Carolina State University in Raleigh. As an undergraduate, she conducted research under Dr. April James at N.C. State University. Her undergraduate research project, entitled "How different geological regions affect the electrical conductivity of streams" was presented at the Fall 2009 North Carolina Undergraduate Research and Creativity Symposium, at the University of North Carolina at Wilmington, Wilmington, N.C.

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List of Acronyms

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
DCA	Dichloroethane
DCE	Dichlroethylene
CFC-11	Trichlorofluoromethane
CFC-12	Dichlorodifluoromethane
EPA	Environmental Protection Agency
FYR	Five-Year Review
GIS	Geographic Information System
HRS	Hazard Ranking System
MTBE	Methyl tert-butyl ether
NC	North Carolina
NCDENR	North Carolina Department of Environment and Natural Resources
NPL	National Priorities List
OSWER	Office of Solid Waste and Emergency Response
PCE	Perchloroethylene
ROD	Record of Decision
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
US	United States
UST	Underground Storage Tank
VC	Vinyl Chloride
VI	Vapor Intrusion
VOC	Volatile Organic Compound

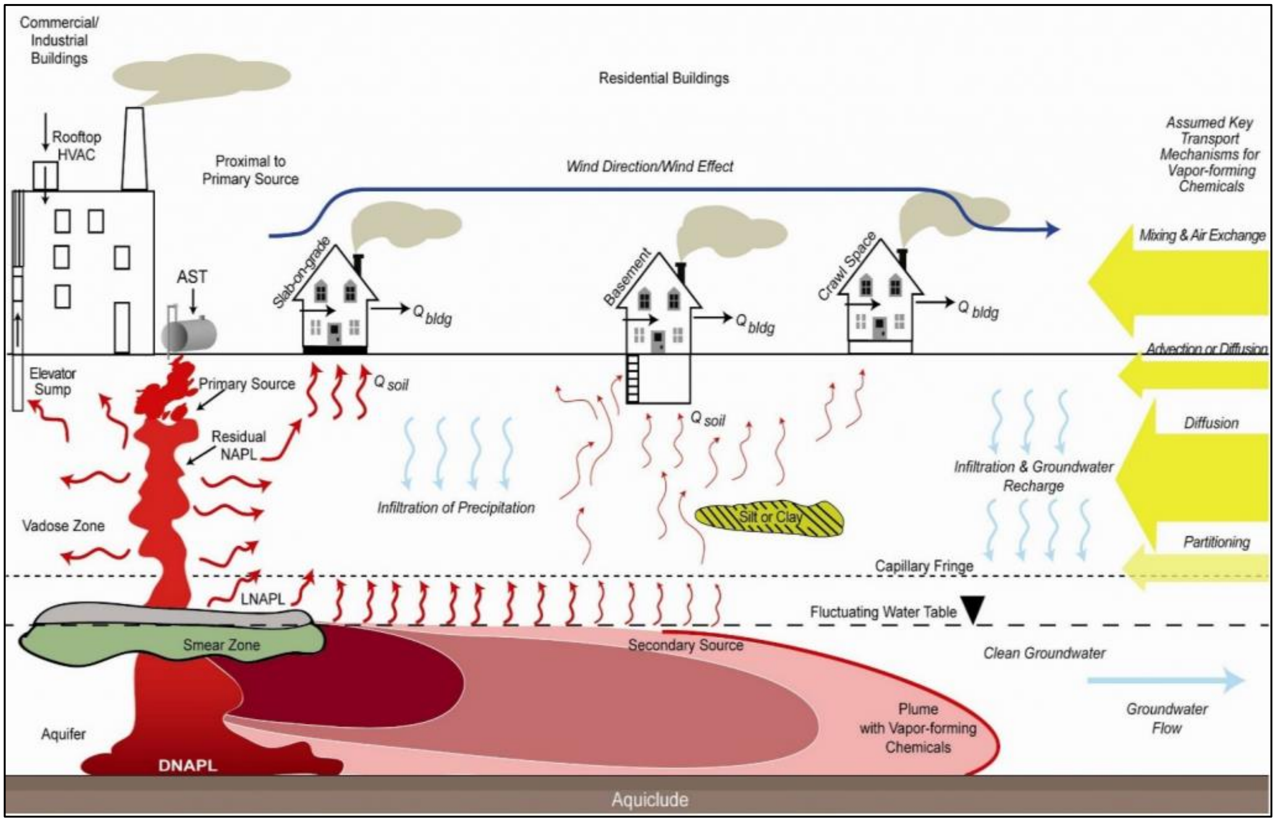
Introduction

The United States Environmental Protection Agency's (U.S. EPA) Superfund Program, also known as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), has been active since 1980. The program is charged with protecting the environment and human health by cleaning up hazardous waste sites across the United States (U.S.). To help the U.S. EPA determine which Superfund sites require further investigation, the National Priorities List (NPL) was created. The NPL is a comprehensive index of sites with known releases of contaminants or hazardous substances. Sites are included on the NPL based on the Hazard Ranking System (HRS) which is a numeric system that uses information from preliminary site assessments to determine the potential risk to human health and the environment. Sites with scores above a certain threshold are eligible for inclusion on the NPL (Scorecard, 2011). Across the U.S. there are approximately 1,323 site on the NPL. Currently there are 39 NPL sites listed in North Carolina (N.C.) (U.S. EPA, 2016a).

Volatile organic compounds (VOCs) are one of the many types of contaminants found at Superfund sites. VOCs can be emitted by a number of household products and materials such as cleaners, carpets, adhesives, etc. VOCs at Superfund sites can originate from a variety of sources such as dry cleaning facilities or leaking underground storage tanks (USTs). These compounds are of concern because of their ability to migrate in groundwater and toxicity to humans and animals. In addition, VOCs commonly have high vapor pressures making them prone to volatilization into the air. These compounds can cause short-term health effects such as eye, nose and throat irritation, dizziness, headaches, nausea, vomiting, and increased symptoms for asthma. In the long-term, VOCs can increase the risk of cancer and damage to the kidneys, liver, and central nervous system (MDH, 2016). The most common VOCs detected in aquifers and at contaminated sites include: chloroform, perchloroethylene (PCE), methyl tert-butyl ether (MTBE), trichloroethylene (TCE), toluene, dichlorodifluoromethane (CFC-12), 1,1,1-trichloroethane (TCA), chloromethane, bromodichloromethane, trichlorofluoromethane (CFC-11), bromoform, dibromochloromethane, trans-1,2-dichloroethene (trans-1,2-DCE), methylene chloride, and 1,1-dichloroethane (1,1-DCA) (USGS, 2015).

Due to their ability to readily volatilize, VOCs present a new potential exposure pathway for humans, vapor intrusion (VI). VI is the migration of VOCs from the subsurface into buildings above contaminant plumes. U.S. EPA just released a new guidance document in 2015 titled, *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air,* the purpose of which is to promote enhanced approaches and national consistency for addressing VI at contaminated sites. According to Eklund et al. (2012) aside from EPA's document, 35 states, including North Carolina, have released their own VI guidance. These technical guidance documents provide a wealth of information on factors affecting VI and how to assess and mitigate contaminated sites. According to the newest U.S. EPA guidance (2015c), the VI pathway is considered complete when the following five conditions are met: 1) A source is present underneath or near the building(s); 2) A route is available for vapors to migrate toward the building(s); 3) A route is available for soil gas entry into the building(s), e.g. conduits, etc.; 4) The vapor-forming chemical(s) is detected indoors; 5) The building(s) is (or are) occupied. An illustration of a vapor intrusion conceptual site model is presented in **Figure 1**.

Figure 1. Illustration of Vapor Intrusion Conceptual Site Model (U.S. EPA, 2015c)



VI has been a known pathway for human exposure for decades, but some contaminated sites on the EPA's NPL may still be a risk due to a lack of VI investigation/mitigation, therefore it would be beneficial to have a consistent way to rank sites. Tier 1 primary screening as described in the U.S. EPA (2002) guidance titled, *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)*, is a preliminary analysis that uses available information to assess the potential for VI. This initial screening uses specific criteria that can be determined through reviewing readily available documents such as Five Year Reviews (FYR) or Record of Decision (ROD) documents. The evaluation can help determine whether the potential for vapor intrusion exists at a site by asking the following questions:

1. Are chemicals of sufficient volatility and toxicity present or suspected to be present?

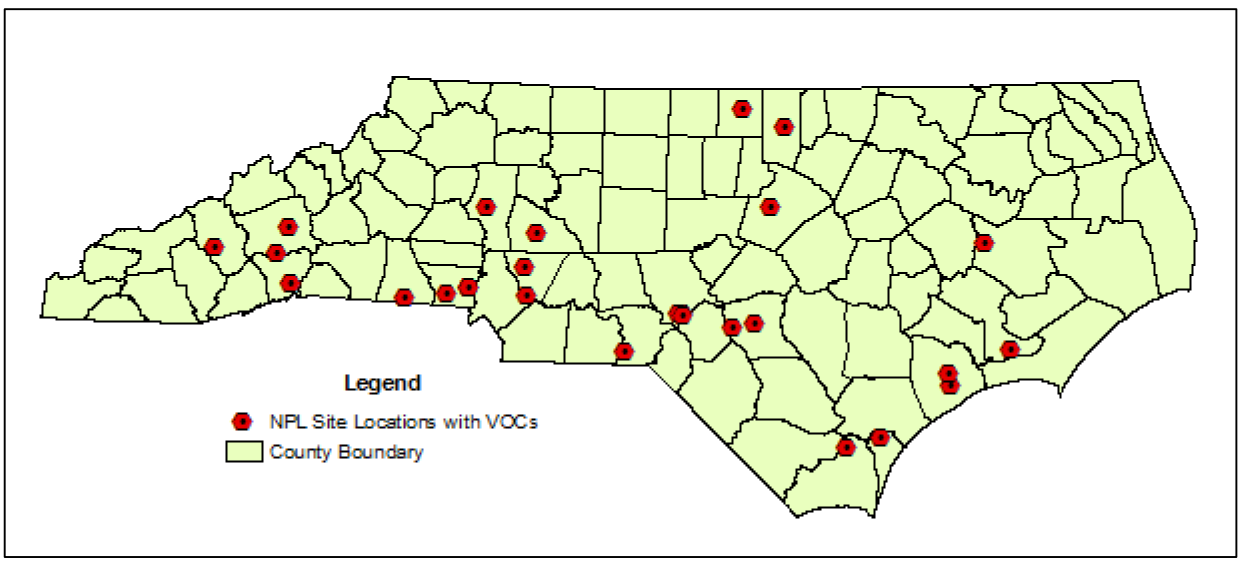
2. Are occupied buildings located above or in close proximity to subsurface contamination?
3. Do current conditions pose a risk and is immediate action required?

By building on the screening steps presented in U.S. EPA (2002) and through the creation of a site calculator and risk-ranking system, one can protect human health by identifying high risk sites for further investigation. The goal of this study is to use information and data collected from the EPA Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) and NCDENR CARA3 databases to determine which sites in North Carolina are the most at risk for vapor intrusion (NCDENR, 2015c, U.S. EPA, 2016b). Sites with the potential for human exposure will be identified to indicate where additional investigation and/or remedial activities may be required.

Methods

To select the study sites, the EPA CERCLIS and CARA3 Portal databases were queried for NPL sites in North Carolina contaminated with VOCs. From this query, twenty-seven sites in were identified as having VOC contamination. An overview of NPL site locations contaminated with VOCs in North Carolina are presented in **Figure 2.** From November 2015 to March 2016, a scientific literature review was performed focusing on state and federal guidance documents and criteria for vapor intrusion. While there are a number of factors affecting the potential for VI, the risk-ranking tool in this study only focused on a few specific parameters that can be gathered from a preliminary site assessment, ROD, or FYR documents.

Figure 2. Location of Superfund sites contaminated with VOCs in North Carolina



Based on the information gathered during the literature review, the following preliminary screening criteria for vapor intrusion were identified: chemical volatility and toxicity, monitoring of biodegradation/daughter products, the success of the selected remedy, depth to groundwater, current or past VI investigations, number of single-family homes in the vicinity of the plume, number of multi-family residential buildings in the vicinity of the plume, number of commercial buildings in the vicinity of the plume, number of institutional facilities in the vicinity of the plume, potential for future development in the vicinity of the plume, and approximate population within one mile of the site. Each of these criteria is detailed in the section below.

Site Criteria for Evaluation

Sufficiently volatile and toxic chemicals - Based on U.S. EPA (2015c), the potential for vapor intrusion generally increases with increasing VOC concentrations. The preliminary screening assessment provides some uncertainty about VOC concentrations in groundwater because the data is not always provided in the documents. Therefore, the input was changed from chemical concentrations to chemical volatility and toxicity. For a chemical to be considered a significant risk for vapor intrusion, it must have a Henry's Law Constant greater than 10^{-5} atm m^3/mol and either a cancer risk of greater than 10^{-6} or a non-cancer hazard index greater than one. See **Appendix A** for a summary of chemicals that are considered sufficiently volatile and toxic and are a potential concern for vapor intrusion (U.S. EPA, 2002).

Monitoring of biodegradation/daughter products - VOCs have the potential to degrade into new daughter products through natural processes in the subsurface. When a remedy is in place at a site, it is important to determine if monitoring includes the daughter products which can also have the potential for VI. For example, TCE can breakdown into products that include cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, vinyl chloride (VC), and ethene (ITRC, 1999).

Success of the selected remedy - The success of the site remedy selected by the ROD is important in determining if the mitigation strategy is protective of human health in the short- and long-term. If the selected remedy is not improving conditions at the site then a re-evaluation of the mitigation strategy may be needed.

Depth to groundwater - Based on the literature, many states, including North Carolina, consider 100 feet vertically as the exclusion distance for VI investigations. This implies that if the contaminant plume is greater than 100 feet below the surface then there is no potential for VI and an investigation is not needed. The potential for VI increases with decreasing depth to groundwater (NCDENR, 2014b).

Assessment of the VI pathway - This criteria helps to determine if the vapor intrusion pathway has already been assessed for buildings above the contaminant plume or if a detailed investigation of the pathway needs to be performed. A detailed VI investigation would include sampling indoor air of nearby buildings to characterize human exposure (U.S. EPA, 2015c).

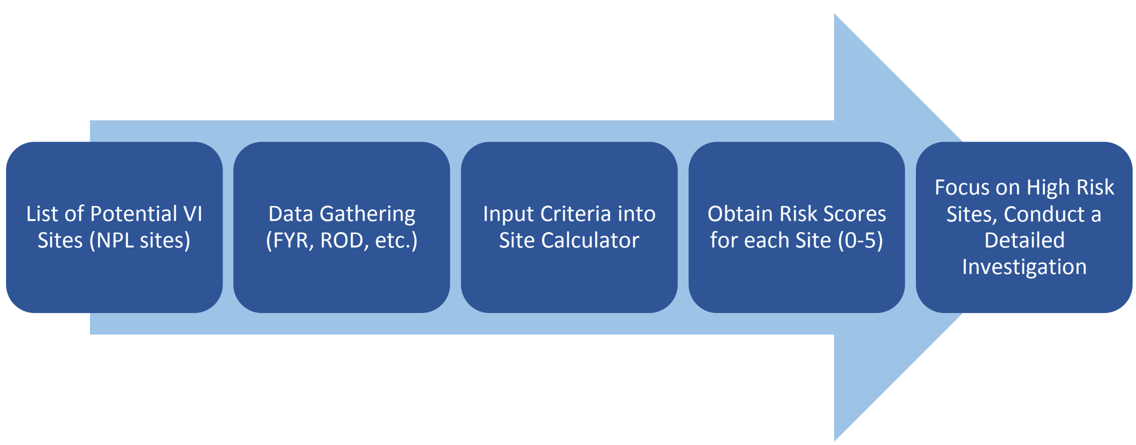
Buildings/homes in the vicinity of the plume - These criteria are the most important for assessing potential risks to humans. If there are no buildings above the contaminant plume, then the VI pathway is not complete. An estimate of single-family, multi-family, commercial, and institutional buildings above or near the plume help to assess the number of receptors potentially affected by vapor intrusion.

Potential for future development near plume - While the VI pathway may not be currently be complete due to a lack of buildings above the plume, there is still the potential for future development to be affected. This criteria assesses the possibility for future development near the plume by determining if there are any institutional controls such as a land use limitations that would inhibit future growth on the site.

Approximate Population within 1 mile of the site - As the population surrounding the site increases, the potential for human exposure increases. Based on the literature, the presence of conduits such as sewer and utility lines in the contaminant plume can become preferential pathways for VOCs to enter buildings. The presence of these preferential routes could facilitate vapor migration to greater distances and concentrations than what would normally be expected (U.S. EPA, 2015c).

Data for the parameters were collected for each site using publicly available documents and mapping software such as Google Earth or ArcMap. The data was then analyzed using a risk-ranking/site calculator tool which was developed throughout the project in Microsoft Excel spreadsheet form. The tool's intent was to use high-level preliminary screening information to create a ranking system or prioritization index to assist in identifying sites that have the greatest potential for vapor intrusion and are a risk to human health. These high risk sites would then be recommended for a further detailed VI investigation and/or mitigation. A depiction of the process from NPL site list to risk-ranking is presented in **Figure 3.**

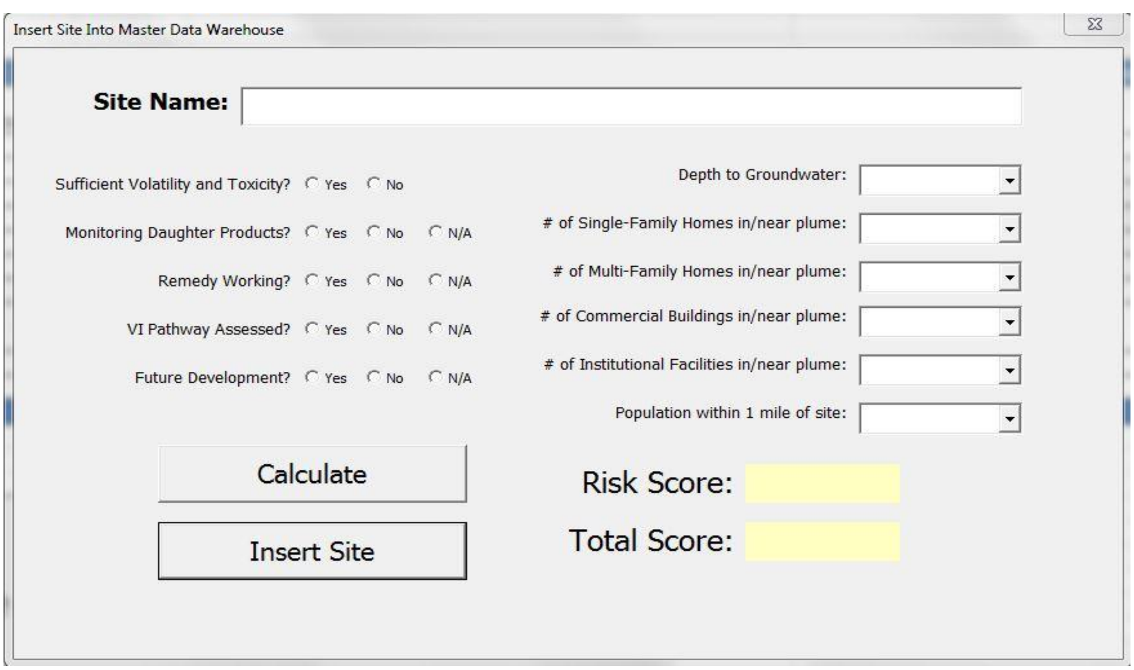
Figure 3. Depiction of the Site Ranking Process



Similar to the Hazard Ranking System for NPL sites, a site calculator was developed to assess the relative risk associated with VOC contamination at sites in North Carolina. The site calculator contains a set of calculations behind the ranking system for the subset of sites. The site calculator uses a set of possible inputs and scores for each parameter along with a "weight of importance" to create a risk score, 0-5. A risk score of 0 or 1 indicated that there was little to no risk for VI. A risk score of 2 or 3 indicated a moderate risk for VI at a site. A risk score of 4 or 5 indicated a high risk for vapor intrusion and the need for further investigation. **Figure 4** below depicts an overview of the two iterations of the site calculator user interface, the spreadsheet version and user-friendly format version. The tool and project documents are available online at https://sites.google.com/site/knsmith3ea665project/.

Figure 4. Overview of the two iterations of the Site Calculator User Interface

Criteria	Type of Input	Max Score	SITE A	SITE B	SITE C
Are chemicals at the site of sufficient volatility and toxicity? See U.S. EPA (2002) Chemical Datasheet	Y/N	Y	Y	Y	Y
Monitoring of daughter products in groundwater?	Y/N/NA	N	Y	Y	Y
Is the selected remedy working?	Y/N/NA	N	N	Y	N
Depth to groundwater	# range	1	70	8	10
Has the VI pathway been assessed?	Y/N/NA	N	N	Y	N
Number of single-family homes in vicinity of plume (estimate)	# range	80	0	25	50
Number of multi-family residential buildings in vicinity of plume (estimate)	# range	80	0	0	2
Number of commercial buildings in plume vicinity (estimate)	# range	80	5	1	50
Number of institutional facilities (e.g. schools, hospitals, etc.) in plume vicinity (estimate)	# range	6	0	3	1
Potential for future development near plume?	Y/N/NA	Y	Y	N	Y
Approximate Population within 1 Mile (from EPA Superfund website)	# range	100000	100001	1001	50000
Total Score:	--	495	125	288	405
Risk Score:	0-5	5	1	2	4



The weight of importance varies for each parameter based on human exposure and the general site requirements needed for VI to occur. For example, multi-family residential and institutional buildings have a higher weight of importance than the other building parameters because there are more occupants and/or sensitive populations exposed. The risk score was calculated by dividing the total score for each site by the maximum site score which was then divided by five. To ensure the tool ranked sites appropriately, four validation sites from around the U.S. that were known to have a high potential for vapor intrusion were included in the assessment. **Table 1** presents the criteria included in the site calculator along with possible inputs, scores, and weight of importance.

Table 1. Inputs and Criteria Weights for the Site Calculator

Criteria	Type of Input	Possible Inputs and Associated Score	Criteria Weight of Importance (Out of 100)
Are chemicals at the site of sufficient volatility and toxicity? See Chemical Datasheet	Y/N	N = 0; Y = 5	5
Monitoring of daughter products in groundwater?	Y/N/NA	Y = 0; N = 5; NA = 2	2
Is the selected remedy working?	Y/N/NA	Y = 0; N = 5; NA = 2	2
Depth to groundwater	# Range	101+ = 0; 76-100 = 1; 51-75 = 2; 26-50 = 3; 16-25 = 4; 0-15 = 5; NA = 3	15
Has the VI pathway been assessed?	Y/N/NA	Y = 0; N = 5; NA = 2	5
Number of single-family homes in vicinity of plume (estimate)	# Range	0 = 0; 1-5 = 1; 6-10 = 2; 11-15 = 3; 16-20 = 4; 21+ = 5	15
Number of multi-family residential buildings in vicinity of plume (estimate)	# Range	0 = 0; 1-5 = 1; 6-10 = 2; 11-15 = 3; 16-20 = 4; 21+ = 5	20
Number of commercial buildings in plume vicinity (estimate)	# Range	1 = 0; 1-5 = 1; 6-10 = 2; 11-15 = 3; 16-20 = 4; 21+ = 5	10

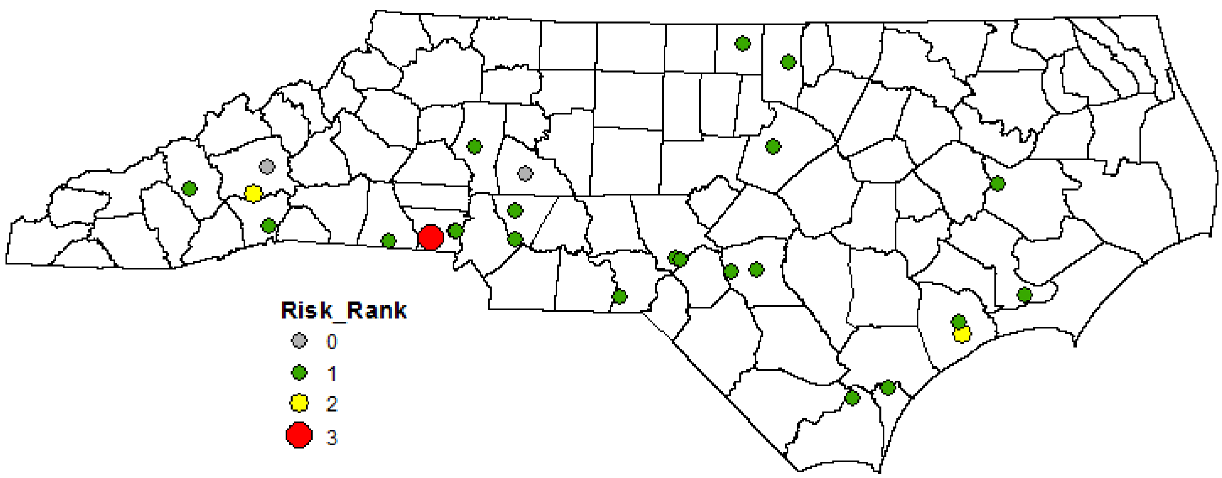
Criteria	Type of Input	Possible Inputs and Associated Score	Criteria Weight of Importance (Out of 100)
Number of institutional facilities (e.g. schools, hospitals, etc.) in plume vicinity (estimate)	# Range	0 = 0; 1+ = 5	20
Potential for future development near plume?	Y/N/NA	N = 0; Y = 5; NA = 2	5
Approximate Population within 1 mile (retrieved from EPA Superfund website)	# Range	0 = 0; 1-100 = 1; 101-1000 = 2; 1001-5000 = 3; 5001-10000 = 4; 10000+ = 5	1
Output	**0-5**		**100**

NA = Not Available

Results and Discussion

A review of the final site rankings from the tool are presented in **Table 2**. A map presenting the final site rankings in North Carolina is shown in **Figure 5.** The tool identified two sites, FCX Inc. (Washington Plant) and Bypass 601, as having a risk score of zero meaning there is no risk for vapor intrusion. 22 out of 27 sites in North Carolina had a risk score of one, which infers that there is little potential for vapor intrusion. It was determined that many of these low-risk sites are located in rural areas therefore they do not have many if any nearby human receptors. If no buildings are located above or near the plume then the VI pathway is incomplete.

Figure 5. Map presenting final site rankings for VOC contaminated sites in North Carolina



Only two sites, JFD Electronics/Channel Master and North Belmont PCE, were given a risk score of two. The JFD Electronics/Channel Master site was considered a moderate risk for vapor intrusion because of the number of multi-family residential buildings, approximately 20, located above or near the VOC plume. The North Belmont PCE site was also considered a moderate risk for VI due to the proximity of the plume to residential areas and institutional facilities such as the North Belmont Elementary School to the south of the site. Both sites have already been assessed for vapor intrusion which provides some validation for the tool.

Table 2. Final Risk-Ranking of Vapor Intrusion Potential for VOC Contaminated Sites in North Carolina

Site Name	Risk Score	Site Name	Risk Score
Davis Park Road TCE	3	Geigy Chemical Corp. (Aberdeen Plant)	1
JFD Electronics/Channel Master	2	General Electric Co/Shepherd Farm	1
North Belmont PCE	2	GMH Electronics	1
ABC One Hour Cleaners	1	Jadco-Hughes Facility	1
Aberdeen Contaminated Ground Water	1	National Starch & Chemical Corp.	1
Aberdeen Pesticide Dumps	1	North Carolina State University (Lot 86)	1
Benfield Industries. Inc.	1	Potter's Septic Tank Service Pits	1
Blue Ridge Plating Company	1	Ram Leather Care Site	1
Camp Lejeune Military Res. (OUs 21 & 78)	1	Reasor Chemical Company	1
Cape Fear Wood Preserving	1	Bypass 601 Groundwater Contamination	0
Carolina Transformer Co.	1	FCX, Inc. (Washington Plant)	0
Celanese Corp. (Shelby Fiber Operations)	1	Electrovoice*	4
Charles Macon Lagoon and Drum Storage	1	Commencement Bay, South Tacoma Channel*	4
Chemtronics, Inc.	1	Fruit Avenue Plume*	3
Cherry Point Marine Corps Air Station	1	Reilly Tar & Chemical Corp. (St. Louis Park Plant)*	3
FCX, Inc. (Statesville Plant)	1		

*Validation sites outside of North Carolina

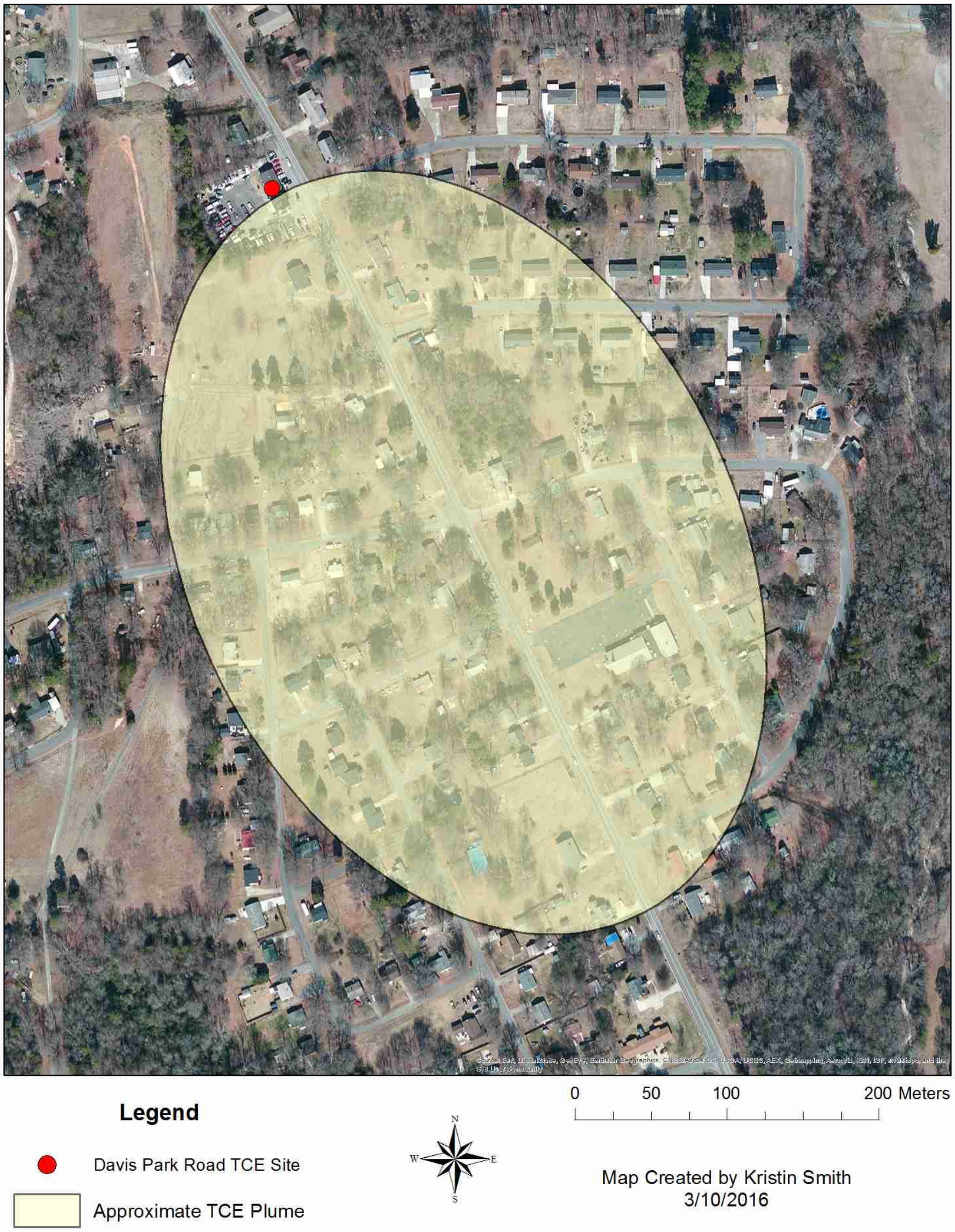
Davis Park Road TCE Site

Of the twenty-seven sites assessed in North Carolina, the Davis Park Road TCE site in Gaston County resulted in the highest risk score of three, which according to the ranking system is a moderate risk for vapor intrusion. The site is contaminated with TCE, PCE, and chloroform from leaking underground storage tanks (USTs) originating from the Davis Park Road Auto Repair Shop, formerly Moore's Transmission and Auto Repair Shop. The site includes approximately 20 acres of businesses and residential homes. A map showing the site and plume is presented in **Figure 6.**

The contaminants of concern (COCs) on the site were both sufficiently volatile and toxic according to the U.S. EPA (2002) summary data table. Daughter products, such as DCE, are also being monitored at the site. According to the 2015 FYR, the natural attenuation remedy implemented at the site is working and is protective of human health and the environment. The depth to groundwater on the site ranged from three to 45 feet, well below the 100 ft. depth to groundwater criteria.

While the site was located in a relatively rural area, with a population of approximately 1,001 – 5,000 within one mile of the site, the risk to human exposure played a major role in the risk score. The estimated number of single-family homes in the vicinity of the plume was the greatest driver for the higher risk score. It was estimated using Google Earth and plume maps from the site documents that approximately 75 homes were located above or near the VOC plume. In addition, there were estimated to be one commercial and one institutional, a church, building located above or near the plume. According to the FYR document, NCDENR just recently conducted a vapor intrusion assessment at the site and concluded that the risk of exposure was within the range for residential properties. This fact helps to validate the results from the site calculator because it identified a site that was also considered potentially high-risk by a state regulatory agency (U.S. EPA, 2015d).

Figure 6. Davis Park Road TCE Site Contamination Map



Uncertainties

One potential issue that could affect the effectiveness of the tool could be the amount of information available for each site. Some sites may not have a FYR document available yet which could limit the amount of information for input into the tool. Without this information, some sites may not be prioritized as accurately as others. The site calculator attempts to mitigate this by allowing the user to input "Not Available" for the missing criteria which will increase the final risk score to be as conservative as possible.

Based on the literature review, there is a knowledge gap in the comparison of remediation strategies for contaminated sites. EPA employs a number of remediation strategies to contain and cleanup contaminant plumes. Some of the remediation technologies used at sites include monitored natural attenuation, in situ flushing, bioremediation, soil vapor extraction, etc. While the site calculator tool currently includes the success of the selected remedy, the accuracy of the tool could potentially be increased by weighting the effectiveness of each treatment technology.

Concentration data for monitoring wells within the plumes may not be readily available in the documents used for the assessment. According to U.S. EPA 2(015a), higher concentrations of VOCs increase the potential for vapor intrusion. Therefore, the accuracy of the tool could be improved if concentration data were available and included. There may also be some uncertainty with how soil types affect the potential for VI. Coarse-grained soils present a greater potential for vapor intrusion than fine grained soils (U.S. EPA, 2015a). These issues, if addressed, have the potential to further refine the capability of the tool and increase the accuracy of the risk scores.

Conclusions

In summary, this project utilized publicly available site documents to assess the potential for vapor intrusion at twenty-seven VOC contaminated Superfund sites in North Carolina. Although the vapor intrusion pathway has been studied for decades, some Superfund sites may still be at risk for exposure to humans due to a lack of VI investigation/mitigation. This project built on the criteria presented in U.S. EPA (2002) to create a new preliminary screening site-calculator tool. The objective of this tool was to rank sites contaminated with VOCs to help identify high risk sites where there is the potential for human exposure and where additional VI investigation is needed.

The tool identified 24 sites as having a risk score of zero or one, indicating that there was little to no risk for vapor intrusion. This was determined to be because many of the sites were located in rural areas where no buildings are located above or near the plume. Two sites were given a risk score of two which indicates a moderate risk for vapor intrusion. These sites had an increased risk score due to multi-family residential buildings, schools, and businesses located above or near the plume.

The site with the highest resulting risk score was Davis Park Road TCE. This site had a large number, approximately 75, single-family homes located above or near the plume which drove the risk. Based on the results of the tool, the Davis Park Road TCE site has the highest potential for vapor intrusion and human exposure. As stated in the 'Uncertainties' section, the effectiveness of the tool could be improved with the inclusion of soil, concentration, and remediation technology data. Further research into all areas of vapor intrusion could help to increase our assessment, guidance, and treatment of this potential pathway for human exposure.

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Appendix A. Summary Chemical Datasheet from U.S. EPA, 2002

Table A-1. Summary Chemical Datasheet from U.S. EPA (2002)

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
83329	Acenaphthene	YES	YES
75070	Acetaldehyde	YES	YES
67641	Acetone	YES	YES
75058	Acetonitrile	YES	YES
98862	Acetophenone	YES	YES
107028	Acrolein	YES	YES
107131	Acrylonitrile	YES	YES
309002	Aldrin	YES	YES
319846	alpha-HCH (alpha-BHC)	YES	YES
62533	Aniline	YES	NO
120127	Anthracene	NO	YES
56553	Benz(a)anthracene	YES	NO
100527	Benzaldehyde	YES	YES
71432	Benzene	YES	YES
50328	Benzo(a)pyrene	YES	NO
205992	Benzo(b)fluoranthene	YES	YES
207089	Benzo(k)fluoranthene	NO	NO
65850	Benzoic Acid	NO	NO
100516	Benzyl alcohol	YES	NO
100447	Benzylchloride	YES	YES
91587	beta-Chloronaphthalene	YES	YES
319857	beta-HCH (beta-BHC)	YES	NO
92524	Biphenyl	YES	YES

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
111444	Bis(2-chloroethyl)ether	YES	YES
108601	Bis(2-chloroisopropyl)ether	YES	YES
117817	Bis(2-ethylhexyl)phthalate	NO	NO
542881	Bis(chloromethyl)ether	YES	YES
75274	Bromodichloromethane	YES	YES
75252	Bromoform	YES	YES
106990	1,3-Butadiene	YES	YES
71363	Butanol	YES	NO
85687	Butyl benzyl phthalate	NO	NO
86748	Carbazole	YES	NO
75150	Carbon disulfide	YES	YES
56235	Carbon tetrachloride	YES	YES
57749	Chlordane	YES	YES
126998	2-Chloro-1,3-butadiene (chloroprene)	YES	YES
108907	Chlorobenzene	YES	YES
109693	1-Chlorobutane	YES	YES
124481	Chlorodibromomethane	YES	YES
75456	Chlorodifluoromethane	YES	YES
75003	Chloroethane (ethyl chloride)	YES	YES
67663	Chloroform	YES	YES
95578	2-Chlorophenol	YES	YES
75296	2-Chloropropane	YES	YES
218019	Chrysene	YES	YES
156592	cis-1,2-Dichloroethylene	YES	YES

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
123739	Crotonaldehyde (2-butenal)	YES	YES
98828	Cumene	YES	YES
72548	DDD	YES	NO
72559	DDE	YES	YES
50293	DDT	YES	NO
53703	Dibenz(a,h)anthracene	YES	NO
132649	Dibenzofuran	YES	YES
96128	1,2-Dibromo-3-chloropropane	YES	YES
106934	1,2-Dibromoethane (ethylene dibromide)	YES	YES
541731	1,3-Dichlorobenzene	YES	YES
95501	1,2-Dichlorobenzene	YES	YES
106467	1,4-Dichlorobenzene	YES	YES
91941	3,3-Dichlorobenzidine	YES	NO
75718	Dichlorodifluoromethane	YES	YES
75343	1,1-Dichloroethane	YES	YES
107062	1,2-Dichloroethane	YES	YES
75354	1,1-Dichloroethylene	YES	YES
120832	2,4-Dichlorophenol	YES	NO
78875	1,2-Dichloropropane	YES	YES
542756	1,3-Dichloropropene	YES	YES
60571	Dieldrin	YES	YES
84662	Diethylphthalate	YES	NO
105679	2,4-Dimethylphenol	YES	NO
131113	Dimethylphthalate	NA	NO

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
84742	Di-n-butyl phthalate	NO	NO
534521	4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	YES	NO
51285	2,4-Dinitrophenol	YES	NO
121142	2,4-Dinitrotoluene	YES	NO
606202	2,6-Dinitrotoluene	YES	NO
117840	Di-n-octyl phthalate	NO	YES
115297	Endosulfan	YES	YES
72208	Endrin	YES	NO
106898	Epichlorohydrin	YES	YES
60297	Ethyl ether	YES	YES
141786	Ethylacetate	YES	YES
100414	Ethylbenzene	YES	YES
75218	Ethylene oxide	YES	YES
97632	Ethylmethacrylate	YES	YES
206440	Fluoranthene	NO	YES
86737	Fluorene	YES	YES
110009	Furan	YES	YES
58899	gamma-HCH (Lindane)	YES	YES
76448	Heptachlor	YES	YES
1024573	Heptachlor epoxide	YES	NO
87683	Hexachloro-1,3-butadiene	YES	YES
118741	Hexachlorobenzene	YES	YES
77474	Hexachlorocyclopentadiene	YES	YES

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
67721	Hexachloroethane	YES	YES
110543	Hexane	YES	YES
74908	Hydrogen cyanide	YES	YES
193395	Indeno(1,2,3-cd)pyrene	NO	NO
78831	Isobutanol	YES	YES
78591	Isophorone	YES	NO
7439976	Mercury (elemental)	YES	YES
126987	Methacrylonitrile	YES	YES
72435	Methoxychlor	YES	YES
79209	Methyl acetate	YES	YES
96333	Methyl acrylate	YES	YES
74839	Methyl bromide	YES	YES
74873	Methyl chloride (chloromethane)	YES	YES
108872	Methylcyclohexane	YES	YES
74953	Methylene bromide	YES	YES
75092	Methylene chloride	YES	YES
78933	Methylethylketone (2-butanone)	YES	YES
108101	Methylisobutylketone	YES	YES
80626	Methylmethacrylate	YES	YES
91576	2-Methylnaphthalene	YES	YES
108394	3-Methylphenol (m-cresol)	YES	NO
95487	2-Methylphenol (o-cresol)	YES	NO
106455	4-Methylphenol (p-cresol)	YES	NO
99081	m-Nitrotoluene	YES	NO

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
1634044	MTBE	YES	YES
108383	m-Xylene	YES	YES
91203	Naphthalene	YES	YES
104518	n-Butylbenzene	YES	YES
98953	Nitrobenzene	YES	YES
100027	4-Nitrophenol	YES	NO
79469	2-Nitropropane	YES	YES
924163	N-Nitroso-di-n-butylamine	YES	YES
621647	N-Nitrosodi-n-propylamine	YES	NO
86306	N-Nitrosodiphenylamine	YES	NO
103651	n-Propylbenzene	YES	YES
88722	o-Nitrotoluene	YES	YES
95476	o-Xylene	YES	YES
106478	p-Chloroaniline	YES	NO
87865	Pentachlorophenol	YES	NO
108952	Phenol	YES	NO
99990	p-Nitrotoluene	YES	NO
106423	p-Xylene	YES	YES
129000	Pyrene	YES	YES
110861	Pyridine	YES	NO
135988	sec-Butylbenzene	YES	YES
100425	Styrene	YES	YES
98066	tert-Butylbenzene	YES	YES
630206	1,1,1,2-Tetrachloroethane	YES	YES

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [1]	Is Chemical Sufficiently Volatile? [2]
79345	1,1,2,2-Tetrachloroethane	YES	YES
127184	Tetrachloroethylene	YES	YES
108883	Toluene	YES	YES
8001352	Toxaphene	YES	NO
156605	trans-1,2-Dichloroethylene	YES	YES
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	YES	YES
120821	1,2,4-Trichlorobenzene	YES	YES
79005	1,1,2-Trichloroethane	YES	YES
71556	1,1,1-Trichloroethane	YES	YES
79016	Trichloroethylene	YES	YES
75694	Trichlorofluoromethane	YES	YES
95954	2,4,5-Trichlorophenol	YES	NO
88062	2,4,6-Trichlorophenol	YES	NO
96184	1,2,3-Trichloropropane	YES	YES
95636	1,2,4-Trimethylbenzene	YES	YES
108678	1,3,5-Trimethylbenzene	YES	YES
108054	Vinyl acetate	YES	YES
75014	Vinyl chloride (chloroethene)	YES	YES

[1] A chemical is considered sufficiently toxic if the vapor concentration of the pure component (see Appendix D) poses an incremental lifetime cancer risk greater than 10-6 or a non-cancer hazard index greater than 1.

[2] A chemical is considered sufficiently volatile if its Henry’s Law Constant is 1 x 10-5 atm-m3/mol or greater (US EPA, 1991).

Appendix B. Summary of Inputs and Results for Each Site from the Site Calculator

Table B-1. Summary of Inputs and Results for Each Site from the Site Calculator

Site Name	Are chemicals at the site of sufficient volatility and toxicity? See Chemical Datasheet	Monitoring of daughter products in groundwater?	Is the selected remedy working?	Depth to groundwater	Has the VI pathway been assessed?	Number of single-family homes in vicinity of plume (estimate)	Number of multi-family residential buildings in vicinity of plume	Number of commercial buildings in plume vicinity (estimate)	Number of institutional facilities (e.g. schools, hospitals, etc.) in plume vicinity (estimate)	Potential for future development near plume?	Approximate Population within 1 Mile (from EPA Superfund website)	Total Score:	Risk Score:
ABC One Hour Cleaners	Y	Y	N	70	N	0	0	5	0	Y	100001	**125**	**1**
Aberdeen Contaminated Ground Water	Y	Y	NA	43	Y	5	0	2	0	N	100	**100**	**1**
Aberdeen Pesticide Dumps	Y	Y	Y	25	N	10	5	3	0	Y	1000	**192**	**1**
Benfield Industries, Inc.	Y	N	Y	2	N	0	0	1	0	Y	1001	**168**	**1**
Blue Ridge Plating Company	Y	Y	Y	10	N	0	0	1	0	N	1001	**138**	**1**

Bypass 601 Ground Water Contamination	Y	N	Y	NA	N	0	0	1	0	N	1001	**73**	**0**
Camp Lejeune Military Res. (USNAVY)	Y	Y	N	50	N	0	0	9	0	Y	50000	**150**	**1**
Cape Fear Wood Preserving	Y	N	Y	18	N	0	0	0	0	NA	5001	**134**	**1**
Carolina Transformer Co.	Y	N	Y	4	N	0	0	0	0	Y	1000	**157**	**1**
Celanese Corp. (Shelby Fiber Operations)	Y	Y	Y	39	Y	0	0	5	0	Y	1001	**103**	**1**
Charles Macon Lagoon and Drum Storage	Y	Y	Y	14	N	1	0	0	0	N	100	**141**	**1**
Chemtronics, Inc.	Y	N	Y	40	N	0	0	2	0	N	101	**117**	**1**
Cherry Point Marine Corps Air Station	Y	Y	Y	4	Y	0	0	20	0	Y	101	**162**	**1**
Davis Park Road TCE	Y	Y	Y	3	Y	75	0	1	1	Y	1001	**308**	**3**
FCX, Inc. (Statesville Plant)	Y	N	Y	45	Y	3	0	2	0	N	1001	**108**	**1**

FCX, Inc. (Washington Plant)	Y	N	Y	30	Y	0	0	0	0	N	1001	**83**	**0**
Geigy Chemical Corp. (Aberdeen Plant)	Y	N	NA	35	N	0	0	0	0	Y	1001	**132**	**1**
General Electric Co/Shepherd Farm	Y	Y	Y	3	N	0	0	1	0	Y	1001	**158**	**1**
GMH Electronics	Y	Y	NA	10	Y	0	0	1	0	NA	100	**125**	**1**
Jadco-Hughes Facility	Y	Y	Y	5	N	2	0	0	0	N	1001	**143**	**1**
JFD Electronics/Channel Master	Y	Y	N	7	Y	0	20	1	0	N	1001	**203**	**2**
National Starch & Chemical Corp.	Y	N	Y	13	Y	0	0	1	0	N	1001	**123**	**1**
North Belmont PCE	Y	Y	Y	8	Y	25	0	1	3	N	1001	**288**	**2**
North Carolina State University (Lot 86, Farm Unit #1)	Y	Y	Y	25	N	0	0	0	0	N	1001	**113**	**1**
Potter's Septic Tank Service Pits	Y	N	Y	1	N	0	0	0	0	Y	101	**157**	**1**

Ram Leather Care	Y	Y	NA	12	N	0	0	1	0	NA	1001	**152**	**1**
Reasor Chemical Company	Y	N	Y	3	N	0	0	0	0	N	1001	**138**	**1**
Electrovoice*	Y	Y	Y	50	N	150	25	3	1	Y	1001	**403**	**4**
Fruit Avenue Plume*	Y	Y	N	40	Y	100	10	50	5	Y	10001	**370**	**3**
Commencement Bay South Tacoma Channel*	Y	Y	N	10	N	50	2	50	1	Y	50000	**405**	**4**
Reilly Tar & Chemical Corp. (St. Louis Park Plant)*	Y	Y	N	70	N	75	2	25	2	Y	10001	**360**	**3**

* Validation sites outside of North Carolina