

**NORTH CAROLINA  
DEPARTMENT OF ENVIRONMENTAL QUALITY**

*Revised*  
***TECHNICAL GUIDANCE***  
*for*  
***RISK-BASED ENVIRONMENTAL  
REMEDiation OF SITES***

**For all applicable sites according to  
NC General Statutes 130A-310.65 through 310.77**



**April 2020**

# **DEPARTMENT OF ENVIRONMENTAL QUALITY**

## **Revised**

# **TECHNICAL GUIDANCE FOR RISK-BASED ENVIRONMENTAL REMEDIATION OF SITES**

## **Executive Summary**

The North Carolina Department of Environmental Quality (DEQ) is pleased to release this Revised Technical Guidance for Risk-Based Environmental Remediation of Sites that better reflects the provisions enacted in NC General Statutes 130A-310.65 through 310.77. These statutes establish an expanded risk-based framework for making cleanup decisions at contaminated properties. This guidance is the culmination of significant work by members of the DEQ Remediation Team and it is intended to satisfy the mandates of the Statutes.

This guidance provides, to the extent practicable, a common set of methods and standards for risk-based cleanup of contaminated sites. The risk-based approach described in this guidance hinges on the expectation that data density and the level of effort to assess a contaminated site can, and should, be a function of the complexity of a site's risks and its setting. The use of risk-based decision-making allows more freedom for setting and achieving cleanup levels, and at the same time increases the responsibility to thoroughly understand site conditions, potential receptors, exposure pathways, and risks posed by contaminants remaining in the environment. Selecting a risk-based remedy involves a balance between the level of certainty in understanding site conditions and the practicality of using engineered and/or land-use controls to manage risk where understanding of the site is limited. The ability to employ land-use controls to manage risks carries with it a responsibility to ensure that such controls are protective, achievable, sustainable, consistent with surrounding land uses, maintained and enforced.

DEQ believes that the paradigm shift toward a risk-based remediation approach presents an opportunity for state environmental cleanup programs to work collegially with remediating parties to develop remedial strategies that appropriately protect human health and the environment. Remediating parties are encouraged to communicate with their oversight program early in the process to discuss site conditions and ensure that the requirements for risk-based closure are well understood.

## TABLE OF CONTENTS

<b>1. INTRODUCTION.....</b>	<b>1</b>
1.1 Legislative Background .....	2
1.2 Unrestricted Versus Restricted Land Use .....	2
<b>2. INSTRUCTIONS, FORMS AND FEES.....</b>	<b>4</b>
2.1 Consent Requirement.....	4
2.2 Community Involvement .....	5
<b>3. REMEDIAL INVESTIGATION REPORT .....</b>	<b>5</b>
3.1 Evaluating Background Concentrations .....	7
3.2 Delineating the Extent of Subsurface Contamination.....	8
3.3 Evaluating Surface Water Quality .....	8
3.3.1 Surface Water Classification.....	9
3.3.2 Surface Water Protection .....	9
3.4 Addressing Investigation Data Gaps.....	11
<b>4. DEVELOPING THE CONCEPTUAL SITE EXPOSURE MODEL .....</b>	<b>11</b>
4.1 Identifying Receptors.....	12
4.1.1 Human Receptors.....	12
4.1.2 Potable Water Supplies .....	13
4.1.3 Surface Water.....	13
4.1.4 Environmentally Sensitive Areas.....	14
4.1.5 Other Points of Compliance.....	15
4.2 Understanding Contaminant Fate and Transport .....	15
4.2.1 Soil to Groundwater Transport through Leaching .....	16
4.2.2 Groundwater Transport.....	18
4.2.3 Predicting Maximum Extent of Contamination .....	19
4.2.4 Predicting Groundwater Discharge to Surface Water.....	21
4.2.5 Evaluating Plume Stability .....	22
<b>5. DATA QUALITY NEEDS .....</b>	<b>25</b>
5.1 Field Data Quality Assurance/Quality Control.....	25
5.2 Method Detection Limits and Sample Quantitation Limits.....	25
<b>6. EVALUATING SITE-SPECIFIC RISK.....</b>	<b>26</b>
6.1 Screening Individual Contaminant Concentrations .....	26
6.1.1 Preliminary Soil Remediation Goals (PSRGs) .....	26



6.1.2	Groundwater .....	27
6.1.3	Surface Water.....	27
6.1.4	Sediment .....	28
6.1.5	Indoor Air.....	28
6.2	Calculating Cumulative Risk using the DEQ Risk Calculator .....	29
6.3	Unique Risk Evaluation Procedures for Select Contaminants.....	30
6.3.1	Lead.....	30
6.3.2	Polychlorinated Biphenyls (PCBs).....	30
6.4	More Advanced Human Health Risk Assessment .....	30
<b>7.</b>	<b>CALCULATING SITE-SPECIFIC REMEDIATION LEVELS .....</b>	<b>31</b>
<b>8.</b>	<b>RISK MANAGEMENT AND ENSURING REMEDY PROTECTIVENESS.....</b>	<b>31</b>
8.1	Engineered Controls.....	32
8.2	Institutional Controls .....	33
8.2.1	Reliance on State and Local Land-Use Controls .....	34
8.3	Restricting Land-Uses.....	34
8.3.1	General Property-Use Restrictions .....	34
8.3.2	Requirements for Properties with Soil Contamination .....	35
8.3.3	Requirements for Properties with Groundwater Contamination .....	36
8.3.4	Requirements for Properties with Vapor Intrusion Risks .....	37
8.4	Recordation of Documents .....	37
<b>9.</b>	<b>REMEDIAL ACTION PLAN.....</b>	<b>37</b>
9.1	Content .....	38
9.2	RAPs that Include Active Remediation .....	38
9.2.1	Financial Assurance Requirements.....	40
9.3	RAP Approval and Implementation.....	40
<b>10.</b>	<b>REMEDIAL ACTION COMPLETION AND NO FURTHER ACTION.....</b>	<b>41</b>
10.1	Annual Certification of Land-Use Restrictions .....	41
10.2	Cancellation of Land-Use Restrictions .....	41



**LIST OF FIGURES**

Figure 1-1 Flow Diagram of Document Topics. ....1

**LIST OF TABLES**

Table 1-1 Requirements for Unrestricted versus Restricted Property Use .....3  
Table 4-1 USEPA Equation to Calculate the Protection of Groundwater Remediation Goals  
(From the USEPA 1996 Soil Screening Guidance). ....17  
Table 4-2 Graphical Methods to Evaluate Plume Stability .....24  
Table 8-1 Conditions Requiring Institutional Controls .....35

**GLOSSARY OF RISK EVALUATION TERMS** .....43

**APPENDIX A** Sample Analyses to Identify Site Contaminants

**APPENDIX B** Annual Report Form for Perpetual Land-Use Restrictions

## LIST OF ACRONYMS

Csat	soil saturation limit
CSEM	conceptual site exposure model
DEQ	Department of Environmental Quality
DWM	Division of Waste Management
DWR	Division of Water Resources
EC	engineered control
HI	hazard index
HQ	hazard quotient
IC	institutional control
IMAC	interim maximum allowable concentration
LUR	land-use restrictions
Max	ceiling concentration
MCL	maximum contaminant concentration
NAPL	non-aqueous phase liquid
NCAC	North Carolina Administrative Code
NFA	no further action
NOIR	notice of intent to remediate
OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyls
PSRG	preliminary soil remediation goals
PGPSRG	protection of groundwater preliminary soil remediation goals
QA	quality assurance
QC	quality control
RAGS	Risk Assessment Guidance for Superfund (USEPA)
RAP	remedial action plan
RSL	regional screening levels
SESD	Science and Ecosystem Support Division (USEPA)
SIM	Selected Ion Monitoring
SPLP	synthetic precipitation leaching procedure
SQL	sample quantitation limit
TCLP	toxicity characterization leaching procedure
USEPA	United States Environmental Protection Agency
VI	vapor intrusion

## LIST OF LINKS (in order of appearance)

North Carolina General Statutes (G.S.) 130A-310.65 through 310.77

<http://deq.nc.gov/permits-regulations/risk-based-remediation/statutes-and-rules>

North Carolina Department of Environmental Quality Risk-Based Remediation website

<https://deq.nc.gov/permits-regulations/risk-based-remediation>

Administrative Procedures and Forms for Risk-Based Environmental Remediation of Sites

<https://deq.nc.gov/permits-regulations/risk-based-remediation/forms>

Contaminated Property: Issues and Liabilities Brochure

[https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL\\_ContaminatedPropertiesPublication\\_20160718.pdf](https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_ContaminatedPropertiesPublication_20160718.pdf)

Property Owner Consent

[https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL\\_Property%20Owner%20Consent%20form\\_20160722.pdf](https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Property%20Owner%20Consent%20form_20160722.pdf)

Notice of Intent to Remediate

[https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL\\_Notice%20of%20Intent%20to%20Remediate\\_20160722.pdf](https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Notice%20of%20Intent%20to%20Remediate_20160722.pdf)

Fee Calculation Instructions

[https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL\\_Fee%20Calc%20Instructions\\_20160722.pdf](https://ncdenr.s3.amazonaws.com/s3fs-public/Waste%20Management/DWM/FINAL_Fee%20Calc%20Instructions_20160722.pdf)

Field Branches Quality System and Technical Procedures

<http://www.epa.gov/region4/sesd/fbqstp/>

EPA reference for determining background concentrations of inorganic contaminants in soil and sediment

<https://www.epa.gov/remedytech/determination-background-concentrations-inorganics-soils-and-sediments-hazardous-waste>.

Risk Evaluation Resources, including the following:

- PSRG (Soil and Sediment Screening) Table
- 15A NCAC 02L Groundwater Standards and IMACs
- 15A NCAC 02B Surface Water Standards
- DEQ Risk Calculator

<https://deq.nc.gov/permits-rules/risk-based-remediation/risk-evaluation-resources>

NC Surface Water Classifications map

<https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=6e125ad7628f494694e259c80dd64265>

DEQ Risk Evaluation Equations and Calculations

<https://files.nc.gov/ncdeq/Waste%20Management/DWM/SF/RiskBasedRemediation/updates-december-2019/2.-2019-RiskAssessEqnsandCalcs.pdf>

USEPA website pertaining to contaminant transport modeling

<http://www.epa.gov/land-research/models-tools-and-databases-land-and-waste-management-research>

EPA Regional Screening Levels

<https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables>

USEPA's National Listing of Fish Advisories General Fact Sheet 2011

<https://19january2017snapshot.epa.gov/sites/production/files/2015-06/documents/technical-factsheet-2011.pdf>

DWM Vapor Intrusion Guidance

<https://deq.nc.gov/about/divisions/waste-management/waste-management-permit-guidance/dwm-vapor-intrusion-guidance>

User's Guide for the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children

<https://semspub.epa.gov/work/HQ/176289.pdf>

Adult Lead Methodology Guidance

<https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#recommend>

EPA Lead Guidance

<https://www.epa.gov/superfund/lead-superfund-sites>

EPA Superfund guidance for human health risk assessments

<https://www.epa.gov/risk/superfund-risk-assessment-human-health-topics>

## 1. INTRODUCTION

The intent of this guidance is to outline key elements and procedures specified in [North Carolina General Statutes \(G.S.\) 130A-310.65 through 310.77](#) for implementing consistent and successful contaminant assessment and risk-based remediation strategies across applicable North Carolina Department of Environmental Quality (DEQ) programs when possible. Other risk-based remediation programs in DEQ’s Division of Waste Management (DWM), including those overseeing underground storage tank sites, dry-cleaning solvent sites, and pre-regulatory landfill sites have their own guidance documents that provide the detailed technical requirements for risk-based remediation specified in their statutes and/or rules.

A risk-based remedy can be considered for a site when the site assessment is complete and documented in a remedial investigation report on file with DEQ.

Remediating parties are encouraged to meet with their oversight program early in the process to discuss site conditions and ensure that the requirements are well understood.

This guidance illustrates the type and format of information that should be presented in a proposed remedial action plan (RAP) to demonstrate that a risk-based remedy is appropriate for the site and protective of human health and environmental receptors. Direct links are provided to the [DEQ Risk-Based Remediation website](#) where the risk statutes, required forms and worksheets, an Excel-based risk calculator, and other resources mentioned in this guidance can be found. Figure 1-1 is a flow diagram of the main topics presented in this document.

**Figure 1-1. Flow Diagram of Document Topics**



A risk-based remedy may be one of several cost-effective alternatives for a site, or it may be part of an iterative approach relying on multiple strategies over time. For example, monitoring groundwater conditions following a previously approved active or passive remedy may demonstrate that groundwater conditions have improved or are predictable. In these cases, the approved remedy may be modified to a risk-based remedy if risk to receptors can be managed through land- and groundwater-use restrictions.

Professional decision-making and judgment are necessary to weigh the cost of implementation and overall effectiveness of potential remedies. For this reason, and to protect public interests, licensed firms and professionals must oversee remedial actions per G.S. 130A-310.12 and G.S. 143-215, including those based on risk.



Due to the wide range of conditions encountered at contaminated sites, these guidelines cannot address every conceivable situation and every DEQ remediation program requirement. Please contact specific remediation program representatives to inquire about additional information or supplemental remediation guidance.

### 1.1 Legislative Background

In 2011, legislation was passed that allows remediation of contaminated sites based on site-specific remediation levels that are adequate to protect public health and the environment according to the current and anticipated future use of a property. The legislation is found in Part 8 of Article 9 of Chapter 130A of the G.S. 130A-310.65 through 310.77. Whereas previously virtually all sites have had the option for risk-based soil cleanup and vapor mitigation levels, groundwater cleanup in most remediation programs had to meet the 15A North Carolina Administrative Code (NCAC) 02L .0202 Groundwater Standards (15A NCAC 02L Standards).

In 2015, amendments to G.S. 130A-310.65 through 310.77 expanded the risk-based remediation option to include virtually all regulated sites, except those subject to remediation pursuant to the Coal Ash Management Act of 2014 and the requirements of animal waste management systems.

***DEQ risk-based remediation programs (year established):***

- Leaking Petroleum Underground Storage Tank Cleanup Program (1988)
- Dry-Cleaning Solvent Cleanup Program (1997)
- Pre-1983 Landfill Assessment and Remediation Program (2007)
- Hazardous Waste and RCRA Sites (2011)
- Inactive Hazardous Sites (20115)
- Petroleum releases from aboveground storage tanks and other sources (2015)
- Division of Water Resources Sites (2015)
- Permitted Solid Waste Sites (2015)

***DEQ Programs with no risk-based alternative:***

- Sites Regulated under the Coal Ash Management Act
- Permitted Animal Waste Management Systems

It should be noted that the term “site” in this document means the location of known releases of hazardous substances. In some cases, the “site” may encompass multiple properties. Also, a property may have multiple sites due to multiple distinct releases. As a result, terms such as “on-site” and “off-site” can become confusing. To avoid confusion, this document uses the term “source site” or “source property” to refer to the property where the release occurred and “non-source property” to refer to the neighboring properties affected or potentially affected by the release.

Use residential screening values for unrestricted use. Unrestricted use includes residential properties, hospitals, daycares, K-12 schools or any property frequented by children.

Use commercial/industrial screening values for non-residential (restricted) use. These properties will require additional controls including, but not limited to, LURs.

As a result, terms such as “on-site” and “off-site” can become confusing. To avoid confusion, this document uses the term “source site” or “source property” to refer to the property where the release occurred and “non-source property” to refer to the neighboring properties affected or potentially affected by the release.

### 1.2 Unrestricted Versus Restricted Land Use

Remediating parties may have a choice for how a site is restored based on the property owners’ consent and intended use of the property. Sites cleaned up to



unrestricted-use remediation standards (or naturally occurring background levels, whichever is higher) are characterized by residual contaminant concentrations that meet 15A NCAC 02L Standards and acceptable risk for any use, including residences, schools and daycare facilities. In some cases, it is not technically or economically feasible to achieve unrestricted-use cleanup levels, nor is it always possible to predict whether a particular cleanup approach will ultimately meet the unrestricted-use standards, so a restricted-use cleanup option may be preferred.

- Considerations for selecting a remedy:**
- Protection of public health and the environment
  - Property owner and public acceptance
  - Planned future land use
  - Technical feasibility
  - Effectiveness and protectiveness
  - Cost
  - Time required to meet cleanup objective

A remediating party will need to consider several factors when selecting a remedial alternative: protecting public health and the environment; property owner, public, and stakeholder input; the current and intended future use of each affected property as they relate to the surrounding land uses, cost and technical feasibility of implementing an engineered remedy versus a risk-based alternative; the effectiveness and protectiveness of the selected remedy; and the time required to meet the cleanup objectives. Site-specific remediation levels will rely on land-use restrictions and possibly engineered controls that restrict full use of the

property and require annual inspection and reporting. A comparison of the cleanup requirements based on the long-term property use objectives are presented in Table 1-1.

**Table 1-1. Requirements for Unrestricted versus Restricted Property Use**

	<b>Unrestricted Property Use</b>	<b>Restricted Property Use With Institutional Controls</b>
Administrative fees required?	Program specific	Yes
Property owner permission needed for site-specific remediation levels?	No	Yes
Institutional controls needed?	No	Yes
Ongoing annual maintenance and inspection of land-use restrictions required?	No	Yes
Soil and sediment cleanup levels	Site-specific for residential use	Site -specific for non-residential use
Groundwater cleanup levels	NC 015A NCAC 02L Standards	Site-specific
Surface water cleanup levels	NC 015A NCAC 02B Standards	NC 015A NCAC 02B Standards
Indoor air vapor	Site-specific for residential use	Site-specific for non-residential use



## 2. INSTRUCTIONS, FORMS AND FEES

Before a RAP is prepared for a risk-based cleanup under the provisions of G.S. 130A-310.65 through 310.77, confirm that the remedial investigation is complete, and the report is in the state files. Follow the required steps described in the [Procedures and Forms](#) page on the DEQ Risk-Based Remediation website. These procedures are required by the statutes and have been prepared to provide remediating parties the instructions, the required forms, and a fee schedule for risk-based cleanups. The following information must be submitted to the appropriate remediation program for approval before a risk-based RAP is developed. The Department must agree that the site is eligible, the remedial investigation is complete, and the fees are appropriately calculated based on the maximum predicted areal extent of contamination. Most importantly, **affected property owners must provide written consent to site-specific remediation levels that rely on institutional controls**. If any of these conditions are not met, then a risk-based remedy cannot be considered, and time and cost need not be expended on a risk-based RAP. The following steps are explained and links to the required forms are provided in the administrative procedures:

1. Confirm program eligibility.
2. Complete the remedial investigation or site assessment.
3. Provide the “*Contaminated Property: Issues and Liabilities*” brochure to all affected property owners and obtain their written consent.
4. Complete a Notice of Intent to Remediate (NOIR) and mailing list.
5. Calculate the required fees worksheet with instructions).
6. Provide documents to DEQ for approval then issue the NOIR via U.S. certified mail with return receipt.
7. Pay the fee(s) and submit a RAP presenting data to demonstrate that contaminant migration is stable or predictable and all unacceptable risk to human health and the environment can be mitigated through engineered and/or institutional controls.

### 2.1 Consent Requirement

Analysis of the feasibility of implementing institutional controls should begin early in the remedial decision-making process. G.S. 130A-310.73A(2) requires that the remediating party obtain consent from all affected property owners and other persons that may possess property interests in the land. Affected property owners include owners of source properties, adjacent contaminated non-source properties, and uncontaminated properties where a contaminant plume could be expected to migrate if groundwater is used on that property. Non-financial encumbrance-holders on the property, including utility easements and rights-of-

***Consent for site-specific cleanup levels is required from the following property owners:***

- Source property
- All properties where a release has migrated, including publicly owned property (rights-of-way, roads, sidewalks)
- All properties where a release is predicted to migrate under natural conditions
- Non-source properties that are not predicted to become contaminated under natural conditions, but where a future water supply well could potentially draw the plume onto those properties



way, must be made aware of any proposed land-use restrictions to ensure that there are no conflicting interests.

The request for consent provided to affected property owners must be accompanied by the DEQ brochure entitled “*Contaminated Property: Issues and Liabilities*” and a copy of the risk-based environmental cleanup statutes to inform property owners of the potential issues and liabilities associated with contamination on their property. This brochure was prepared in consultation with the Consumer Protection Division of the North Carolina Department of Justice and the North Carolina Real Estate Commission to provide current and future owners and users of contaminated properties with information about risk-based environmental cleanups, potential risks from residual contamination, and possible real estate issues regarding contaminated property. Remediators need to provide a copy of this brochure to all property owners affected by contamination that will be addressed using site-specific remediation levels.

Following RAP approval, property owners consenting to site-specific remediation levels will be required to sign institutional control documentation limiting the use of their property (e.g., restricting groundwater use, at a minimum), and certifying annually to DEQ on a prescribed form that the institutional controls are inspected and maintained.

## 2.2 Community Involvement

A draft NOIR and a mailing list must be prepared by the remediating party and submitted to the relevant DEQ remediation program for review. The mailing list shall, at a minimum, include all owners of contaminated property, all owners of property to which the contamination is expected to migrate, all owners of land adjoining contaminated parcels, and local governments having taxing or land-use jurisdiction over the contaminated property. Note that adjoining properties include owners of property opposite of a roadway.

The NOIR must direct the recipient to the remedial investigation report in the DEQ files and include a statement of intent to clean up the site to site-specific remediation levels. Proof of mailing must be submitted to the Department. All information and comments received by the remediating party in response to the NOIR must be submitted to the Department and addressed in the RAP as appropriate.

This NOIR requirement does not take the place of other public participation requirements. In most programs, a second public notice is issued once the proposed RAP is final. Adjoining property owners, the local health department, and any others who have expressed interested in the site cleanup activities are solicited for public comment on the RAP. The RAP notice documents the comment period and provides instructions for reviewing documents online and submitting comments. The final RAP is not approved by DEQ until all public comments are received and addressed by the remediating party.

## 3. REMEDIAL INVESTIGATION REPORT

A remedial investigation report shall be in the state file that includes the following information per G.S. 130A-310.69(a):

1. A legal description and map of the site's location.
2. Identification of adjacent property owners and land uses.
3. A survey of water supply wells, public water intakes, environmentally sensitive areas, surface waters, and other receptors within 1,500 feet of the site.
4. A discussion of the hazardous waste management practices employed on the source property, including a list of types and amounts of waste generated, treatment and storage methods, and ultimate disposition of wastes, if known.
5. A description of the facility's past and current permit status.
6. A narrative description of the methodology used in the investigation, including sampling procedures and a description of groundwater monitoring well design and installation procedures. Sample collection, preservation and container selection should follow the most current United States Environmental Protection Agency (USEPA) Region IV Science and Ecosystem Support Division (SESD) [Field Branches Quality System and Technical Procedures](#).
7. Analytical data that meet the analytical method-specific quality control requirements and performance criteria. Sample and sample extract holding times, preservatives, containers and sample collection procedures should meet USEPA Region IV SESD Field Branches Quality System and Technical Procedures. All special procedures and quality control measures and results should be met and documented in the laboratory report.
8. A description of field and laboratory quality control and quality assurance procedures followed during the remedial investigation.
9. A description of methods used to manage investigation-derived wastes.
10. A description of local geologic and hydrologic conditions, including a brief description of the major aquifers, confining units, groundwater flow direction, surface water features, and any structural features such as faults, fracture systems, geologic intrusions, and subsurface geologic or man-made features that could serve as preferential groundwater flow paths.
11. A description of the source property releases, contaminants and their concentrations in the site media, including vapors.
12. A site map, drawn to scale, showing benchmarks, directional arrow, location of property boundaries, buildings, structures, all perennial and nonperennial surface water features, drainage ditches, dense vegetation, contaminant spills or disposal areas, underground utilities, storage vessels, and existing water supply wells on the source property.
13. Site maps and cross sections drawn to scale, that show all sample locations with isoconcentration contours of contaminant extent. Geologic cross-sections of the site should show topography, lithology, water-bearing zones, confining layers, and analytical results.
14. Tabulation of analytical results for all sampling events.
15. Copies of all laboratory reports.
16. A description of procedures and the results of any special assessments; and any other information required by the Department or considered relevant by the investigator.

The remedial investigation shall assess all contaminated areas of the site, including types and levels of contamination.

### 3.1 Evaluating Background Concentrations

Naturally occurring background concentrations can contribute to the site's total contaminant concentrations and risk. Background contaminants can either be naturally occurring substances that are present in the environment in forms that have not been influenced by human activity, or anthropogenic substances that are present due to human activities not specifically related to the site. Sufficient sampling should take place to statistically quantify these potential contributions to site in a legally defensible manner. Statistics play a major role in establishing background concentration levels, and methods vary widely in their degree of complexity. The methodology used to eliminate naturally occurring compounds should be well-documented.

Soil. Due to the varying concentrations of naturally occurring inorganic chemicals in the subsurface, site-specific, natural background concentrations should be established for sites with inorganic contamination. In some locations, regional background levels of anthropogenic dioxins, polynuclear aromatic hydrocarbons (PAHs) and/or PCBs may exist due to air fallout from industrial and non-industrial combustion sources and/or transformer/electrical grid discharges.

To withstand technical and regulatory scrutiny, natural background data should be collected outside the area of contamination, but from within a geologic unit and soil type similar to that found in the contaminated area, and from a comparable soil profile depth. Anthropogenic background due to air fallout may require data from a larger area. A USEPA reference for determining background concentrations of inorganic contaminants in soil and sediment can be found here: <https://www.epa.gov/remedytech/determination-background-concentrations-inorganics-soils-and-sediments-hazardous-waste>.

Groundwater. Although published groundwater concentration ranges may be available in some regions for naturally occurring inorganic compounds, a more valid and accepted approach for determining background concentrations is to collect samples from wells outside the influence of a site. In many cases, background concentrations in groundwater will be relatively easy to establish. However, determining background levels may be more difficult where background concentrations are higher than the 15A NCAC 02L Standards, or where the local geology contains the same naturally occurring inorganic constituents as the site.

At a minimum, background data should be collected from a hydraulically upgradient location from the site and within the same groundwater horizon (depth/zone). The number of background samples needed will be driven in part by the size of the site and its geologic or hydrologic complexity, and the requirements of any statistical methods used.

Surface Water and Sediment. If the 15A NCAC 02B standards are exceeded in surface water for organic or inorganic contaminant and the source of sediment or surface water contamination is unclear, samples should be collected upstream of the source property to establish contaminant contributions from upstream. If upstream contamination is detected, then an upstream source of contamination can be considered. Confirmation samples should be collected at low surface water

flow conditions. Confirm additional procedures and the number of stream and/or sediment samples needed with the appropriate remediation program manager.

### **3.2 Delineating the Extent of Subsurface Contamination**

To properly manage risks, contamination in all media must be delineated laterally and vertically to the unrestricted-use screening levels found on the [Risk Evaluation Resources](#) page of the DEQ Risk-Based Remediation website.

#### Soil

The extent of soil contamination must be defined in all directions to the residential health-based preliminary soil remediation goals (PSRGs) to determine the appropriate placement of institutional controls. Delineating the vertical extent of soil contamination is important for evaluating construction worker risk and risk to groundwater through leaching.

#### Groundwater

The lateral and vertical extent of groundwater contamination should be defined to determine distances to neighboring properties and potential receptors, including water supply wells, surface water bodies, existing and future occupied structures, and sensitive environments. The number and spatial extent of sampling points should be commensurate to the degree of certainty needed to make protective land-use decisions and to understand fate and transport.

Hazardous substances with a density greater than water often require a more complex assessment and remediation strategy. If the vertical extent of dense contaminants proves technically difficult and costly to determine, contact the appropriate remediation program to discuss the necessity and whether other lines of technical evidence may be considered. For example, assessment methods that show decreasing concentrations with depth or that identify hydrogeologic features (e.g., confining beds, or discontinuous fractures) that limit flow paths, may be options that an oversight program may consider to satisfy vertical delineation.

Where property access is not granted for lateral delineation of groundwater contamination, or ideal drilling locations are inaccessible due to physical constraints (e.g., wetlands, steep slopes and railroads), predictive computer modeling may be used to predict maximum extent. Documentation of accessibility issues, property access requests, and any other relevant information should also be presented and assistance from DEQ requested before models are considered. The remediating party must demonstrate that sufficient data have been collected to allow for reliable predictions. Computer models should consider all assessment and monitoring data. Input data should be clearly documented. Fate and transport modeling is discussed later in this guidance.

### **3.3 Evaluating Surface Water Quality**

The use of a surface water body, the stream type, and its classification must be determined in order to understand its potential use and determine the appropriate 15A NCAC 02B Standard. Three stream types are described as follows:

- Ephemeral streams only carry stormwater in direct response to precipitation. They may have a well-defined channel but typically lack the biological, hydrological, and physical characteristics commonly associated with intermittent or continuous conveyances of water. These features are typically not regulated by Division of Water Resources (DWR) or the U.S. Army Corps of Engineers.
- Intermittent streams have a well-defined channel that contains water for only part of the year (typically during winter and spring). The flow may be heavily supplemented by stormwater. When dry, they typically lack the biological and hydrological characteristics commonly associated with continuous conveyances of water. These features are regulated by DWR and may be regulated by the U.S. Army Corps of Engineers.
- Perennial streams have a well-defined channel and contain water year-round. Although groundwater is the primary source of water, they also carry storm water runoff. They exhibit the typical biological, hydrological, and physical characteristics commonly associated with the continuous conveyance of water. These features are regulated by DWR and typically regulated by the U.S. Army Corps of Engineers.

### 3.3.1 Surface Water Classification

In September 2017, the DWR provided the tabulated water body classifications and criteria that the State of North Carolina employs to protect the designated uses of its surface waters. The tables should be consulted prior to surface water sampling to ensure the appropriate samples are collected for analysis.

DWR classifies surface water according to their best uses (e.g., swimming, fishing, drinking water supply) and applies an associated set of water quality standards to protect those uses. All waters must at least meet the standards for Class C (fishable or swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water (Water Supply Classes I through V). Surface water classification data are available online on the [DWR Surface Water Classifications map](#). For further assistance in determining a water body classification, contact DWR.

### 3.3.2 Surface Water Protection

To determine whether a surface water body that may be affected by the site meets the 15A NCAC 02B Standards, groundwater, pore water and sediment samples should be collected from locations spanning the full width of the area where a plume is known or predicted to discharge. When practical, sampling should be conducted at low- or base-flow conditions. In addition, surface water, pore water and sediment samples should be collected from a sufficient number of upstream, downstream or offshore locations to further evaluate whether contaminated groundwater is discharging to surface water and, if so, to understand any attenuation away from the seepage face. The number of samples should be statistically significant to support decisions regarding compliance with the surface water standards. Seasonal variability in base flow, discharge conditions and potential tidal influences need to be considered when developing a sampling plan.

Since contaminant detections in surface water can be intermittent and inconsistent, consideration will be given to the site-specific concentration, frequency, magnitude and duration of sample detections in both groundwater and surface water. Lines of evidence to evaluate plume discharging conditions may include the following:

- Classification of the water body (designated use) and classification of downstream uses.
- Chemical classification (e.g., volatile, semi-volatile, metals and PAHs) and nature of the contaminant (mobility, chemistry, miscibility, persistence, toxicity).
- Local hydrogeology, distance from plume to edge of surface water, stream type and morphology, differences in hydraulic head, and tidal influence.
- Stability of the groundwater contaminant plume.
- Surface water flow characteristics, including volume or flux across a specific discharge area.
- Presence or evidence of seeps and/or contamination along the source property stream banks.
- Field measurements of temperature and electrical conductivity differences between groundwater and surface water.
- Background concentrations from naturally occurring and anthropogenic sources in both groundwater and from upstream or regional sources.
- Attribution considerations from upstream sources of contamination.

It should be noted that characterization and understanding of conditions at and near a groundwater-surface water discharge point cannot be used to fully support a protective groundwater remedy unless surface water quality standards are consistently met, and contaminated soil and ongoing groundwater sources have been removed, remediated, controlled, or are demonstrated to be stable.

Contaminants in the discharging plume have the potential to accumulate in the bottom sediment, substrate, or banks of a surface water body, by sorption, precipitation, accumulation in pore water, or biological activity. In such cases, the human health risks associated with sediment contamination are addressed in the same manner as risks from contaminated soil, whereas risks to ecological receptors will need to be characterized by other methodology. Contaminated sediment that is impacting surface water above the 15A NCAC 02B Standards must be remediated.

If groundwater discharge to surface water is suspected, an average of at least two surface water samples should be compared with the appropriate “chronic” standard, for long-term exposure (relative to the life cycle of the organism). Acute standards are more appropriate for a “slug” of contamination from an instantaneous discharge with exposures of 96 hours or less. The following procedures are provided to assist with the tables:

1. Identify the classification and designated use of the surface water body using the Designated Uses table.
2. On the 15A NCAC 02B Standards table, note whether compounds have standards for total metals (t) and dissolved (d). In general, total numbers are based on human health and

dissolved numbers are for aquatic life. For contaminants that have both total and dissolved standards (e.g., arsenic), both analyses should be run.

3. Contaminants with only one standard should be analyzed accordingly (e.g., dissolved only for the chromium species).
4. For the metals that are hardness dependent (e.g., cadmium, chromium, copper, lead, nickel, silver and zinc), an in-stream hardness value should be collected at the time of sampling to calculate the freshwater aquatic life standard using the calculation included in the table.

### 3.4 Addressing Investigation Data Gaps

Data gaps following completion of a remedial investigation report may need to be addressed for effective decision-making on assessing and mitigating site risks. Examples of additional data needs may include the following:

- An updated receptor survey.
- An updated vapor intrusion evaluation.
- Aquifer testing.
- Geotechnical parameter analysis, including bulk density and porosity, to evaluate contaminant transport rates.
- Assessment of deep groundwater conditions downgradient where dense contaminants may have a vertical component of migration.
- Contaminant analyses with appropriate laboratory reporting limits.
- Analysis of a contaminant’s biological, physicochemical breakdown, and/or transformation products.

If additional analyses are needed, soil and groundwater laboratory analyses for specific contaminants are specified in Appendix A, including special sampling and analytical procedures for polychlorinated biphenyls (PCBs) in soil.

Remediators should ensure that any laboratory retained is currently certified to either analyze applicable parameters under 15A NCAC 2H .0800 or is a contract laboratory under the USEPA Contract Laboratory Program. Always confirm with the laboratory that reporting or quantitation limits allow comparison with the appropriate state cleanup standards or screening levels for every site contaminant, where possible.

## 4. DEVELOPING THE CONCEPTUAL SITE EXPOSURE MODEL

Evaluating current and potential future site-related risk requires the development of a conceptual site exposure model where the exposures pathways and receptors are known. The level of detail in the CSEM should match the complexity of the site and risk contaminated media pose to receptors. A detailed and complete CSEM is the basis for selecting an appropriate and effective remedy for a site. The following sections focus on the elements of a CSEM required to

demonstrate site conditions are well-understood, and a risk-based remedy is appropriate and protective of all current and potential future receptors.

#### 4.1 Identifying Receptors

Human receptors (adults and/or children) are defined by the current and future land uses, such as residential, industrial/commercial, schools or childcare facilities, farmland, or recreational areas. Ecological receptors include any living non-human organisms, their habitat, and natural resources which could be adversely affected by environmental contamination resulting from a release at, or migration from, a site.

Receptor surveys should be routinely reviewed and updated, as needed, to account for contaminant migration, development of surrounding properties, and changes in land-use. If a threat is noted, immediate actions may be warranted to abate any imminent hazard to public health or the environment.

##### 4.1.1. Human Receptors

An evaluation of risk includes identifying scenarios in which a person/receptor may reasonably be exposed to site contamination. Human receptors living on a contaminated source property will have a much higher exposure duration than a trespasser. The exposure routes in these scenarios consider ingestion and dermal contact with contamination and inhalation of contaminated vapors. In general, the various human receptor scenarios are a function of the amount of time a person spends in the vicinity of the site and whether they are a child or adult. The following receptors should be identified for the source and neighboring non-source properties:

***Conceptual Site Exposure Model should be supported by:***

- Regional maps showing key hydrogeologic features
- Current and potential future receptors
- Potentiometric maps
- Isoconcentration maps
- Cross sections showing lithology and contaminant distribution
- Tabulated historic data
- Graphs showing contaminant concentrations over time and distance

- Resident – Residential settings include single-family homes, townhouses, apartment buildings, college/university dormitories, daycare facilities, K-12 schools, and hospitals. Other property uses may be considered residential due to the exposure potential and the sensitive nature of the potentially exposed population.
- Non-resident (worker) – Non-residential settings include office buildings, and commercial and industrial facilities. Receptors in this setting are adult workers who spend a regular work week at the facility. Colleges and universities (excluding dormitories) are considered non-residential use. Risks in occupational settings that fall under the jurisdiction of the Occupational Safety and Health Administration (OSHA) may be handled differently.
- Construction Worker – The construction worker scenario assumes that workers may be exposed to contamination during large-scale (typically greater than ½-acre according to USEPA) construction activities. The construction worker scenario includes additive exposure to airborne dust and particulates.

- Recreator – The recreator exposure scenario refers to people who spend a limited amount of time playing, fishing, hunting, hiking, or engaging in other outdoor activities where contamination may be present. Recreational exposure scenarios are developed on a site-specific basis.
- Trespasser – The trespasser scenario is highly dependent upon the individual site characteristics, the surrounding area demographics, and the level of security at a property. Current exposures are likely to be higher at inactive sites than at active sites because there is generally little supervision at abandoned facilities. At most active sites, security patrols and maintenance of barriers, such as fences, serve to limit or prevent trespassing. USEPA Region 4 considers the “typical trespasser” to be an adolescent aged 7-16. Frequency and duration of exposure parameters should be site-specific.

#### 4.1.2 Potable Water Supplies

All sources of potable water, including active and inactive water supply wells, springs, surface water intakes and private, community and irrigation wells, should be identified within 1,500 feet from the edge of contamination. For permitted solid waste landfill sites, the well-survey radius should extend 1,500 feet from the edge of the waste. If the site is greater than one hundred (100) acres in size, the inventory and map should cover a one-mile radius from the center of each source area. Wells used for industrial process water should also be identified if workers could be exposed to water from these sources, or if the water may be used in the consumer product manufacturing process.

A potable water supply area survey and data search should include one or more of the following activities:

- Visually inspect properties to identify evidence of water supply wells such as well houses and well heads.
- Review city water and sewer use billing records for nearby properties. Properties that have no water use record should be assumed to use water supply wells.
- Review county environmental health departments for private water supply well records, which may include drilling and construction logs, records of well samples collected by the county for bacteria analysis, plats with wells located for properties under design. Some septic tank permits have water supply well locations indicated.
- Mail surveys to surrounding properties inquiring about water supply wells.
- Review DWR maps of surface water intake locations.

The potential receptors should be tabulated and keyed to their locations on a receptor map with the level of threat from site contamination noted. The area(s) served by a municipal water supply should be noted.

#### 4.1.3 Surface Water

All surface waters, including wetlands, should be identified within 1,500 feet from the edge of contamination. Surface water use for fishing and/or recreation, and the potential for trespassers

should be identified. Wetlands are defined as those areas inundated or saturated by surface or groundwater for a portion of the year and support vegetation typically adapted for life in saturated soil conditions. Since wetlands provide a habitat for numerous plants and animals, all wetlands that could be threatened by site contamination should be identified.

The U.S. Army Corps of Engineers determines the presence and location of wetlands under the jurisdiction of Section 404 of the Clean Water Act. In general, if an area is saturated with water and contains hydrophytes and hydric soils, it is a jurisdictional wetland.

#### **4.1.4 Environmentally Sensitive Areas**

All properties affected or predicted to be affected by the site should be evaluated for the existence of environmentally sensitive areas listed below. Governing agencies should be contacted to determine if any special sampling (such as aquatic toxicity testing or fish tissue sampling) is necessary:

- State parks
- Areas important to maintenance of unique natural communities
- Sensitive areas identified under the National Estuary Program
- Designated state natural areas
- State seashore, lake and river recreation areas
- Rare species (state and federal threatened and endangered)
- Sensitive aquatic habitat
- State wild and scenic rivers
- National seashore, lake and river recreation areas
- National parks or monuments
- Federal designated scenic or wild rivers
- Designated and proposed federal wilderness and natural areas
- National preserves and forests
- Federal land designated for the protection of natural ecosystems
- State-designated areas for protection or maintenance of aquatic life
- State preserves and forests
- Terrestrial areas utilized for breeding by large or dense aggregations of animals
- National or state wildlife refuges
- Marine sanctuaries
- National and state historical sites
- Areas identified under coastal protection legislation

- Coastal barriers or units of a coastal barrier resources system
- Spawning areas critical for the maintenance of fish and shellfish species within river, lake or coastal tidal waters
- Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which such fish spend extended periods of time
- State lands designated for wildlife or game management

If any sensitive environments near the site warrant an ecological risk evaluation, contact a DEQ risk assessor for guidance on how to proceed.

#### **4.1.5 Other Points of Compliance**

DEQ-issued permits at active facilities set conditions to minimize contaminant releases and ensure unrestricted use standards are achieved at compliance boundaries set by applicable rules. In cases where a release resulted in contaminated groundwater beyond the compliance boundary of a permitted site, permittees should contact their oversight agency to determine if risk-based remediation is a viable option.

Property boundaries may be considered points of compliance when contaminant plumes that threaten or migrate onto a neighboring property will either (i) need to be remediated to the 15A NCAC 02L Standards at the property boundary, or (ii) need to have the consent from affected neighboring property owners to impose institutional controls on groundwater use.

### **4.2 Understanding Contaminant Fate and Transport**

A release will typically migrate from its point of origin downward through unsaturated soil to the water table and then transition laterally as influenced by the groundwater flow velocity and hydraulic gradient. Volatile contaminants can also accumulate in soil gas and migrate into structures. Subsurface contaminant movement depends on the chemical properties of the contaminants and the physical, chemical, and biological characteristics of the subsurface. Understanding a contaminant’s mobility and persistence in the environment is an important component of a CSEM.

Understanding contaminant transport requires an evaluation of spatial and temporal variability of contaminant concentrations within and across each environmental medium. A comprehensive and quantitative understanding of the processes controlling the fate and transport of subsurface contaminants is helps to understand the threat to nearby receptors and develop effective plans for risk mitigation and/or cleanup. The factors that affect contaminant fate and transport generally fall into the following categories:

- Aquifer properties governing advection, dispersion, and diffusion.
- Contaminant solubility, mobility and volatility.
- Nature of soil matrix.

- Chemical and biological factors that may degrade or alter the parent compound and the resulting chemical artifacts.

#### **4.2.1 Soil to Groundwater Transport through Leaching**

Contaminants released to soil can move downward as free-phase liquids or migrate downward as rainwater infiltrates the unsaturated soil depending on the mass and volume released. When low-permeability soil units impede vertical migration, the contaminants can also spread laterally in the vadose zone. When the soil moisture content is low, pore water movement becomes limited and contamination dissolved in pore water or sorbed to soil can remain in the vadose zone for long periods of time, serving as a long-term source of groundwater contamination. High contaminant concentrations can form a non-aqueous-phase liquid (NAPL) that does not dissolve in or easily mix with water. The PSRG table provides the contaminant concentration in soil indicating the presence of NAPL, as the Soil Saturation Limit ( $C_{sat}$ ). NAPL can also remain for extended periods of time as a continuous source of groundwater contamination.

##### ***4.2.1.1 Site-Specific Calculation***

The potential for soil contamination to leach to groundwater is an important pathway to understand in the CSEM, especially if groundwater is not yet contaminated. The USEPA soil leachate equation (see Table 4-1) with DEQ-selected default fate and transport parameters appropriate for North Carolina is used to estimate the leaching potential. The equation assumes the following:

- Infinite soil source (i.e., steady-state concentrations are maintained over the exposure period).
- Uniformly distributed contamination from the surface to the top of the aquifer.
- No contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) in soil.
- Instantaneous and linear equilibrium oil/water partitioning.
- Unconfined, unconsolidated aquifer with homogeneous and isotropic hydrologic properties.
- Receptor well at the downgradient edge of the source.
- No contaminant attenuation in the aquifer.
- No NAPLs present.

**Table 4-1. USEPA Equation to Calculate the Protection of Groundwater Remediation Goals (USEPA 1996 Soil Screening Guidance).**

$$C_{soil} = C_{gw} \left[ k_s + \frac{(\theta_w + \theta_a H')}{P_b} \right] df$$

	Parameters	Default Values	Units
$C_{soil}$	Calculated Source Concentration for soil	not applicable	mg/kg - soil
$C_{gw}$	Applicable Groundwater Target Concentration: 15A NCAC 02L Standard or Site-specific remediation Level	chemical-specific	mg/L - water
df	Dilution factor	20 (0.5 acre source size) <sup>1</sup>	unitless
$k_s$	Soil-water partition coefficient for organic constituents $k_s = k_{oc} \times f_{oc}$ for inorganic constituents $k_s = k_d$	chemical-specific	L/kg
$k_{oc}$	Soil organic carbon-water partition coefficient	chemical-specific	L/kg
$f_{oc}$	Fraction of organic carbon in subsurface vadose soils	0.001 (0.1%) <sup>2</sup>	kg/kg
$k_d$	Soil-water partition coefficient for inorganics	chemical-specific (pH=5.5)	L/kg
$\theta_w$	Water-filled soil porosity-vadose soils	0.3 <sup>2</sup>	Lwater/Lsoil
$\theta_a$	Air-filled soil porosity-vadose soils	0.13 <sup>2</sup>	Lair/Lsoil
$P_b$	Dry bulk density	1.5 <sup>2</sup>	kg/L
$H'$	Henry's Law constant-dimensionless where: $H' = \text{Henry's Law constant (atm- m}^3/\text{mole)} \times \text{conversion factor of } 41$	chemical-specific	unitless

1. USEPA default value from 1996 Soil Screening Guidance
2. DEQ default value appropriate for North Carolina.

Site-specific leachability of unsaturated soil contamination can be better approximated by using site-specific aquifer properties rather than the default properties. Substitute site-specific values for organic carbon content, water-filled porosity, air-filled porosity, and dry bulk density, if available. The equations is used in the DEQ Risk Calculator as shown in the DEQ [Risk Evaluation Equations and Calculations](#) document.

#### 4.2.1.2 Analytical Leaching Procedures

A soil's leachability may be directly determined by collecting several unsaturated soil samples from the source area (highest contaminant levels) and submitting them to the analytical laboratory for analysis using the Synthetic Precipitation Leaching Procedure (SPLP) or Toxicity Characterization Leaching Procedure (TCLP). TCLP is a procedure that uses organic acids to simulate typical landfill conditions. For this reason, SPLP may be a more appropriate procedure because it is more representative of leaching under natural rainfall conditions. If contaminant concentrations in the source area soil leachate are below the respective groundwater remediation goals (15A NCAC 02L Standards or site-specific remediation levels), then the leaching criterion is considered to be met.

If contaminant concentrations in the source area soil leachate exceed the target groundwater cleanup level, then a leachability threshold soil concentration can be determined by using a regression evaluation. Collect at least five (5) unsaturated soil samples from across the contaminated area (highest to lowest concentrations). Samples should come from similar five-foot stratigraphic depth intervals. Split soil samples must be analyzed for total contaminant concentration (in mg/kg) and SPLP leachability (in  $\mu\text{g/L}$ ). The data from multiple samples are then plotted as total soil concentration (in mg/kg) versus leachate concentration (in  $\mu\text{g/L}$ ) to determine the linear correlation. The target protection of groundwater soil threshold concentration then becomes the value corresponding to a leachate concentration equivalent to the groundwater remediation goal for that contaminant determined using the linear regression equation and an appropriate safety factor. This threshold concept is helpful in determining soil cleanup levels to guide soil removal and treatment options.

*Note:* If a laboratory model other than SPLP is proposed to determine leachability, its scientific validity must be demonstrated, and its precision and accuracy must be commensurate with its stated use.

#### 4.2.2 Groundwater Transport

Groundwater movement is governed by horizontal and vertical hydraulic gradients and aquifer hydraulic conductivity across the site. Sufficient water level data should be collected to calculate horizontal and vertical gradients and depict groundwater flow direction across the property. Aquifer and/or slug tests can approximate site-specific aquifer hydraulic conductivity. Geotechnical analyses of soil samples provide site-specific porosity, bulk density, and other aquifer properties key to determining groundwater transport at a site. The following characteristics that could influence groundwater velocity, direction, and discharge across the property should be identified:

- Local geology
  - groundwater flow system framework
  - groundwater flow horizons and their orientation, thickness, and properties
  - confining units, if present
  - bedrock fractures and other preferential flow zones

- lithology
- geologic structures
- geologic heterogeneities or anomalies
- Site features
  - Man-made utility conduits
  - Impervious cover
  - Surface water impoundments
- Geomorphology
  - Recharge and discharge environments
  - Tidal influences on coastal surface waters
- Pumping wells: past, current, future

The monitoring well network should be designed to reflect the complexity of the subsurface conditions and define and track the spatial extent of contamination. Monitoring data should be gathered over a sufficient timeframe to understand seasonal fluctuations, effects of active remediation (e.g., soil source removal, groundwater pump and treat, or substrate injection), and whether natural attenuation is occurring.

The concentration of a groundwater contaminant will generally decrease as it migrates away from the source due to dilution, adsorption to matrix materials, or physical/chemical degradation. The distance over which contaminant concentrations decrease to acceptable levels will depend on the chemical properties of the contaminant, the physical properties of the aquifer, and the magnitude of the contamination.

Groundwater plumes resulting from petroleum-related releases have been extensively documented and shown to migrate and degrade within reasonably predictable parameters in most cases. Conversely, groundwater plumes of persistent, higher-density chemicals (e.g., tetrachloroethene) can both migrate to great depths and extend for long distances – sometimes more than a mile. Sentinel wells should be placed at key locations and screened at appropriate depths to detect advancing contamination ahead of a receptor or property boundary

#### **4.2.3 Predicting Maximum Extent of Contamination**

Contamination extent, fate and transport should be well-understood to predict the ultimate extent of contamination. Further emphasizing the need for plume stability and predictability in a risk-based remedy, G.S. 130A-310.73A(a)(2) states that “...site-specific remediation standards shall not allow concentrations of contaminants on the off-site property to increase above the levels present on the date the written consent is obtained,” implying that the plume’s behavior must be well-understood and predictable.

A risk-based remedy relies on the placement of institutional controls on all properties affected by the contamination. Therefore, adequately predicting the maximum plume extent is critical for proper placement of institutional controls. Although many fate and transport models are available,

DEQ requires that numerical models be used only in support of trends in site monitoring data. The remediating party should first make use of conservative, simplistic models and calculations, like the transport modules in the DEQ Risk Calculator, before expending efforts on complex models that require more assumptions.

More complex model simulation results and predictions rely heavily on the type, quantity, and quality of the field data available to define the input parameters and boundary conditions during model development. Because major decisions may be based on modeling results, it is essential that modeling be conducted in a manner that provides confidence that the simulated results represent actual field conditions.

Models are useful for predicting contaminant fate and transport in groundwater, as long as they are calibrated to adequately reproduce measured observations of the groundwater system. It is important to choose models that are appropriate for the contaminants and site conditions. Model inputs should be values that are representative of site conditions and derived from on-site measurements or analytical testing. Use of literature-based parameters or undocumented site-specific parameters is discouraged.

The following information is not intended to direct model application, as that should be performed by a user familiar with model operation, but rather provides general guidance for model selection, documentation, and verification.

#### ***4.2.3.1 Input Data***

Groundwater models cannot be used as a substitute for site-specific measurements of water quality and field data. Rather, the site-specific measurements should be used to constrain the modeling by providing data for model calibration, measurements of hydrostratigraphic unit geometries and properties, as well as sources and sinks to be modeled. A robust conceptual site model is critical in the modeling process. If the investigator incorrectly conceptualizes the hydrogeologic environment, then groundwater model results will be incorrect and yield invalid predictions. The regional and site-specific hydrogeologic data in the conceptual site model is used to formulate a set of assumptions and concepts that can be evaluated quantitatively with the numeric or analytic models used for analysis and prediction.

Key aquifer parameters are expected to be gathered, including bulk density, porosity, hydraulic conductivity, and aquifer thickness. The spatial array of monitoring points used to measure these parameters should be sufficient, in the simplest cases, to understand the change in concentration in at least three points along the transect of the plume. More complex plumes or aquifers will require more monitoring points.

#### ***4.2.3.2 Model Selection***

The user will need to decide whether it is more appropriate to use an analytical model versus numerical; deterministic or stochastic; steady state or transient; and also, a one-, two- or three-dimensional model. A model should be chosen based on its applicability to the site, availability of the required input data, and the defined purpose and objective of the modeling effort. It is important to choose a model that simulates the natural system as accurately as possible. Models should be 1) thoroughly documented in readily accessible published format, 2) peer-reviewed in the scientific

literature (includes appropriate government publications from USGS or USEPA), and 3) appropriate to the site under investigation. Useful models can be found on the [USEPA website](#).

#### **4.2.3.3 Model Documentation**

Site-specific models should be described in sufficient detail so that the model reviewer may determine the appropriateness of the model and confidence in the model results. Modeling documentation must detail the process by which the model was selected, developed, calibrated, and utilized. The documentation should:

1. Identify the type of model selected (e.g., analytical, numerical), model software (e.g., BIOCHLOR), and version (e.g., Version 2.2).
2. Describe its applicability and limitations as they relate to the problem to be simulated. The model should be capable of simulating the site-specific hydraulic, geochemical, and contaminant conditions.
3. Provide a detailed description of the model fundamentals (e.g., equations), boundary conditions (e.g., stream, receptor), assumptions, and input parameters (e.g., hydraulic conductivity). Specify the processes by which all input parameters were generated (e.g., field measurement, literature value) or calculated (e.g., 95% upper confidence limit (UCL), average concentration).
4. Describe the model calibration and the degree to which the simulated model conditions match actual field conditions and the process by which input parameters were selected to achieve a match between the model's simulated conditions and actual field conditions.
5. Present the sensitivity analysis whereby various input parameters are used to determine ranges of uncertainty in values of a specific parameter.
6. Provide the simulation output sheets and a detailed description of the validity of the predictive simulation, model assumptions, model limitations, and recommendations for model refinement and/or performance monitoring.

#### **4.2.4 Predicting Groundwater Discharge to Surface Water**

All remedial measures, including risk-based remedies, need to be designed to ensure that surface water quality criteria (15A NCAC 02B Standards) are met, and the best uses of the surface waters are protected. For wetlands, both soil, sediment and standing water should be assessed if they are affected or threatened by the site contamination. A “multiple lines of evidence” approach will help remediating parties assemble the appropriate information to demonstrate that proposed remedies are protective of the surface water quality standards into the future.

A thorough understanding of the contaminants of concern and their source; the chemical, geological, and hydraulic characteristics of the aquifer; and the extent, and the transport behavior of the contaminant plume is necessary to allow critical decision-making regarding surface water protection. At sites where groundwater contamination has been delineated, contaminant sources have been addressed, and sufficient data are available, one of the following determinations may be appropriate:

- If lines of evidence demonstrate that contamination does not, and will not, extend to any surface water feature, surface water is considered protected.
- If lines of evidence demonstrate that contamination does, or may, extend to a surface water feature, but does not, and will not, exceed any applicable 15A NCAC 02B Standards, a surface water is considered protected. If a standard is not available in the 15A NCAC 02B table, contact DWR for the calculation of a provisional value.
- If lines of evidence demonstrate that contamination has caused a detection in surface water in excess of any aquatic life or human health standards, the remediating party will need to evaluate the site-specific circumstances (e.g., magnitude, duration and frequency) of the groundwater discharge to surface water to determine whether the discharge constitutes a violation of the applicable 15A NCAC 02B Standards.
- If the magnitude, duration and frequency of contamination is consistently elevated, then the 02B Standards are considered violated and the site is ineligible for a risk-based closure.

If the groundwater contaminant concentrations and surface water flow rate are known, the Risk Calculator can predict the surface water contaminant concentration using simple advective transport and dispersion equations.

#### 4.2.5 Evaluating Plume Stability

A risk-based groundwater remedy is most applicable to a groundwater contaminant plume that is predictable, stable or shrinking over time. A plume is considered to be “stable” when monitoring data representative of the entirety of the plume demonstrate that the plume is not expanding and that, overall, contaminant concentrations are not increasing over time. A stable plume indicates that groundwater contamination is contained and there is no increased risk to future receptors. Stability does not imply lack of change, but rather change and variability within predictable and manageable limits over time frames of regulatory interest. A risk-based remedy must demonstrate either of the following according to G.S. 130A-310.73A:

***A demonstration of plume stability should include:***

- Sufficient spatial coverage of sample points to define the plume’s configuration and monitor its behavior.
- At least four (4) site-wide sampling events over time to understand contaminant trends.
- At least eight (8) sampling events for statistical evaluation.
- Maps of plume’s spatial extent over time.
- Graphs of individual well trends over time.
- Graph of concentration vs. distance over time.
- Calculations of plume area, plume mass, plume center of mass, and/or mass flux analyses.

- No contamination will migrate beyond the source property at levels above unrestricted-use standards, or
- Contaminant concentrations on a non-source property shall not increase above the calculated site-specific remediation levels, and written consent for site-specific remediation levels is obtained from the non-source property owner.

Potential property-use changes that could alter plume stability, such as increased infiltration due to site development activities or use of future water supply wells, need to be considered when developing a remedial strategy. To effectively manage long-term risks, institutional controls should be protective of both current and potential future risks.

#### **4.2.5.1 Data Needs**

A history of groundwater monitoring data is needed to understand a plume's current behavior and stability, and to predict future behavior. The number of spatial and temporal monitoring points must be directly proportional to the certainty of understanding plume conditions and protecting receptors. There should be a sufficient number of monitoring points to demonstrate contaminant trends over time throughout the plume.

Monitoring well network design should be based on all available information concerning the processes and factors expected to control contaminant distribution. For example, original contaminant source distribution, site geology, and hydrology can influence spatial and temporal variability of plume shapes, which should govern the monitoring locations and sample frequency decisions. Monitoring frequency should account for any variability in plume concentrations and extent due to seasonal water table fluctuations, tidal influence, contributing contaminant sources, remediation, and/or natural attenuation. Data results at key monitoring wells should be used to interpret the behavior of the plume as a whole.

#### **4.2.5.2 Data Analysis**

Assessing plume stability requires analyzing historic groundwater data from individual well locations by using the following methods.

- Graphical methods (i.e., qualitative evaluation)
  - Concentration versus time plots, concentration versus distance plots, and concentration isopleths maps
- Quantitative methods
  - Statistical methods include well-by-well trend analysis (i.e., Mann-Kendall, linear regression)
  - Plume-based methods (i.e., plume area, plume mass, plume center of mass, and mass flux analyses)

#### **Graphical or Qualitative Evaluation**

Plume stability should be supported by tabulated historic data, contaminant concentration contour maps, concentration versus time graphs for select monitoring wells and concentration versus distance graphs showing concentrations along the plume centerline at select time points. Displaying the data in visual form is the best way to support conclusions made regarding plume stability as shown in Table 4-2.

Comparing isoconcentration maps over time can provide compelling visual evidence for natural attenuation. However, a comparison of plume size over time does not always provide a complete

analysis. In the case of a plume that discharges to a surface water body, or plume geometry that is persistent over time, the plume shape may not change but the overall plume average concentration and mass may be increasing or decreasing. The change in plume mass would not necessarily be reflected in the visual analysis.

Quantitative Evaluation

In addition to qualitatively evaluating plume behavior with visual depictions of site data, quantitative analysis of changes in overall plume concentration and mass can help demonstrate plume stability. A common approach for evaluating plume stability is the use of statistical analysis for single-well data. However, meaningful statistical tests will require substantial monitoring timeframes (eight or more consecutive events) to acquire sufficient data. Determination of temporal trends at individual well locations using regression, Mann-Kendall, or Mann-Whitney methods are common approaches for assessing plume stability. However, chemical concentration trends at individual monitoring wells may not reflect plume trends as a whole. At a given site, some wells may exhibit decreasing trends while others exhibit indeterminate or even increasing trends.

**Table 4-2. Graphical Methods to Evaluate Plume Stability**

Graphical Method	Description	Probability of Significant Risk of Plume Expansion	
		High	Low
Concentration versus Time Plots	Contaminant concentrations versus time at each monitoring well can depict the plume’s attenuation rate. Graphs should include groundwater level data, as groundwater fluctuations can affect concentrations.	Trends in most wells visually stable and/or increasing	Trends in all relevant wells visually decreasing
Concentration versus Distance Plots	Contaminant concentrations versus distance along the plume centerline can reveal the plume’s maximum extent in one dimension. Overlaying several sampling events may reveal an advancing or retreating plume along its centerline.	Moderate or no visual decrease in concentration along the plume centerline and generally increasing trends in plots over time.	Significant visual decrease in concentration along the plume centerline and general decreasing trends in plots over time.
Concentration Isoleth Maps	Isoleth maps can depict the spatial extent of the plume in two dimensions. Graphing several sampling events may reveal an expanding or shrinking plume.	Generally increasing plume size over time.	Discernable decrease in plume size and extent over time.

When evaluating trends in the overall plume area, average concentration and mass provide a more thorough understanding of the entire plume stability, as opposed to isolated locations within the plume. Plume-based methods include plume area, plume mass, plume center of mass, and mass flux analyses. With advances in computing power and the increasing size of datasets, plume-wide trend estimates of center of mass, total dissolved mass, plume area, and mass distribution have been put forward as useful tools in determination of plume stability. Mass flux and mass discharge estimates do have limitations. Reliable mass flux and mass discharge estimates often require more detailed characterization of hydraulic conductivity and groundwater flow than is typically available at most sites. Collecting the data necessary will increase total project cost. The costs may be relatively low for estimates based on models or mathematical analyses of existing data, but they can be significant for high-resolution mapping (measuring fluxes at relatively closely-spaced points along one or more transects or sampling at multiple depth intervals at each sampling point). The uncertainty involved in mass flux and mass discharge estimates can be significant, thus the uncertainty should be quantified and discussed.

## 5. DATA QUALITY NEEDS

### 5.1 Field Data Quality Assurance/Quality Control

Duplicate, equipment rinsate and trip blanks samples provide quality assurance (QA) and quality control (QC) of the field data collected. Program-specific guidance and professional judgment should be used to select and support appropriate QA/QC measures. In some cases, additional data may be needed for certain work phases, such as confirmation samples collected for site closure.

### 5.2 Method Detection Limits and Sample Quantitation Limits

The method detection limit (MDL) reported by the analytical laboratory represents the minimum concentration of a chemical detected by the instrumentation. MDLs are established using matrices with little or no interfering species and are considered the lowest possible reporting limit. The sample quantitation limit (SQL) is typically defined as the MDL adjusted to reflect sample specific actions, such as dilution or use of smaller aliquot sizes, and considers sample characteristics, sample preparation, and analytical adjustments. The practical quantitation limit (PQL) is often higher than the SQL and incorporates laboratory operating conditions and is a report of the minimum concentration at which the laboratory can be expected to reliably measure a specific chemical contaminant during day-to-day analysis of different sample matrices.

To calculate risk, samples should be analyzed using approved methods that can attain SQLs equal to or less than the DEQ screening levels or regulatory standards, or the method with the lowest MDLs. The laboratory should be advised of the desired limits ahead of time. Elevated SQLs affect proper delineation, statistical analysis and risk evaluation, so analyses where the SQLs exceed 10 times the USEPA method detection limits should be explained by the lab. All detected constituents must be considered contaminants even if they were not definitively quantified, unless they were ruled out in the QA/QC evaluation or are demonstrated to be naturally occurring background compounds. Any quality control concerns, data qualifiers or flags should be documented, evaluated and discussed. Data censored by elevated SQLs or PQLs should be noted

and discussed. DEQ reserves the right to require consideration and further evaluation of censored chemicals when conducting a risk evaluation.

## 6. EVALUATING SITE-SPECIFIC RISK

Human-health risk assessment is a scientific process for predicting the likelihood of adverse health effects from exposure to contaminants. Consult with a DEQ risk assessor if a site may have ecological concerns. Human-health risk assessment is approached in a multi-step process that begins by making conservative assumptions and progresses to more site-specific assumptions and evaluations.

Complex risk assessments are not always necessary, especially for sites where contributing sources are removed and site data indicate that the contamination is stable and predictable and can be mitigated through institutional controls.

DEQ's human health risk assessment process follows USEPA's tiered process. State-established preliminary remediation goals (screening levels), are available for individual contaminants, and the cumulative risk of site contaminants may be calculated using the DEQ Risk Calculator. If risk is exceeded using the default exposure parameters in the Risk Calculator, then the exposure parameters may be adjusted (with DEQ approval) to better reflect site conditions. If the cumulative target risk for noncarcinogenic effects is exceeded, a target-organ risk evaluation may be conducted with review by a DEQ toxicologist. The DEQ approach is consistent with the USEPA Risk Assessment Guidance for Superfund (RAGS) and is briefly described below.

### 6.1 Screening Individual Contaminant Concentrations

The first step in DEQ's risk assessment process is a screening evaluation in which individual contaminant concentrations shown to be unrelated to background conditions are compared to conservative screening levels discussed below.

#### 6.1.1 Preliminary Soil Remediation Goals (PSRGs)

The following DEQ soil screening levels can be found on the Risk-Based Remediation website under [Risk Evaluation Resources](#):

- Residential Health-Based PSRGs
- Industrial/Commercial Health-Based PSRGs
- Protection of Groundwater PSRGs (PGPSRGs)

These levels are considered preliminary because they are the first step in assessing risk at a site. They are conservative because they assume that there are a maximum of five non-carcinogenic contaminants detected in a specific media at a site. Final remediation standards can be calculated based on the actual number of contaminants at the site and the cumulative risk they pose, as discussed later in this document.

### 6.1.1.1 Human Health PSRGs

The PSRGs are calculated using the chemical database, toxicity values, default exposure parameters, and equations found in the [USEPA RSL tables](#). DEQ updates the PSRGs following the release of USEPA’s updates which is usually twice per year. The PSRGs are the concentration of a chemical that corresponds to the specified "target risk" for a given exposure scenario. The target risk for individual contaminants categorized as a cancer risk is 1 in 1,000,000 (or 1E-06). The hazard quotient (HQ) for contaminants with non-cancerous health effects is 0.20.

The unrestricted-use or residential PSRGs are calculated using a residential exposure scenario that includes both adult and child (1 to 6 years of age) exposures. Restricted use (industrial/commercial) screening levels are only applicable for non-residential, commercial, or industrial exposure settings that will not be frequented by children. The industrial/commercial PSRGs assume a 40-hour work-week, adult-only exposure scenario. If the site is currently, or likely to become, agricultural, risks will need to be calculated for an agricultural setting in consultation with a DEQ toxicologist due to the concern for possible uptake of contaminants by plants and livestock.

The term **cancer risk** will be used throughout this document to denote the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen.

A **hazard quotient (HQ)** is the ratio of the amount of a contaminant a person is exposed to versus the amount that may cause non-cancer harmful effects. The **hazard index (HI)** is the sum of hazard quotients for a given scenario.

Each contaminant must be screened against the appropriate level presented in the PSRG Table. All contaminants, including “J” flagged values (reported values identified by the laboratory as estimated concentrations), that exceed screening levels must be included as site contaminants in further risk evaluation.

### 6.1.1.2 Protection of Groundwater Preliminary Soil Remediation Goals

The protection of groundwater PSRGs represent contaminant concentrations in a given soil type that, if exceeded, may leach contaminants from soil to groundwater at concentrations exceeding the 15A NCAC 02L Standards. They are calculated using the USEPA equation and conservative default parameters presented in Table 4-1.

## 6.1.2 Groundwater

To determine if groundwater meets the unrestricted-use standard, maximum contaminant concentrations in groundwater are compared to the most conservative (i.e., lowest) of the 15A NCAC 02L Standards, interim maximum allowable concentrations (IMACs) and the USEPA Maximum Contaminant Level. For contaminants without 15A NCAC 02L Standards, the remediating party should contact their remediation program representative at DEQ.

## 6.1.3 Surface Water

All surface waters must meet the 15A NCAC 02B Classifications and Water Quality Standards Applicable to Surface Waters of North Carolina. They are established by the DWR Classifications

and Standards Unit and serve as both screening levels and cleanup standards to protect human health and aquatic life based on the classification of use established by DWR. Refer to the DWR’s [NC Surface Water Classifications map](#) to determine a surface water body’s classification.

There is no option to calculate a site-specific remediation level for surface water. Therefore, if groundwater is discharging to a surface water body at levels that violate the 15A NCAC 02B Standards in magnitude, duration and frequency, groundwater must be actively remediated such that the 15A NCAC 02B Standards are met. To determine whether a surface water body that is in violation of the 15A NCAC 02B Standards, refer to Section 4.2.4.

Risk-based cleanup levels are not allowed for surface waters.

### 6.1.3.1 Human Consumption of Aquatic Life

If bioaccumulative contaminants are detected in a receiving surface water body that can support edible aquatic life, a biota evaluation (e.g., fish, shellfish, crabs) may be needed. USEPA provides fish consumption advisories to inform people about the recommended level of consumption for fish caught in local waters or whether consumption should be limited or avoided due to contamination with chemical pollutants. Common bioaccumulative chemicals include mercury, PCBs, chlordane, dioxins, and DDT ([National Listing of Fish Advisories General Fact Sheet 2011](#)). Refer to USEPA guidance to identify other bioaccumulative chemicals, which are generally identified as those with a log  $K_{ow}$  from ~3.5 to ~6.5 or greater. Investigations of bioaccumulative chemical exposures through the food chain will likely require the development of site-specific screening values and remediation levels, requiring a more detailed risk evaluation conducted by a toxicologist.

### 6.1.4 Sediment

Sediment can be contaminated through surface runoff, groundwater discharge or both. Maximum sediment concentrations are compared to the health-based PSRGs for soil. This approach is overly conservative since sediment will usually be covered by water, limiting direct contact as a human health pathway. If sediment becomes a risk driver, or is an exposure risk to the ecological system, a detailed site-specific exposure evaluation should be conducted.

### 6.1.5 Indoor Air

With the advent of the DEQ Risk Calculator, DWM is no longer relying on groundwater, soil gas and indoor air screening levels for the residential and non-residential VI exposure scenarios. The DEQ Risk Calculator must be used to determine the human-health risk (see the following section). Risk can be calculated using indoor air, soil gas, or groundwater data. If only groundwater data are available, and the allowed risk is exceeded, then soil gas data must be collected for further VI risk evaluation. Consult the [DWM VI Guidance](#) for procedures on conducting a step-wise vapor intrusion evaluation.

It is essential that vapor intrusion evaluations proceed in a logical, step-wise fashion. Refer to the [DWM VI Guidance](#) when conducting a VI assessment and use the DEQ Risk Calculator to determine risk.

## 6.2 Calculating Cumulative Risk using the DEQ Risk Calculator

Where more than one contaminant exists at a site and a screening level is exceeded, cumulative risk can be calculated by entering maximum concentrations of all detected contaminants into the DEQ Risk Calculator for a specific area. The area could be the entire site to be conservative, an distinct exposure area (e.g., a portion of a building for indoor air risk), or even a specific location (e.g., a boring location for soil risk). The calculator can calculate and sum the combined site-wide risks of all contaminants in soil, groundwater, surface water, vapor and sediment, and compare the calculated risk with the allowed risk targets established in law: The target cumulative risk for contaminants with a cancer risk is 1 in 10,000 (which is the upper-end of USEPA’s acceptable risk range of 1E-06 to 1E-04) and a non-cancer hazard index (HI) of 1.0.

The DEQ Risk Calculator, User Guide, and Risk Evaluation Equations and Calculations are available on the [Risk Evaluation Resources](#) webpage. These documents are updated regularly, so it is important to always use the most recent versions.

The DEQ Risk Calculator is an Excel-based, menu-driven program available to the public that calculates risk to receptors from exposure to contaminated media. A *Risk Calculator User Guide*, available as a link within the Risk Calculator or on the Risk-Based Remediation website, presents step-by-step instructions on its use. The calculator has multiple modules that quantify health risks for defined exposure scenarios. Inputs, equations, and procedures used in the Risk Calculator are consistent with those described in USEPA risk assessment guidance, including USEPA Risk Assessment Guidance for Superfund (USEPA, 1991 and USEPA, 2004), USEPA Soil Screening Guidance (USEPA, 1996 and USEPA, 2002), USEPA Region 4 Human Health Risk Assessment Supplemental Guidance (USEPA, 2014a), and the USEPA RSL website. Where USEPA default equations or inputs are not available, the DEQ has established North Carolina specific inputs for exposure scenarios (e.g., infiltration rates for leaching soil and particulate emission factors for construction worker exposure).

The DEQ Risk Calculator also has conservative contaminant migration equations: the soil to groundwater pathway is built with the equations and default parameters in Table 4-1, and the groundwater transport pathway incorporates a simple Domenico groundwater transport equation for dissolved contaminant plumes. The aquifer parameters for each migration pathway can be modified with documented rationale for site-specific values. By entering a desired target concentration at a receptor, reverse-mode calculations can determine cleanup levels in the source area. For example, the reverse mode calculators can help identify the threshold concentration for leaching soil or source groundwater concentrations that should preclude off-property plume migration. This calculator is not appropriate for evaluating complex sites where conditions such as fractured rock, complex geology, NAPL or pumping wells exist.

The Risk Calculator’s chemical and toxicity database (chem-tox) values are obtained directly from USEPA’s RSL Chemical-Specific Parameters Supporting Table. The Risk Calculator will be updated after USEPA releases their updates, which is typically twice per year. It should be noted that the DWM “industrial/commercial” PSRG screening levels and the “non-residential worker” scenario in the risk calculator correspond to the USEPA RSL “composite worker” exposure scenario. The construction worker equations in the risk calculator use sub-chronic (short term)

toxicity data while the remaining receptor equations use chronic (longer term) toxicity data.

### 6.3 Unique Risk Evaluation Procedures for Select Contaminants

#### 6.3.1 Lead

Currently there is no USEPA reference dose or cancer potency factor to quantify risks associated with exposures to lead using the Risk Calculator. Lead exposure risk is characterized based on predicted blood lead levels. Refer to the PSRG table for the soil screening levels that are developed based on the combined exposure from lead in soil and well water. The USEPA's Maximum Contaminant Level (MCL) for lead in drinking water is 15 micrograms per liter ( $\mu\text{g/L}$ ). If either of these levels is exceeded, the [Integrated Exposure Uptake Biokinetic \(IEUBK\) Model for Lead in Children](#) and the [Adult Lead Methodology \(ALM\)](#) may be used to assess the site-specific risks and calculate remedial levels. The USEPA has also developed the ALM for evaluating the potential risks from lead in pregnant females. Refer to the [USEPA lead guidance](#) for additional information.

#### 6.3.2 Polychlorinated Biphenyls (PCBs)

Although risk from PCBs can be determined using the Risk Calculator, their evaluation warrants some explanation due to the complex mixtures, varying toxicities of individual congeners and data needs. The general protocol for evaluating PCBs at a site is presented below:

1. Determine which PCB congeners are present at the site using USEPA Method 1668 (see Appendix A-2).
2. Risks associated with the 12 dioxin-like congeners (identified in Table A-2) are assessed individually. Risks for the remaining 197 congeners are evaluated as the sum of the non-dioxin-like congeners.
3. Calculate the concentration of the total non-dioxin-like PCB congeners.
 
$$\sum \text{total PCBs} = \sum \text{total dioxin-like congeners} + \sum \text{total non-dioxin-like congeners}$$

$$\sum \text{total non-dioxin-like congeners} = \sum \text{total PCBs} - \sum \text{total dioxin-like congeners}$$
4. Enter the concentrations for the 12 dioxin-like PCB congeners into the risk calculator and enter the total non-dioxin-like congeners concentration into the risk calculator as "Polychlorinated Biphenyls (high risk)".

### 6.4 More Advanced Human Health Risk Assessment

If the DEQ Risk Calculator indicates an unacceptable risk, a more detailed risk evaluation can be conducted by a professional risk assessor or toxicologist. Since toxicity values may be based on multiple target organs/critical effects, a more detailed toxicological evaluation will consider the risk to each target organ.

It is anticipated that the vast majority of risk evaluations will be conducted using methodologies involving screening levels and the Risk Calculator. While a professional toxicological evaluation may be conducted at any site, it is usually only required for larger, more complex sites where the added cost of the risk assessment may result in a more cost-effective cleanup strategy.

Guidance for conducting a more detailed site-specific risk assessment is provided in [USEPA Superfund Guidance For Human Health Risk Assessments](#). Discussions with DEQ risk assessors or toxicologists prior to initiating such a detailed risk assessment are essential. In these cases, documents describing current and future site uses, sampling strategies to fill data gaps, exposure parameters and models, toxicity values, and processes for assessing risk and calculating cleanup levels should be approved by DEQ.

## 7. CALCULATING SITE-SPECIFIC REMEDIATION LEVELS

Site-specific remediation levels are target concentrations at which the site meets a level of risk that is acceptable, protective and sustainable. Establishing cleanup levels requires consideration of all contaminated media and how other media are affected by contaminants left in-place. For example, in determining a cleanup goal for soil, the resulting property use must be compatible with surrounding land uses; contaminants left in place cannot further deteriorate other media (groundwater, surface water, and indoor air); and measures must be implemented to manage risks resulting from contaminated media.

The industrial-commercial PSRGs can be used as final cleanup levels for soil in lieu of determining an industrial-commercial cleanup level using the Risk Calculator. In both cases, the property use will be restricted to industrial/commercial only. Remedial goals for groundwater are considered to be met when groundwater contamination poses no unacceptable risk to current and future receptors for the following reasons:

1. Contributing sources of contamination have been removed or depleted.
2. Plume conditions are stable or improving.
3. Future risks can be managed with a groundwater-use restriction.

Where active remediation of soil or groundwater is necessary to address unacceptable risks, target cleanup levels can be calculated using the DEQ Risk Calculator. Where one contaminant is present at a site, the user can enter a series of concentrations until the calculated risk meets the acceptable targets (see the Risk Calculator User Guide for more details). Calculating site-wide cleanup levels becomes more difficult when there are several contaminants unless a risk driving contaminant is evident at the site. Remediating parties will be expected to demonstrate that the cleanup level calculations include appropriate input parameters, assumptions, and safety factors commensurate with the complexity of the site and level of uncertainty.

## 8. RISK MANAGEMENT AND ENSURING REMEDY PROTECTIVENESS

Once the risks are quantified, active remediation, engineered controls, and/or institutional controls must be implemented to manage those risks in a way that ensures protection of human health and the environment. Risk-management decisions consider the significance of the risk and how it should be addressed. To effectively manage risk, the following factors should be considered:

- **Scientific:** The level of risk calculated from the risk evaluation, and the cleanup levels needed to mitigate unacceptable risks.
- **Technical feasibility:** Feasibility of implementing a risk management option.
- **Economic:** The cost of risk mitigation and the benefit of the outcome.
- **Social:** Land use, zoning, community input.
- **Political:** Interactions among branches of the federal government, local government entities, special interest groups, or concerned citizens.

All proposed risk-based remedies must demonstrate that they are protective of existing and potential future receptors (e.g., future water supply wells and occupants of future structures).

## 8.1 Engineered Controls

Engineered controls (ECs) encompass a variety of engineered and constructed physical barriers to contain and/or prevent exposure to contamination on a property. Many different types of ECs can be implemented, depending on the contaminants found and the type of media impacted. The following is a list of the more commonly used ECs. Individual DEQ remediation programs may have a preference or specifications for certain technologies, so coordination with the Department is highly encouraged.

- **Capping in Place (Asphalt or Concrete)** – The use of paved areas (e.g., parking lots, roadways) and building slabs as surface barriers, or caps, over contaminated soil reduces surface water infiltration, stabilizes contaminated soils, and prevents dermal contact with the contaminated soil.
- **Capping in Place (Clean Fill)** – Placement of a defined thickness of clean fill over an area of contaminated soil prevents dermal contact with the contaminated soil. The thickness is typically 18 inches but may vary among remediation programs. A geotextile fabric marker beneath the clean fill is typically required, and erosion control measures must be in place.
- **Passive Depressurization Systems** – Installation of a passive vapor control system in conjunction with a vapor barrier beneath buildings minimizes potential migration of volatile contamination to indoor air. A passive depressurization system relies on a natural convection of air to draw air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Active Depressurization Systems** – Installation of an active vapor control system in conjunction with a vapor barrier beneath buildings minimizes potential migration of volatile contamination to indoor air. An active depressurization system consists of a fan or blower which draws air from the soil beneath a building and discharges it to the atmosphere through a series of collection and discharge pipes.
- **Groundwater Migration Barriers**– The use of groundwater flow, chemical or impermeable barriers impede or prevent migration of contaminated groundwater or leachate.

Other less common ECs include:

- **Security Barriers and Fencing** – Used to restrict access to contaminated areas.
- **Solidification/Stabilization** – Injecting or mixing cement into contaminated soil to lock contaminants into a structurally sound mass of solid material for disposal.
- **Geotextile Fabric Barriers** – Separate, filter, drain, or reinforce soils.
- **Engineered Caps** – Designed to meet specific performance and containment requirements such as permeability.
- **Leachate Collection Systems** – Direct and collect contaminated leachate and then transport it to another location for disposal.

In all cases, ECs must be inspected and maintained for integrity and effectiveness, at least annually, and the results reported to DEQ in an annual inspection report.

## 8.2 Institutional Controls

Institutional controls cannot render use of a property as incompatible with the surrounding land use.

Restricted property use must comply with land-use and development controls adopted by a municipality or county.

Institutional controls are required for all sites that do not meet unrestricted-use (residential) standards. They are administrative or legal instruments that limit the full use of contaminated property to protect receptors from current or potential future exposure to contamination. Institutional controls also identify the presence of engineered controls and specify their long-term maintenance and monitoring requirements.

The DEQ institutional control documents (in the form of a survey plat notice and/or a land-use restriction document) provide notification that residual contamination remains on a property. Engineered controls such as caps, mitigation barriers, or fencing, are also described and identified in the documents. Table 8-1 shows the institutional controls required on contaminated property.

The legal documents are recorded with the Register of Deeds in the county where the site is located. Although the content of the documents is similar, the title of the documents may differ among DEQ remediation programs. However, for all risk-based cleanups under G.S. 130A-310.65 through 310.77, the survey plat notice can be titled “Notice of Residual Contamination.” Existing DEQ institutional controls on a property (e.g., as part of a Brownfields agreement) may be relied upon as the site remedy as long as the contamination does not extend beyond the source property and any land-use restrictions (LURs) are sufficient to mitigate all identified risks. The DEQ program that signed the documents will maintain responsibility to ensure inspection and maintenance of the LURs.

### **8.2.1 Reliance on State and Local Land-Use Controls**

Properties with only groundwater contamination may rely on state or local land-use controls in lieu of LURs provided they are reiterated on a Notice of Residual Contamination (survey plat) and the following are true:

1. There is no associated human health or environmental risk on the property due to vapor intrusion or other contaminated media.
2. Permission for the Notice is obtained from the property owner(s).

The Notice of Residual Contamination may be filed by the property owner or the person who proposes to remediate the site. Rules 15A NCAC 02C .0107 (b)(1) and 15A NCAC 02C .0112(a) must be referenced on the notice in the notes section to restrict future water-supply wells on the property. Reliance on these existing rules and other local land-use controls eliminates the need for property owners to annually report the maintenance and inspection of recorded LURs, since that requirement only runs with the land-use restriction document.

### **8.3 Restricting Land-Uses**

LURs are developed for each contaminated media according to the intended land use. DEQ has a standard set of LURs associated with the risks posed, and others may be proposed by the property owner. Easements and non-financial encumbrances must be considered when planning LURs. All rights-to-use must not be hindered without written agreement from the easement or encumbrance holder(s). If LURs were previously recorded without DEQ's involvement, they will need to be subordinated or cancelled in some cases. In general, LURs typically follow the principles outlined below for each contaminated medium.

#### **8.3.1 General Property-Use Restrictions**

Each remedy that relies on LURs will need to consider the current and anticipated land uses from a risk perspective and tailor the restrictions accordingly. For example, if a property is restricted to non-residential use, an evaluation of risk to construction workers, if large-scale development is planned, and trespassers, if the property is unsecured, may be necessary.

Restricting a property to “industrial use only” is not equivalent to “non-residential use only.” “Industrial use” in the zoning context generally allows for parks, recreational areas and day care facilities on industrial property. Similarly, “commercial use” can vary greatly to include schools and activities similar to industrial use. If the intent of the proposed restriction is to prohibit residential, day care, and school uses, the restriction should list the specific uses for which the property may not be used.

**Table 8-1. Conditions Requiring Institutional Controls**

<b>Media Contaminated</b>	<b>Condition</b>	<b>Land-Use Restriction Document<sup>1</sup></b>	<b>Notice of Residual Contamination (Survey Plat)<sup>2</sup></b>
<b>Groundwater Only</b>	Current or predicted contamination in <b>groundwater only</b> poses ingestion risk only (no vapor exposure risk)		X
<b>Groundwater and Soil and/or Vapor</b>	Contamination in <b>groundwater and other media</b> (e.g., soil, vapor) above unrestricted use poses multiple exposure risks (ingestion, dermal, inhalation)	X	X
<b>Potential Groundwater</b>	A <b>threat of groundwater contamination</b> migration exists if pumping wells are installed on the property		X <sup>3</sup>

<sup>1</sup> Land-use restriction documents may require annual inspection and certification by the property owner at the discretion of the Department.

<sup>2</sup> The Notice of Residual Contamination will have a “notes” section that states the condition of the property (e.g., current, predicted, or potential threat of groundwater contamination) and recites State or local land-use controls, including the following language in the box below. Additional local ordinances relating to water line connection requirements, or well-installation or groundwater-use restrictions, should also be added as a note. The Notice does not require annual certification.

*Pursuant to 15A North Carolina Administrative Code 02C .0107 (b)(1), “(t)he source of water for any water supply well shall not be from a water bearing zone or aquifer that is contaminated”). Therefore, state law prohibits construction of a water supply well on this property. Further, pursuant to North Carolina General Statute 87-88(c) and 15A North Carolina Administrative Code 02C .0112(a), no well may be constructed or maintained in a manner whereby it could be a source or channel of contamination of the groundwater supply or any aquifer*

<sup>3</sup> The “notes” section should also state that “the property is currently not affected by the identified source-property contamination, but based on the information collected to date, a threat of contamination may exist if water supply wells are installed on the property.”

### 8.3.2 Requirements for Properties with Soil Contamination

Residential Property Use: Soil contamination on residential property must be cleaned up to acceptable risk levels unless an existing building or other engineered barrier overlies the contaminated material, it is technically impracticable to remove soils, or if the property has mixed use with no residences on ground level. In these cases, LURs and proper engineering controls will be necessary.

Soil removal: Remedies not meeting acceptable residential risk levels throughout the soil column, must include a restriction that bars removing soil from the property.

Barriers: If the remedy utilizes barriers (caps) to prevent exposure to soil contamination that poses a risk for the intended property use, the barriers must be defined, visible barriers such as concrete, asphalt, or earthen material with marker fabric beneath and surrounded by bollards or fencing. A building may be an adequate barrier to soil contamination. The following general requirements may apply:

- The area should be generally rectangular in shape and not curved, irregular, or consist of multiple smaller patches of cover so the perimeter can be surveyed and the boundary depicted on the Notice/Survey Plat.
- The perimeter of the capped area must have a visible and physical boundary marked by bollards or fencing (not just paint), or the entire property must be fenced.
- A restriction should state that disturbance of the barrier or underlying soil (digging) is not allowed without DEQ approval. There may be circumstances that specific disturbances are allowed, and these should be noted in the restrictive covenants.
- As part of the annual certification, the owner must inspect barriers and document they have been maintained in accordance with the specifications in the LUR.
- A vegetative cover is an acceptable barrier if the area is fenced with no regular access and the risk assessment indicates it is safe for a worker to maintain the vegetative cover and fence.
- *High vehicular traffic areas* should have durable barriers such as concrete or asphalt. Parking lots, and areas accessible by trucks and cars, are considered high-traffic areas.
- *Low or no vehicular traffic areas* can have an earthen barrier. If soil contamination is present within 10 feet of the ground surface, a geotextile marker fabric must be used to reveal erosion. Typically, contaminated soil is covered by a minimum of one foot of structural fill, geotextile fabric, and 6 inches of amended topsoil, to promote a vegetative cover. If contaminated soil cannot be covered by a minimum of one foot of structural fill, the geotextile fabric can be placed directly on the ground surface and overlain by 12 inches of topsoil.
- High-use areas, such as ball fields, kennel yards and horse-riding rings will require earthen barriers of a thickness greater than 3 feet.
- If irrigation systems, lighting conduit or other infrastructure is desired within the earthen barrier, then the barrier must be of greater thickness, or must be augmented with clean fill, to accommodate the installation and maintenance of such systems.
- For earthen barriers, required maintenance may include measuring the depth and extent of the barrier to ensure compliance with the LURs.

### 8.3.3 Requirements for Properties with Groundwater Contamination

In general, properties where groundwater contamination concentrations exceed the 15A NCAC 02L Standards will have restricted groundwater use. The groundwater-use restriction will



encompass the entire parcel. Some large properties may be subdivided to avoid LURs on uncontaminated portions if most of the property is uncontaminated and a technical demonstration supports such.

Existing and potential future groundwater supply wells in the vicinity of a site must be considered in a risk evaluation to ensure that site contaminant levels are protective of all current and future receptors. Remediators may need to request permission from property owners to restrict groundwater use where future water supply wells could draw contaminants onto those properties (see Note 3 in Table 8-1).

**8.3.4 Requirements for Properties with Vapor Intrusion Risks**

When occupants of buildings on a property are determined to be at risk from landfill gas or volatile vapors emanating from the site, mitigation measures must be implemented. Passive mitigation measures such as improved ventilation, sealing of potential conduits where vapors may be entering the building, and enclosing passively venting sumps may significantly reduce the vapor intrusion risk. In other cases, engineered controls in the form a vapor barrier and/or an active mitigation system may be required.

Remediating parties will be expected to satisfactorily demonstrate through sampling, or other direct means, that the mitigation measures are functioning as designed. Requirements for the property owner’s routine inspection and maintenance of the controls will be included in the LUR document.

**8.4 Recordation of Documents**

If two institutional controls are needed on properties with multi-media contamination, the Survey Plat must be recorded with the Register of Deeds first. The map book and page number provided by the Register of Deeds is then entered into the LUR document. The LUR document is recorded last.

If only a Notice of Residual Contamination is being recorded on a non-source property, no annual inspection and certification is required.

To confirm proper recordation of documents, the remediating party must provide electronic copies of the recorded documents to the appropriate program with the following Register of Deeds notations: (1) the book and page number where the document was recorded and (2) the date of recordation. Confirm that the date of recordation noted on the grantor/grantee pages matches the date on the document. Also, the remediation program may require confirmation that the documents are referenced to the appropriate property on the grantor/grantee pages by either providing proof of a GIS search or request a certification of recordation from the Register of Deeds.

**9. REMEDIAL ACTION PLAN**

The risk-based RAP is a public document that should be written in a clear and concise manner in accordance with this guidance and program-specific requirements. The plan presents preliminary

decisions and/or recommendations for a site that may require revision following DEQ review and public comment.

## 9.1 Content

In general, a RAP should reference the remedial investigation report(s) on file, present the CSEM and a detailed risk evaluation, present the methodology for developing site-specific remediation standards, and describe the key components of the plan to mitigate all unacceptable risks to public health and the environment. According to G.S. 130A-310.69(b), a risk-based RAP should include the key elements outlined below, as applicable:

1. Identify the current and anticipated future uses of property comprising the contaminated site.
2. Identify the current and anticipated future use of groundwater at the contaminated site.
3. Present and describe the CSEM with receptors and exposure pathways (both current and potential future) identified.
4. Address contamination that moves from one medium to another in order to prevent a violation of the remediation standards established under G.S. 130A-310.68. A more stringent remediation standard may be required for a particular medium to control impact on other media.
5. Present the risk assessment and mitigation measures for all unacceptable risks to human health and the environment.
6. Provide for attainment and maintenance of the remediation standards established under G.S. 130A-310.68.
7. Describe the plan for mitigating all unacceptable risks, including the imposition and recordation of land-use restrictions as provided in G.S. 143B-279.9, 143B-279.10, 130A-310.3(f), 130A-310.8, 130A-310.35, 143-215.84(f), and 143-215.85A if the RAP allows contamination in excess of the greater of unrestricted use standards or background standards to remain on any real property or in groundwater that underlies any real property.
8. Address any concerns raised in public comment on the proposed RAP as to the future use of the property and groundwater.
9. Provide for submission of an annual certification to the Department by the property owner that land use at the site is in compliance with land-use restrictions and the land-use restrictions are still properly recorded in the chain-of-title for the property.

## 9.2 RAPs that Include Active Remediation

The option exists to develop a risk-based RAP that attains cleanup levels through a combination of remediation activities that can include treatment, removal and engineering, in addition to institutional controls. However, the person conducting the remediation must demonstrate with reasonable assurance that that site-specific remediation standards are appropriate for the site; the proposed RAP can be implemented within a reasonable timeframe without jeopardizing public health or the environment; that contamination will not migrate to non-source property at levels above unrestricted use standards unless property owner consent is obtained for site-specific remediation levels; and the cleanup levels and objectives were achieved and maintained.

The remediator will need to balance the cost of pursuing an engineered risk-based remedy with the level of certainty that the cleanup objectives will be met and maintained. In addition to the items listed above, the following should be included in a risk-based RAP proposing an active, engineered remedy:

1. Describe actions required to remove, treat, or otherwise appropriately mitigate or isolate the source of contamination to ensure that the source will not cause unrestricted use standards to be exceeded in any uncontaminated medium.
2. Provide a detailed description of the proposed remedial action to be taken; the results of any treatability studies and additional site characterization needed to support the proposed remedial action; plans for post-remedial and confirmatory sampling; a project schedule; a schedule for progress reports to the Department; and any other information required by the Department or considered relevant by the person who submits the proposed RAP.
3. Discuss the ease or difficulty of implementing the RAP, including commercially available remedial measures; expected operational reliability; available capacity and location of needed treatment, storage, and disposal services for wastes; time to initiate remediation; and approvals necessary to implement the remediation.
4. Evaluate the toxicity, mobility, and volume of contaminants, including the amount of contaminants that will be removed, contained, treated, or destroyed; the degree of expected reduction in toxicity, mobility, and volume; and the type, quantity, toxicity, and mobility of contaminants that will remain after implementation of the RAP.
5. Specify any measures that may be necessary to prevent adverse effects to the environment that may occur at levels of contamination that are lower than the standard necessary to protect human health.
6. Specify any measures that may be necessary to prevent any discharge into surface waters during implementation of the RAP that violate applicable surface water quality standards adopted by the NC Environmental Management Commission (Commission).
7. Specify any measures that may be necessary to prevent air emissions during implementation of the RAP that violate applicable air quality standards adopted by the Commission.
8. Provide for methods and procedures to verify that, at the conclusion of the contaminant-reduction phase of remediation, the quantity, concentration, range, or other measure of each remaining contaminant meets the remediation standards established for the site; an acceptable level of risk has been achieved; and no further remediation is required.
9. Evaluate the short-term risks and effectiveness of the remediation, including the short-term risks that may be posed to the community, workers, or the environment during implementation of the RAP, and the effectiveness and reliability of protective measures to address short-term risks.
10. Provide a description of measures that will be employed to ensure that the safety and health of persons on properties in the vicinity of the site and persons visiting or doing business on the site will not be adversely affected by any remediation activity.
11. Discuss the long-term risks and effectiveness of the proposed remediation, including an evaluation of all of the following:

- a. The magnitude of risks remaining after completion of the remediation.
  - b. The type, degree, frequency, and duration of any post-remediation activity that may be required, including, but not limited to, operation and maintenance, monitoring, inspection, reports, and other activities necessary to protect public health and the environment.
  - c. Exposure potential for human and environmental receptors to contaminants remaining at the site.
  - d. Long-term reliability of any engineering and voluntary institutional controls, including repair, maintenance, or replacement of components.
  - e. Time required to achieve remediation standards.
12. Provide a reasonable remedial action cost estimate sufficient for the Department to determine an acceptable level of financial assurance.
13. Provide proof of financial assurance, if required by G.S. 130A-310.72.

### **9.2.1 Financial Assurance Requirements**

Financial assurance may be required to provide a means of ensuring that sufficient funds are available to implement and maintain active remediation systems or controls proposed in a RAP. DEQ proposes to implement provision G.S. 130A-310.72 in a manner that balances the need to ensure that funds are available to maintain critical remedial or engineered control systems with the need to reduce costly requirements that provide little to no benefit protecting public health or the environment.

DEQ does not intend to require financial assurance for risk-based remedies where the mitigation measures involve low-cost activities, such as producing the annual certification document and inspection and maintenance for contaminated soil caps (e.g., parking lot, building footprint, or native soil with vegetative cover). Programs with significant financial assurance experience have found that long-term financial assurance for low-cost activities is unavailable or cost prohibitive; it may not always be possible to secure trusts and escrows for lower cost activities; and corporate guarantees may not be available to all remediating parties.

### **9.3 RAP Approval and Implementation**

DEQ will review and approve a proposed RAP consistent with the procedures set out in 130A-310.71. Most importantly, DEQ will determine whether site-specific remediation standards are appropriate for the site, considering current and future groundwater use, land use, and proximity of contamination to receptors. The requirements for preparing a RAP per G.S. 130A-310.69 and the applicable remediation program must be met. RAPs must identify all current and potential future risks, present the risk mitigation measures, and demonstrate with reasonable assurance that public health and the environment are protected. The RAP must also demonstrate with reasonable assurance that contamination from the site will not migrate to non-source properties above unrestricted use levels unless consent for the necessary institutional controls have been obtained from the property owner.

RAP approval will consider the information presented as well as information provided by local governments and adjoining landowners in response to the NOIR. Additional information may be requested by DEQ in order to make a determination on the proposed RAP. Once DEQ approves the proposed RAP, the public notification requirements of applicable programs can commence. All public comments must be reviewed and addressed by the remediating party or DEQ.

RAP implementation is the onset of active remediation, construction of proposed engineered controls and/or the recordation of institutional controls with the Register of Deeds.

## **10. REMEDIAL ACTION COMPLETION AND NO FURTHER ACTION**

After the RAP has been fully implemented, and the mitigation measures are in place, operational, and demonstrated to be effective, and site-specific remediation goals have been achieved, the remediating party can submit a remedial action completion report. This final report should document that site remediation has achieved the approved cleanup levels or standards, institutional controls are recorded, engineered controls are operational and effective, and monitoring wells are properly abandoned.

The final report can be accompanied by a request that DEQ issue a determination that no further remediation beyond that specified in the approved RAP is required. Once DEQ has issued a no-further-action (NFA) determination, DEQ could require additional remedial action by the remediating party if there is a material change in the facts known to DEQ at the time the NFA determination was issued, or new facts cause DEQ to find that further assessment or remediation is necessary to prevent unacceptable risk to human health or the environment.

### **10.1 Annual Certification of Land-Use Restrictions**

If required in the recorded DPLUR for the property, each year by January 31<sup>st</sup>, current and future owners of properties must conduct, at a minimum, an annual site inspection to confirm compliance with the LURs and submit to DEQ a certification form confirming that the LURs are in place and maintained as specified in the LUR document. According to N.C.G.S. 130A-310.3(f) property owners must enforce the LURs and are expected to take action immediately upon discovery of a violation of the LURs. Failure to do so could cause automatic revocation of DEQ's approval of the environmental cleanup activities. An example annual report form is included as Appendix B.

DEQ may periodically inspect restricted properties with engineered controls for compliance with the property's use restrictions. Owners of restricted properties must allow DEQ access to the property for such inspections.

### **10.2 Cancellation of Land-Use Restrictions**

If the owner demonstrates through sampling that all risks are mitigated, and hazardous substances are no longer present above unrestricted-use cleanup levels, the owner may request that the DEQ Secretary cancel the LUR document. Canceling LURs without prior DEQ approval will cause automatic revocation of approval of the RAP and will subject the party taking such action to enforcement.

## Glossary of Risk Evaluation Terms

**Background** - Three types of background levels may exist for chemical substances: (a) Naturally occurring levels: Ambient concentrations of substances present in the environment, without human influence; (b) Anthropogenic levels: area wide concentrations of contaminants such as dioxins, PAHs and PCBs not from a single source, but due to deposition from air; (c) Concentrations of substances present in the environment due to human-made, upgradient sources (e.g., automobiles, industries).

**Bioaccumulative(tion)** - The net accumulation of a chemical in or on an organism from all sources (food, direct contact with water, diet). The increase in concentration of a chemical in tissue compared to the environment, generally occurs with materials that are more soluble in lipids and organics (lipophilic) than in water (hydrophilic). Generally, a term limited for use to describe uptake by aquatic organisms.

**Capillary Fringe** - The porous material just above the water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void spaces.

**Carcinogen** - An agent capable of inducing cancer.

**Ceiling Concentration (Max)** - The ceiling limit of 100,000 mg/kg is equivalent to a chemical representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may be violated (for example, soil adherence and wind-borne dispersion assumptions) due to the presence of the contaminant itself.

**Chronic Exposure** - Repeated exposure by the oral, dermal, or inhalation route for more than approximately 10% of the life span in humans (more than approximately 90 days to 2 years in typically used laboratory animal species). Typically relates to the evaluation of non-cancer health effects.

**Conceptual Site Exposure Model** - A three-dimensional picture of site conditions that conveys what is known or suspected about the sources, releases and release mechanisms, contaminant fate and transport, exposure pathways, potential receptors, and risks. The conceptual site model is based on the information available at a given point in time and will evolve as more information becomes available.

**Critical Effect** - The first adverse effect, or its known precursor, that occurs to the most sensitive species as the dose rate or exposure concentration of an agent increases.

**Exposure** - Contact made between a chemical, physical, or biological agent and the outer boundary of an organism. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

**Exposure Pathway** - The physical course a chemical or pollutant takes from the source to the organism exposed.

**Exposure Route** - The way a chemical or pollutant enters an organism after contact, e.g., by ingestion, dermal absorption and inhalation.

**Exposure Scenario** - A combination of facts, assumptions, and inferences that define a discrete situation where potential exposures may occur. These may include the source, the exposed population, the time frame of exposure, microenvironment(s), and activities. Scenarios are often created to aid exposure assessors in estimating exposure.

**Hazard Index** - The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, sub-chronic, and shorter-duration exposures.

**Hazard Quotient** - The ratio of estimated site-specific exposure to a single chemical from a site over a specified period to the estimated daily exposure level, at which no adverse non-cancer health effects are likely to occur.

**Human Health Risk Assessment** - The evaluation of scientific information on the hazardous properties of environmental agents (hazard characterization), the dose-response relationship (dose-response assessment), and the extent of human exposure to those agents (exposure assessment). The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree (risk characterization).

**Institutional Controls** - Non-engineering controls used to restrict land use or land access in order to protect people and the environment from exposure to hazardous substances remaining in the site/or facility.

**Leachate** - A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides or fertilizers. Leaching may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, groundwater, or soil.

**Non-Carcinogenic Effects** - Effects other than cancer.

**Particulate Emission Factor** - This factor represents an estimate of the relationship between soil contaminant concentrations and the concentration of these contaminants in air as a consequence of particle suspension.

**ppb** - A unit of measure expressed as parts per billion. Equivalent to 1E-09.

**ppm** - A unit of measure expressed as parts per million. Equivalent to 1E-06.

**Receptor** – The species, population, community, habitat, etc. that may be exposed to contaminants. Receptors may be human or ecological.

**Remediating Party** - the party which has elected (or is deemed to have elected) to perform any Environmental Remediation.

**Soil Saturation Limit (C<sub>sat</sub>)** - The C<sub>sat</sub> is the contaminant concentration above which the contaminant may be present in free phase (NAPL or solid). C<sub>sat</sub> concentrations represent an

upper limit to the applicability of the volatilization factor (VF) model used to generate soil screening levels for the inhalation route, because a basic principle of the model (Henry's law), does not apply when contaminants are present in free phase. VF-based inhalation PSRGs are reliable only if they are at or below Csat.

**Sub-Chronic Exposure** - Repeated exposure by the oral, dermal, or inhalation route for more than 30 days, up to approximately 10% of the life span in humans (more than 30 days up to approximately days in typically used laboratory animal species).

**Target Organ** - The biological organ(s) identified as the location of the most sensitive effect to a specific toxicant for a specific period of exposure to a chemical, physical, or biological agent.

**Vapor Intrusion** - The migration of volatile chemicals from contaminated groundwater or soil into an overlying building.

**Volatilization Factor** - An estimate of the rate at which a chemical is emitted from soil as a vapor.

## **APPENDIX A**

### **Sample Analyses**



**Table A-1. Analyses to Identify Site Contaminants**

<b>Soil and Sediment Samples</b>	
Volatile Organic Compounds <sup>1</sup>	SW-846 Method 8260 Target Compound List
1,4-Dioxane <sup>2</sup>	SW-846 Method 8260 Selected Ion Monitoring (SIM)
Semi-volatile Organic Compounds <sup>1</sup>	SW-846 Method 8270 Target Compound List
Metals <sup>3,4</sup> : antimony, arsenic, beryllium, cadmium, chromium (total), cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium and zinc	USEPA Method or method published in <i>Standard Methods for the Examination of Water and Wastewater</i> having the lowest detection limits or having detection limits below unrestricted-use remediation goals. USEPA Method 1668 should be used for PCB congeners.
Pesticides, polychlorinated biphenyl (PCB) congeners, dioxins, cyanide, formaldehyde and any other analytes	
Hexavalent chromium if total chromium (1) (a) exceeds site-specific natural background concentrations or (b) is a suspected contaminant <u>and</u> (2) exceeds the remedial goal for hex. Cr	SW-846 Method 3060A <sup>5</sup> alkaline digestion coupled with USEPA method or method published in <i>Standard Methods for the Examination of Water and Wastewater</i> having the lowest detection limits or having detection limits below unrestricted-use remediation goals.
<b>Water Samples (including groundwater, surface water and soil leachate)</b>	
Volatile Organic Compounds <sup>1</sup>	SW 846 Method 8260
1,4-Dioxane <sup>2</sup>	SW-846 Method 8260 SIM
Semi-volatile Organic Compounds <sup>1</sup>	SW-846 Method 8270
Metals <sup>3,4,6</sup> (see those listed for soil and sediment)	USEPA Method or method published in <i>Standard Methods for the Examination of Water and Wastewater</i> having the lowest detection limits or having detection limits below the 15A NCAC 02L Standards.
Pesticides, dioxins, cyanide, formaldehyde and any other analytes	
PCB congeners	USEPA Method 1668
Hexavalent chromium if total chromium (1) (a) exceeds site-specific natural background concentrations or (b) is a suspected contaminant <u>and</u> (2) exceeds the remedial goal for hex. Cr <sup>7,8</sup>	USEPA Method 218.7 or Method 218.6 as modified by USEPA Region IV <sup>8</sup> .
<sup>1</sup> Include the USEPA Target Compound List plus a library search of Tentatively Identified Compounds. <sup>2</sup> Include analysis for 1,4-dioxane if chlorinated solvents are present or if it is a suspected contaminant. <sup>3</sup> SW-846 Method 6010 does not have detection limits below the unrestricted-use 15A NCAC 02L Standards for all of the hazardous substance list metals. Therefore, it should not be used for first-phase metals scans. <sup>4</sup> If coal ash deposits are present, boron, iron and vanadium should be added to the metals scan. <sup>5</sup> Method 3060A extraction for soil and sediment samples allows for a 30-day holding time prior to extraction. <sup>6</sup> Rapid analysis of samples is recommended to lessen the contact time with the acid preservative. Filtration of groundwater and surface water samples before digestion is not acceptable. Highly turbid water samples for metals analysis should be collected using a low-flow purging and sampling technique, additional well development, and/or rapid analysis of samples to reduce contact time with the acid preservative. <sup>7</sup> Field filter samples for hexavalent chromium analysis within 15 minutes of sample collection and collect each sample in a pre-preserved container separate from those for other metals analyses. See USEPA Region IV modified Method 218.6 for specific details. <sup>8</sup> Method 218.7 or Method 218.6 as modified by USEPA Region IV should be used. Method 218.7 requires low turbidity and allows for a 14-day holding time. USEPA Region IV has developed a modification of Method 218.6 that allows for a 28-day holding time. Use pre-preserved bottles as specified in the modification to the method. Laboratories should contact the USEPA in Region IV for methodology.	

## A-2. Analyzing for Polychlorinated biphenyls (PCBs) in Soil

Aroclors are varying mixtures of generally 50-100 of the 209 possible PCB related chemicals known as congeners. When released into the environment the congener profile of the original mixture is modified over time and with movement through each subsequent biotic or abiotic environmental medium, a process referred to as “weathering”. As a result, the analytical methods that report Aroclor mixtures do not adequately characterize weathered PCB-contaminated matrices. To adequately characterize PCB concentrations and potential human health and ecological hazards, USEPA Method 1668 should be used to analyze for all 209 congeners. Human health risks are evaluated as the individual concentrations of the 12 dioxin-like congeners (Table A-2) and the risks associated with the remaining congeners are totaled as the “non-dioxin-like congeners”.

Several samples should be collected in the more contaminated areas to identify the congener profile. Then, gross delineation for total PCBs may be conducted using USEPA Method 8082 since this method is typically less costly than Method 1668. Once the extent of total PCBs is known, the final delineation must be conducted using USEPA Method 1668 for all 209 PCB congeners. Due to limitations of Method 8082, however, it may not be used for final delineation.

**Table A-2. List of Dioxin-like PCB Congeners**

IUPAC No.	Dioxin-like PCB Congener
PCB-77	3,3',4,4'-Tetrachlorobiphenyl
PCB-81	3,4,4',5-Tetrachlorobiphenyl
PCB-105	2,3,3',4,4'-Pentachlorobiphenyl
PCB-114	2,3,4,4',5-Pentachlorobiphenyl
PCB-118	2,3',4,4',5-Pentachlorobiphenyl
PCB-123	2',3,4,4',5-Pentachlorobiphenyl
PCB-126	3,3',4,4',5-Pentachlorobiphenyl
PCB-156	2,3,3',4,4',5-Hexachlorobiphenyl
PCB-157	2,3,3',4,4',5'-Hexachlorobiphenyl
PCB-167	2,3,4,4',5,5'-Hexachlorobiphenyl
PCB-169	3,3',4,4',5,5'-Hexachlorobiphenyl
PCB-189	2,3,3',4,4',5,5'-Heptachlorobiphenyl



## **APPENDIX B**

### **Annual Report Form for Perpetual Land-Use Restrictions**



**Annual Report Form for Perpetual Land-Use Restrictions**

Site Name: \_\_\_\_\_

Site ID No.: \_\_\_\_\_

County in NC: \_\_\_\_\_

DEQ Contact and Program: \_\_\_\_\_

**YES NA (not applicable).** Check all that apply:

- All restrictions in the recorded Declaration of Perpetual Land Use Restrictions (DPLUR) document are still in compliance.
- All posted signs and demarcations required by the DPLUR that identify the restricted area(s) are visible and readable.
- The contact information on the signs required by the DPLUR is current.
- All physical markers and barriers (e.g., berms, fences, paved areas, etc.) required by the DPLUR are in place and intact.
- The landfill cover system has been maintained according to the requirements outlined in the DPLUR.
- The DPLUR and Notice are still recorded at the county register of deeds office.

Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Property Owner Certification Statement**

After first being duly sworn or affirmed, I, \_\_\_\_\_, hereby state that: I am over the age of eighteen, I am competent to make this certification based upon my own personal knowledge and belief and, to the best of my knowledge and belief, after thorough investigation, the information contained herein is accurate and complete. I am aware that there are significant penalties for willfully submitting false, inaccurate or incomplete information.

\_\_\_\_\_  
(Signature of Property Owner)

\_\_\_\_\_  
(Date)

\_\_\_\_\_  
(Printed Name and Title of Property Owner)

\_\_\_\_\_  
(Printed Name of Company)