Re: The 2018 Integrated Report Part I

Pursuant to Federal Clean Water Act (CWA) §303(d) and §305(b)

A REVIEW OF LEAD IN SURFACE WATERS

Prepared by

The Bureau of Water

South Carolina Department of Health and Environmental Control

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List of Acronyms

AL	Action Level
ATSDR	Agency for Toxic Substances and Disease Registry
CAA	Clean Air Act
CCC	Criterion Continuous Concentration
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CWA	Clean Water Act
EA	Environmental Affairs (SCDHEC)
HAP	Hazardous Air Pollutant
IARC	international Agency for Research on Cancer
ICP/MS	Inductively Coupled Plasma/Mass Spectrometry
IEUBK	Integrated Exposure Uptake Biokinetic Model
IR	Integrated Report
LCR	Lead and Copper Rule
LWOC	Legacy Waters(s) of Concern
MS4	Multiple Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
RAIS	Risk Assessment Information System (USDOE)
RfC	Reference Concentration
RfD	Reference Dose
RL	Reporting Limit
SCDHEC	South Carolina Department of Health and Environmental Control; the Department
SCDNR	South Carolina Department of Natural Resources
SCDOT	South Carolina Department of Transportation
SFo	Slope Factor, Oral
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedure
TMDL	Total Maximum Daly Load
TRI	Toxic Release Inventory
TRM	Total Recoverable Metal
TSS	Total Suspended Solids
USDOE	United Sates Department of Energy
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WOC	Water(s) of Concern
WWTF	Wastewater Treatment Facility

Units of Measure

cm	centimeter(s)
g	gram(s)
kg	kilogram(s)
mg/Kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
ug/dL	microgram(s) per deciliter
ug/L	microgram(s) per liter
oz	ounces
lbs	pounds
tpy	ton(s) per year

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1.0 Introduction

The South Carolina Department of Health and Environmental Control (SCDHEC; the Department) has proposed to list three (3) freshwater stream sites as being impaired due to exceedances of the chronic aquatic life criterion for lead (SCDHEC 2018c). The 2018 proposed listing is based upon chemical data acquired during the three-year period of 2014 through 2016.

The Department identified another 169 waters as being *Waters of Concern* (WOC) due to indicated exceedances of the chronic aquatic life criterion for lead (SCDHEC 2018) based on the default values used for total suspended solids (TSS) and hardness. The Department has identified these as WOC due to the need for further study and has determined (as discussed in further detail in this Report) that acquiring actual TSS and hardness data simultaneously will provide a more realistic evaluation of actual ambient conditions. Of the total of 169 WOC, 51 of the locations have lead data to evaluate for the 2018 assessment window (2014-2016) and 118 of these locations are being carried forward from previous §303(d) assessment cycles where ambient lead was not assessed. This latter subcategory (118 locations) are identified as *Legacy Waters of Concern* (LWOC). Distribution of the WOCs are:

- WOC Streams – 51 locations
- LWOC Lakes – 30 locations
- LWOC Streams – 88 locations

Figure 1 depicts the three (3) locations proposed for listing as impaired and the noted 169 WOC. Annex 1 presents the list of those locations.

In 2009, as part of an effort to more effectively allocate limited resources over an extensive ambient monitoring network, routine water quality monitoring was discontinued at a number of stream locations in the State. This resulted in a significant number of locations without ambient water quality data available to be addressed after the 2012 assessment cycle. As described herein, lead data that were acquired were not evaluated for several reasons detailed herein. Nonetheless, the Department decided to evaluate those accumulated lead data and carry the 2012, 2014 and 2016 assessment results forward for the purpose of 2018 reporting. Consequently, those locations were reported as WOC or LWOC for lead. No estuarine waters have been identified as either impaired, as WOC or as LWOC due to lead.

Consequently, for the 2018 report, there were a total of 169 locations that were identified as WOC due to the indicated presence of lead in the water column relative to the metric of aquatic life use support. These WOC were not included on the draft 2018 §303(d) List of Impaired Waters because the Department believes currently-available data were insufficient to make final aquatic life use support determinations at the 169 WOC. For further details on how the Department plans to address WOC in future listings, refer to Section 6.2 of this report.

1.1 Purpose

This Report documents the studies, ensuing data and technical process that the Department followed to reach the decision to propose the 2018 lead listings and to evaluate the WOCs and LWOCs. The purposes of this Technical Report are to:

- describe the approach for assessing lead data in this cycle;
- evaluate potential implications for public health impacts;
- provide additional background regarding the topic as related to aquatic life use support; and,
- present a path forward plan for the lead impaired waters and resolution of placement, or not, of the WOC locations on the 2020 §303(d) List of Impaired Waters.

1.2 Background

The Federal Clean Water Act (CWA) §303(d) and §305(b), in accordance with the Code of Federal Regulations (CFR) 40 CFR Part 130, requires all states and United States territories to provide an assessment of the quality of their waters on April 1 of each even-numbered year (biennially) (CFR 2019c). Accordingly, the Department has published a §303(d) list of impaired waters and §305(b) water quality report for all assessed waters and formally submitted those publications to the United States Environmental Protection Agency (USEPA) since onset of the requirement in 1990. A goal of the combined §303(d) and §305(b) reporting, collectively known as the Integrated Report (IR), is to describe the overall health of the State's waters by evaluating designated use support such as aquatic life, human fish and shellfish consumption and recreational uses. The §303(d) list of impaired waters is a subcategory of all assessed waters described in the §305(b) water quality report.

The IR is developed by assessing a variety of physical, chemical and biological monitoring data collected during a specific time frame. Most data are used on the basis of a minimum five-year assessment period. Metals data for aquatic life use support and fecal coliform data for shellfish harvesting use support are assessed based on a three-year assessment period. Readily-available data from each monitoring location are compared with the applicable water quality standard in order to determine attainment status (*i.e.,* impaired or unimpaired).

The §303(d) list identifies waterbodies that do not meet State water quality standards after application of required controls for point and nonpoint source pollutants. The purpose of the list is to identify impaired waters in order to describe the source of impairment and implement corrective actions to improve water quality. The list is used to consider waters for further investigation, additional monitoring, water quality improvement measures, including Total Maximum Daily Loads (TMDLs) and alternative restoration plans. The USEPA retains final approval authority for the §303(d) list of impaired waters.

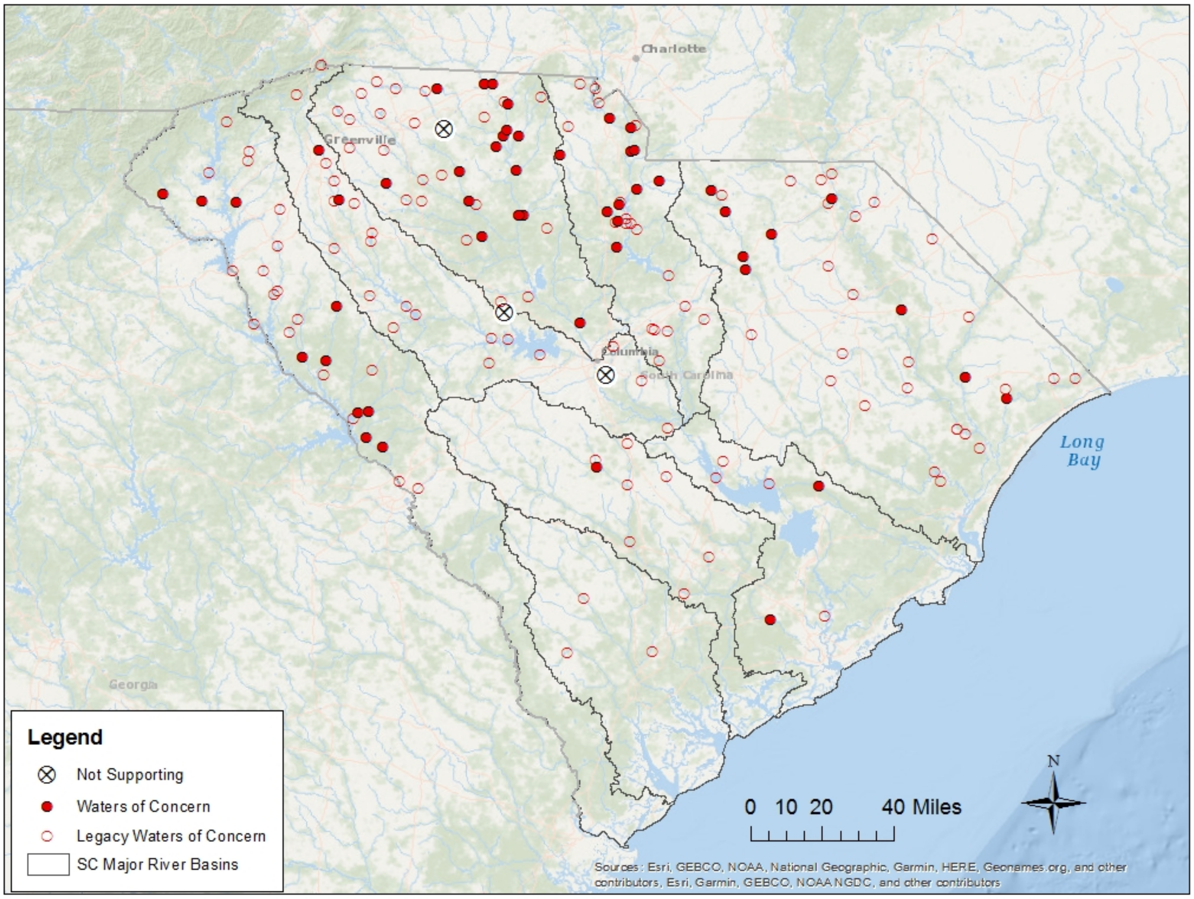
In compliance with 40 CFR 25.4(c) (CFR 2019a), the Department, beginning November 5, 2018, commenced a minimum 30-day public notice to ensure broad notice of the Department's intent to update its list of impaired waters. The 2018 §303(d) List of Impaired Waters was made available for public comment until 5:00pm December 5, 2018 (SCDHEC 2018c). Fourteen sets of comments were received by the Department from the public review period. The Department will provide responses to the comments received and make those available when the draft 2018 list package is submitted to the USEPA for final approval.

Data from an approximate total of 2,100 sites were assessed for the 2018 listing cycle. There were a total of 1,243 aquatic life, human fish and shellfish consumption or recreational impairments identified at 1,042 locations. These locations were included in the draft 2018 §303(d) list of impaired waters. Of the 1,243 total impairments included on the draft 2018 303(d) list, three (3) locations were identified as having aquatic life impairments due to total recoverable lead in the water column. The total recoverable form of metals is used because it is specified in Regulation 61-68, *Water Classifications and Standards.*

In addition to the 303(d) List of Impaired Waters, the Department may also identify waterbodies that demonstrate degradation or are threatened for non-attainment of classified uses through a prescribed assessment methodology. In such cases, the Department does not place waterbodies on the §303(d) list of impaired waters but evaluates those as WOC in detail through the current listing cycle. Accordingly, any or all of those WOC have the potential to be listed as impaired due to lead if confirmed by evaluation.

Figure 1.

Proposed Impaired Locations and Waters of Concern



2.0 303(d) Listing and Waters of Concern Data Assessment for Lead

2.1 Background

During each IR listing cycle, the §303(d) list assessment methodology and determination of attainment of classified uses for each category of pollutants is described and made available for public review and comment. The assessment methodology for ambient metals (including lead) is particularly complex due to variable instream criteria during a given assessment period.

For individual analytes from toxicant classes (*e.g.,* metals, priority pollutants, chlorine, ammonia), if the analyte-specific acute and/or chronic aquatic life criterion is exceeded more than once in three (3) years (*i.e.,* 2014 through 2016 for the 2018 IR), the location is listed as impaired for the analyte of concern. The Department may also use discretion, considering factors other than excursion magnitude and frequency, in order to determine the impairment status due to toxicants. This approach is consistent with that of other States and is approved by USEPA Region 4.

Total recoverable metals (TRM) criteria are adjusted to account for solids partitioning in freshwater. When instream TSS and hardness data are available, the Department pairs instream TSS and hardness values by date to calculate instream criteria for heavy metals. Calculations are specific for each metal and are based on the equations established to protect the State classified uses as promulgated in the State Water Quality Standards (SCDHEC 2014). Instream TRM values measured on the same date as the TSS and hardness are then compared to the calculated acute and chronic criteria to determine if an exceedance of the standard has occurred. Historically, the State has not collected TSS data as part of the surface water quality monitoring program.

An alternate approach may be used in situations where paired instream TSS or hardness data are not available. Under this approach that is consistent with USEPA (Prothro 1993), a default TSS value of 1 milligram per liter (mg/L) or, part per million, is used when no instream TSS data are available, as has been the case for the State. If the TRM criteria are hardness-based for a particular metal, a default value of 25 mg/L is used when no hardness data are available. It is important to note that utilizing this alternate method to calculate instream criteria does not result in an immediate §303(d) impaired waters listing. Instead, a location found to exceed the instream TRM criterion for a given metal more than once in a three (3) year period is considered to be a WOC through the current listing cycle and until such time as additional evaluation is performed to resolve that location's status.

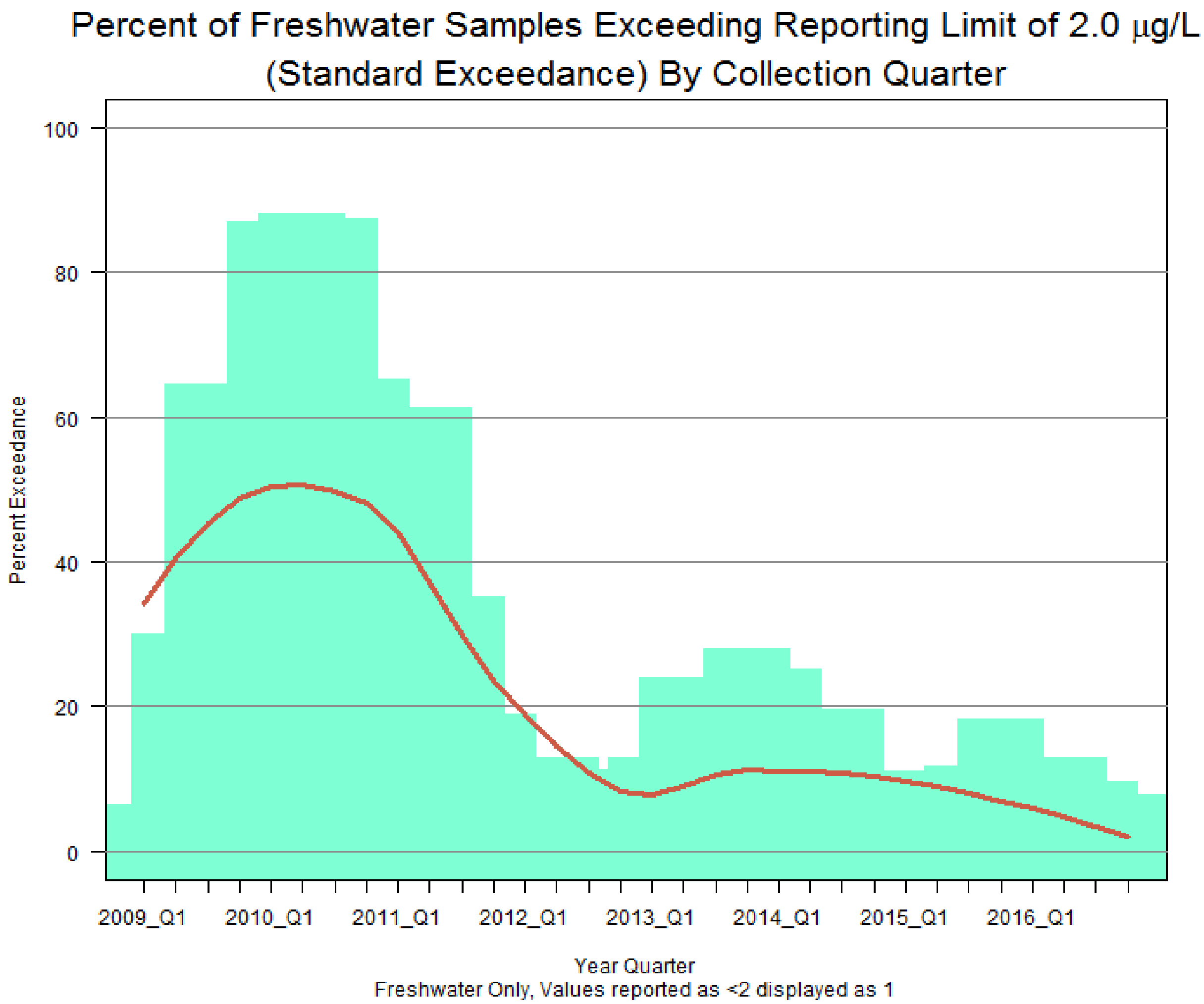
Early in the data assessment activities for the preparation of the 2012 §303(d) List of Impaired Waters (*i.e.,* assessment years for metals 2008 through 2010), it became apparent that, using the default values of 1 mg/L for TSS and 25 mg/L for hardness, there was a significant increase in the number of freshwater locations that exceeded the chronic aquatic life criterion for lead [0.7 microgram per liter (ug/L), or parts per billion]. There was no increase in the number of sample results exceeding the saltwater chronic criterion for lead (8.5 ug/L).

During 2009, the reporting limit (RL) for lead in ambient surface water samples changed from 50 µg/L to 2 µg/L in the Department's Environmental Affairs (EA) Laboratory. The change to 2 µg/L aligned with USEPA-approved test methods for CWA work. This RL was not achievable by the laboratory prior to 2009 due to the limitations of the analytical instrumentation used. The laboratory added Inductively Coupled Plasma-Mass Spectrometry (ICP/MS) using USEPA Method 200.8 in 2009 to achieve the lower reporting limit for lead.

The lower RL of 2 µg/L, resulted in measurable concentrations of lead in ambient water samples where it had not been observed previously at the higher RL of 50 µg/L. Due to this increased number of lead detects, the EA Laboratory examined regional laboratory deionized water systems, sample bottle batches, blanks, duplicates and collaborated with the Aquatic Science Programs to evaluate the sample collection procedures to determine if the lead detects were possibly the result of contamination. Evaluation of the associated quality control data indicated that the data were supported. Analysis of lead in stream samples has been performed by the EA Laboratory using the same procedures and methodology since 2009.

Since 2010, however, the number of sample results greater than the RL for lead in the ambient stream samples (2 ug/L) decreased significantly (Figure 2). When preparing the assessment for the 2014 §303(d) list (*i.e.,* 2010 through 2012 data), due to the noticeable declining trend in the number of sample results observed greater than the RL, it was decided to remove lead from the assessment while the reason for this observed trend was investigated.

Figure 2.



2.2 Sample Acquisition Evaluation

As part of the effort to examine the potential for sample contamination due to sample collection methods, in February 2012, side-by-side sample collection was conducted by the United States Geological Survey (USGS) and SCDHEC monitoring personnel. USGS used clean sample collection techniques while SCDHEC used routine collection methods as specified in the SCDHEC EA Environmental Investigations Standard Operating Procedures (SOP) and Quality Assurance Manual (SCDHEC 2010). Replicate samples for lead analyses were collected for both total recoverable and field-filtered (0.45-micron pore size) forms from two (2) different sample locations, along with trip blanks, field blanks and equipment blanks. A total of 28 samples for lead analyses were collected. All lead analyses were less than the RL of 2 µg/L.

A second study was conducted in March 2012 to evaluate the potential for sample contamination due to sample collection methods by SCDHEC staff following routine collection methods as specified in the Department SOP (SCDHEC 2010). Three (3) SCDHEC routine ambient surface water quality monitoring locations were included in the study; each location had consistently showed lead results that exceeded the RL of 2 µg/L. Each location was visited twice in one (1) day. On the first visit, two (2) replicate samples were collected at each location, along with two (2) equipment blanks, one (1) collected before each replicate. During the second visit, one (1) equipment blank was collected followed by one (1) sample. In addition to the routine lead sample by ICP/MS, one (1) sample was also collected for lead analysis by graphite furnace. One (1) trip blank and one (1) field blank were also included. Of the total of 20 routine ICP/MS lead analyses and three (3) graphite furnace analyses, all lead results were less than the RL of 2 µg/L. Samples for the study were collected at a depth of 0.3 m following routine ambient surface water sampling protocols and as near middle of the stream as was possible. There was no rain preceding this study.

2.3 Default Criterion Basis Evaluation

The Department measures lead (and all metals) in the total recoverable form. The total recoverable form comprises all forms of a particular metal, including fractions *dissolved* in the water column (technically, *dissolved* applied to a metal in ambient waters simply means very small particle sizes that are typically unbound or non-adsorbed) and fractions attached to suspended organic particles or bound in mineral complexes. The dissolved fraction is more biologically-available than the sorbed/bound fraction and, therefore, of more concern for toxic effects to the biota. Nevertheless, the TRM form is used to develop protective limits for National Pollutant Discharge Elimination System (NPDES) permits….

> *By regulation (40 CFR 122.45(c))* [CFR 2019b], *the permit limit, in most instances, must be expressed as total recoverable metal. This regulation exists because chemical differences between the effluent discharge and the receiving water body are expected to result in changes in the partitioning between dissolved and adsorbed forms of metal. As we go from total recoverable to dissolved criteria, an additional calculation called a translator is required to answer the question What fraction of metal in the effluent will be dissolved in the receiving water? Translators are not designed to consider bioaccumulation of metals.* (USEPA 1996)

This technical guidance examines what is needed in order to develop a metals translator. *The translator* is the fraction of TRM in the downstream water that is dissolved; that is, the dissolved metal concentration divided by the TRM concentration. The translator may take one (1) of three (3) forms:

1. It may be assumed to be equivalent to the criteria conversion factors.
2. It may be developed directly as the ratio of dissolved to TRM.
3. It may be developed using a partition coefficient that is functionally related to the number of metal binding sites on the adsorbent in the water column (*i.e.,* concentrations of TSS, total organic carbon or humic substances).

There are no applicable hardness and TSS adjustments to saltwater chronic criteria.

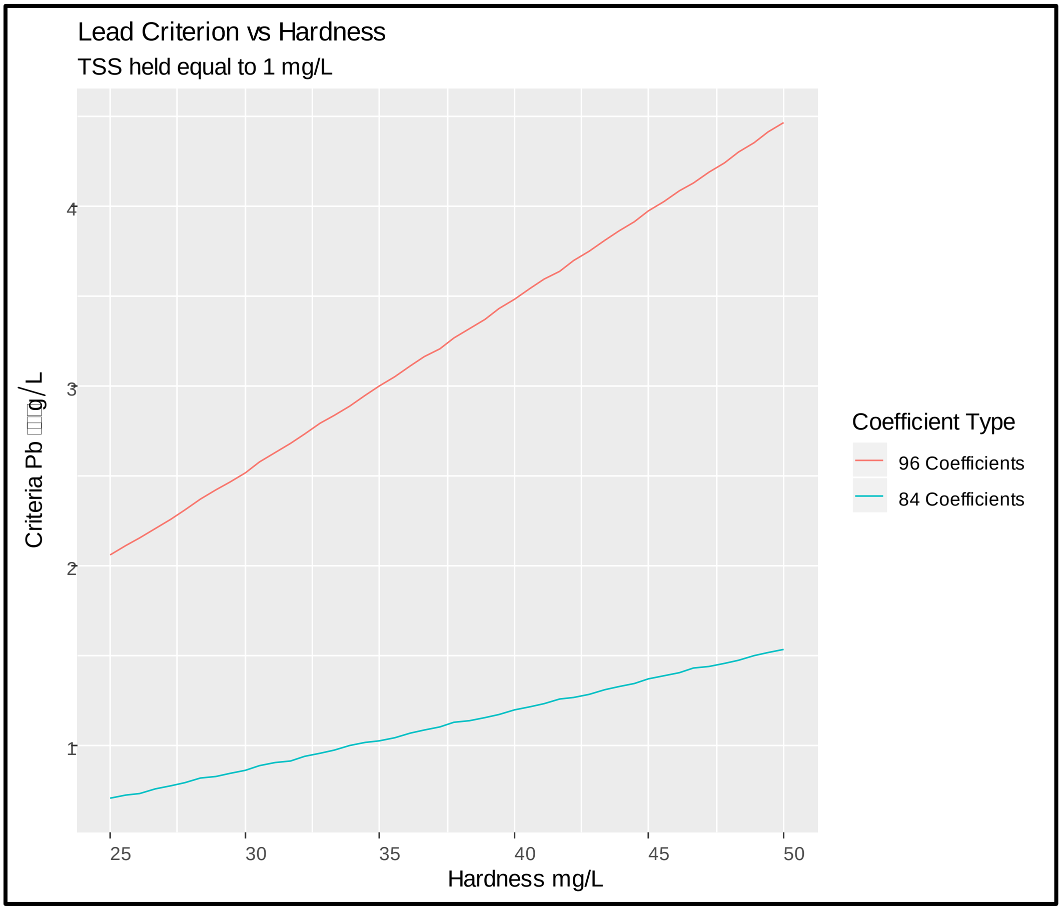
For deriving the appropriate freshwater dissolved criterion for metals, the Department uses Form 3 (from above). Specifically, a hardness component and a total suspended residue component *(i.e.,* TSS) are used to address the potential bioavailability of a metals and, thus, the final value of the criterion. Metals can bind to organic matter, represented by TSS, in the water and become unavailable to the biota through solids partitioning. Similarly, metals can become bound in mineral complexes in the presence of high mineral concentrations, represented by hardness, and also become biologically unavailable.

Hardness

As specified in regulation (SCDHEC 2014), for freshwaters the Department has historically used a default hardness concentration of 25 mg/L when actual hardness is less than 25 mg/L, as is quite common in South Carolina. When hardness is greater than 25 mg/L, the actual hardness value is used in the calculation for the sample-specific criterion.

Figure 3 illustrates the effect of hardness on the chronic aquatic life criterion calculated using both sets of partitioning coefficients when TSS is held to the default value of 1 mg/L.

Figure 3. Effect of Hardness on Calculated Chronic Aquatic Life Criterion When TSS is Held at a Default value of 1 mg/L.

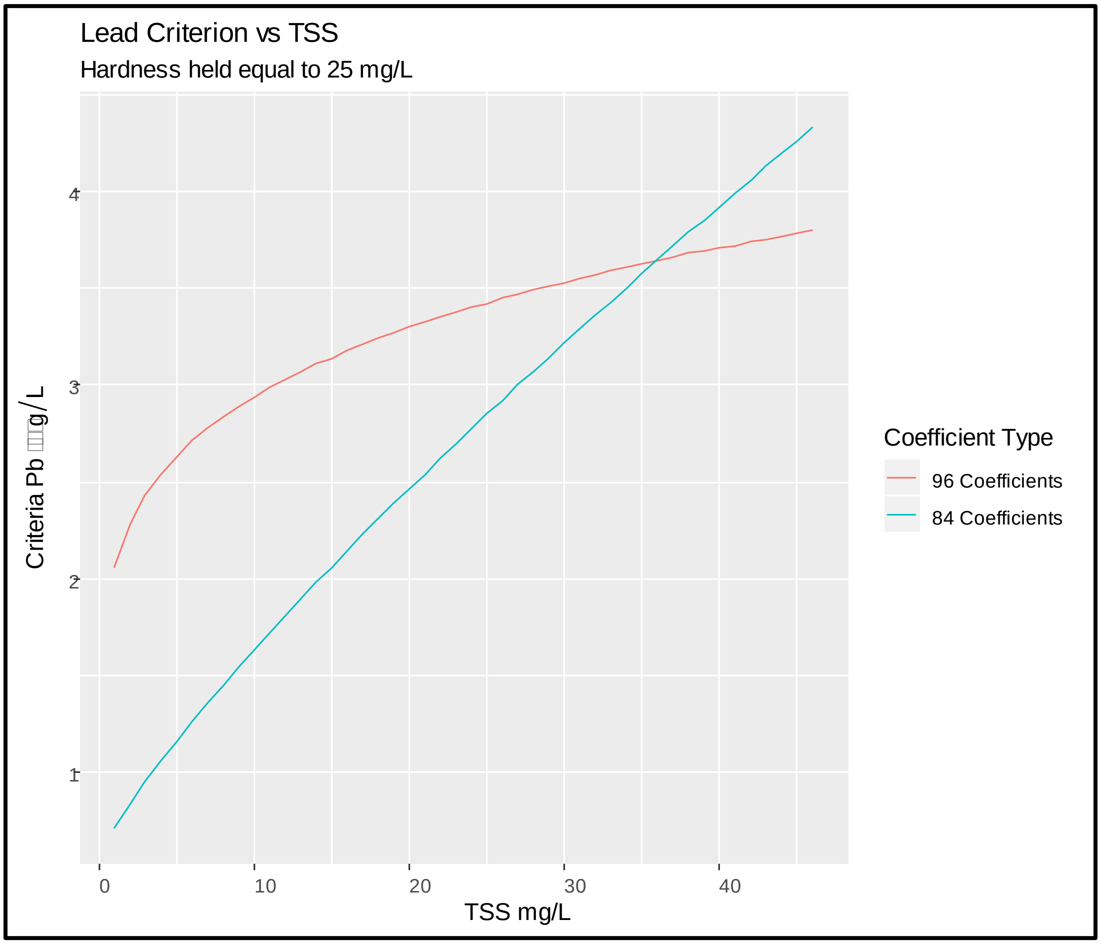


Solids

The Department has historically used a default TSS concentration of 1 mg/L as a conservative value *in lieu* of actual TSS results.

Figure 4 illustrates the effect of TSS on the chronic aquatic life criterion calculated using both sets of partitioning coefficients when hardness is held to the default value of 25 mg/L.

Figure 4. Effect of Hardness on Calculated Chronic Aquatic Life Criterion When



TSS is Held at a Default value of 25 mg/L.

2.4 Calculation of the Sample-Specific Chronic Lead Criterion for Freshwaters

As provided in R.61-68 E.14.d (3), in order to, *appropriately evaluate the ambient water quality for the bioavailability of the dissolved portion of hardness dependent metals, the Department may utilize a federally-approved methodology to predict the dissolved fraction or partitioning coefficient in determining compliance with the water quality standards established in this regulation.* (SCDHEC 2014)

Per R.61-68 E.14.a (3), the Criterion Continuous Concentration (CCC) is based on a hardness of 25 mg/L if the ambient stream hardness is equal to or less than 25 mg/L. Concentrations of hardness less than 400 mg/L may be based on the stream hardness if it is greater than 25 mg/L and less than 400 mg/L and 400 mg/L if the ambient stream hardness is greater than 400 mg/L. In absence of actual stream hardness, the default value of 25 mg/L is used.

2.4.1 Conversion Factor for Dissolved Metals

Attachment 2 to R. 61-68 provides the parameters and equations below for calculating the freshwater dissolved-form lead criteria that are hardness-dependent (SCDHEC 2014):

Parameter	**m_c**	**b_c**	**Freshwater Conversion Factor (CF)**
			(chronic)
Lead	1.273	-4.705	1.46203 - [(ln (hardness) (0.145712)]

where:

m_c and b_c = empirical hardness coefficients for lead
ln = natural logarithm

<u>Formulae to Derive Criteria Chronic Concentration for Lead for Freshwater Aquatic Life</u>

CCC (total) = exp {m_c*[ln (hardness)] + b_c}

CCC (dissolved; CCC_d) = exp {m_c*[ln (hardness)] + b_c} (CF)

<u>Calculation for Dissolved Lead Criterion</u>

CCC_d = exp {1.273*[ln (hardness)] -4.705} (1.46203 - [(In (hardness) (0.145712)])

Note: CCC_d is CC_d from USEPA partitioning coefficient (equation 6.4 per USEPA 1996).

2.4.2 Partitioning Coefficient (Translator)

The partitioning coefficient is a translator for the fraction of the total recoverable metal that is bound to adsorbents in the water column, *i.e.*, TSS.

When the Department issued the November 5, 2018, 30-day public notice for the 2018 §303(d) List, it was based on the following freshwater partitioning coefficient values for lead that had been used in the past (USEPA 1984):

- K_{po} = 3.10E+05 (unitless)
- a = -0.1856 (unitless)

where:

K_{po} is the calculated default metal specific partitioning coefficient
a is the constant for lead (Table 3; USEPA 1996)

After the November 5, 2018 public notice was issued, the data were re-analyzed using the partitioning coefficient values used by the BOW Water Facilities Permitting staff in developing NPDES permit limits (USEPA 1996), as follows:

<u>Streams</u>

- K_{po} = 2.80E+06 (unitless)
- a = -0.8 (unitless)

<u>Impoundments</u>

- K_{po} = 2.0E+06 (unitless)
- a = -0.5337 (unitless)

The following procedure for developing the CCC for lead for freshwater aquatic life are applicable using either partitioning coefficient translators:

Using previously-noted Equation 6.4 (USEPA 1996) once the dissolved metal concentration (CC_d) is known, the instream total recoverable concentration (C_t') that equates to a dissolved in-stream concentration equal to the dissolved criterion:

$$C_t' = CC_d \times \{1+(K_p \times TSS_b \times 10^{-6})\}$$

Default Partitioning Coefficient Estimation Equation [Table 3 (USEPA 1996)]:

$$K_p = K_{po} \times (TSS_b)^a$$

CC_d = Dissolved criterion concentration

TSS_b = In-stream Total Suspended Solids (TSS) concentration (mg/L). The background TSS is assumed to be the measured instream data (in mg/L) or 1 mg/L in the absence of actual instream data (based on the 5th percentile of ambient TSS data on South Carolina waterbodies from 1993-2000).

10^{-6} = unit conversion factor to express C_t' in µg/L.

To determine the allowable in-stream chronic total recoverable water quality criteria [CCC(total recoverable adjusted)], following equation is used:

$$\text{CCC (total recoverable adjusted)} = CCC_d \times [1+ (K_p \times TSS_b \times 10^{-6})]$$

- If the ambient stream lead result exceeds CCC (total recoverable adjusted) based on the measured TSS and hardness collected with the lead sample it constitutes a standard exceedance.

- Lacking actual instream TSS and hardness data, a lead result exceeding CCC (total recoverable adjusted) based on the default hardness of 25 mg/L and the default TSS value of 1 mg/L constitutes a potential standard exceedance.

2.4.3 Default Criterion Outcome

These default values result in a freshwater chronic aquatic life criterion of 2.1 µg/L using the up-to-date values for default partition coefficient estimation. Use of the previous partitioning coefficients resulted in a freshwater chronic aquatic life criterion of 0.7 µg/L.

Because TSS data were extremely limited (the parameter was not part of the parametric coverage in the ambient surface water monitoring program), a year-long study was conducted to collect TSS and turbidity data, beginning May 1, 2016 and ending April 30, 2017. The goals of this study were to:

- characterize the distribution and variability of freshwater TSS across the State in order to examine the validity of universal use of the current default value of 1 mg/L, and,

- evaluate the relationship between TSS and turbidity in order to explore the use of turbidity as a surrogate measure for TSS.

The study demonstrated that using actual TSS results (vs. a default of 1 mg/L in all situations) produced a more realistic evaluation of actual ambient conditions at the time of sampling. While many different possible statistical regression approaches were examined, the relationship between turbidity and TSS was not strong enough to recommend the use of turbidity as a surrogate for TSS.

3.0 Results

All data used in the assessment discussed in this document are available in the Water Quality Portal https://www.waterqualitydata.us/ under Organization ID 21SC60WQ_WQX, where more recent results may also be found. The most recent §303(d) assessment cycle results for each monitoring location forms the basis for the final WOC or listing decision.

3.1 Assessment of Lead Data

Two (2) separate assessments of the lead and supporting parametric data for the 2018 §303(d) List of Impaired Waters were conducted including data from previous §303(d) assessment cycles where ambient lead was not assessed. The initial assessment used to develop the November 5, 2018, 30-day public notice was based on partitioning coefficient values previously used by the Department (USEPA 1984). The lead dataset was subsequently re-analyzed using partitioning coefficient values used by the Water Facilities Permitting staff in developing NPDES permit limits (USEPA 1996).

Annex 2 contains the data summaries for each individual site, including the three (3) locations listed as impaired for the 2018 §303(d) list of impaired waters (BL-001, C-017 and S-290); one (1) location (RS-16312 (Cattail Branch at Chesterfield County Road 54) that went from impaired to fully-supporting; and, all of the Legacy WOC and 2018 §303(d) cycle WOC. The differing assessment classifications based on the two (2) partitioning coefficient scenarios are also documented.

BL-001 (Lawson's Fork Creek at Spartanburg County Road 108) was not listed as impaired in the initial November 5, 2018, 30-day public notice for the 2018 §303(d) list but will be listed based on the re-assessed dataset. As discussed in the following section, subsequent macroinvertebrate date indicates that the location is fully supported but will remain listed and will be addressed in a future listing cycle.

RS-16312 (Cattail Branch at Chesterfield County Road 54) was classified as impaired and to be listed on §303(d) based on the assessment using the USEPA (1984) partitioning coefficients but was classified as fully-supporting based on the USEPA (1996) partitioning coefficients. A review of sample results demonstrated that two (2) of the six (6) individual samples exceeded the calculated criterion under the 1984 partitioning coefficients but none of the six (6) individual sample results exceeded the 1996 calculated criterion. Five (5) of the six (6) samples contained the full suite of parameters necessary to accurately calculate a sample specific criterion; the lone sample missing TSS did not exceed the criterion using a default TSS of 1 mg/L.

Consequently, RS-16312 (Cattail Branch at Chesterfield County Road 54) is now considered to have been listed in error on the initial November 5, 2018, 30-day public notice for the 2018 §303(d) list. It is still being sampled this year, as are the other LWOC/WOC, and will be re-assessed based on the new results (See Section 6).

3.2 Benthic Macroinvertebrate Community Assessments

Benthic macroinvertebrate community assessments were made at two (2) of the three (3) locations listed as impaired in the 2018 §303(d) assessment cycle based on the Initial analysis using the USEPA (1984) coefficients.

- C-017 (Gills Creek at Richland County Road 48) was evaluated on August 15, 2018, and met all requirements for a flowing water macroinvertebrate site evaluation. The location received a Bioclassification Score of 2.8 (Good-Fair) that indicated the location is partially-supporting of aquatic life. This result was consistent with listing as impaired for aquatic life use.

- S-290 (Camping Creek at Newberry County Road 201) was evaluated on August 15, 2018. Although the location had adequate flow, there was a beaver dam immediately upstream from the bridge that created a pond-like condition. This feature could impede drift that allows colonization of macroinvertebrates that may then negatively impact the location. The location received a Bioclassification Score of 2.6 (Good-Fair), indicating that the site is partially supporting of aquatic life. This result is consistent with its listing as impaired for aquatic life use.

- A benthic assessment was not conducted at RS-16312 (Cattail Branch at Chesterfield County Road 54) because there was no flow at the location, either at the bridge or upstream/downstream. Because the Department's macroinvertebrate assessment protocol is designed for flowing waters, an accurate score would not be obtained for a stagnant site.

A benthic macroinvertebrate community assessment was also made at the location to be listed as impaired in the 2018 §303(d) assessment cycle based on the analysis using the USEPA (1996) coefficients.

- BL-001 (Lawsons Fork Creek at Spartanburg County Road 108) was evaluated on July 1, 2019, and met all requirements for a flowing water macroinvertebrate site evaluation. The location received a Bioclassification Score of 4.7 (Good) that indicated the location is fully-supporting of aquatic life. Those benthic data notwithstanding, for consistency with our listing assessment methodology, BL-001 will be carried through the 2018 listing cycle and addressed appropriately in a future cycle.

4.0 Public Health Concerns Review

The purpose of the Clean Water Act's 303(d) evaluation is to assess the condition of waterbodies and plan, restore and protect waters to maintain the chemical, physical and biological integrity of the Nation's waters. It is important to note that waterbodies are listed as impaired when they do not meet water quality standards for their designated use. In the case of the three (s) impaired stations and the 169 WOC identified in this report, the designated use is the protection of aquatic life.

The Department acknowledges that, although the focus of this report is on the noted protection of aquatic life, it is quite reasonable for there to be questions as to the impact, if any, on public health via surface water contact, direct or indirect, from the lead data discussed herein. Consequently, this Section 4.0 presents an analysis and evaluation of the likelihood of public health impact(s) resulting from consumption of treated drinking water and/or fish from as well as swimming in the surface waters affected by lead per the dataset included herein.

Lead, as are other metals, is a naturally-occurring element. It is a bluish-white metal that is very soft and highly malleable. Lead is resistant to corrosion and a poor conductor of electricity, qualities that made it historically very useful in plumbing applications and as a pigment in ceramic glazes for thousands of years (IARC 2006). Primary sources of lead exposure include workplace exposure (*e.g.,* welding); transport of workplace exposure residuals home to families when proper work procedures are not followed; lead paint in older houses (houses built before the 1978 ban on lead-based residential paint); the historical use of organic lead in gasoline (lead can still be found in roadside soils from this historical usage); and, historical use of lead in industries (*e.g.,* the lining of acid storage tanks used in historical fertilizer plants). Exposure to lead can also come from some older drinking (i.e., generally, pre-1986) water taps, interior water pipes or pipes connecting a house to the main water supply pipe in the street where corrosion of older fixtures, or from lead solder used to connect the pipes, causes lead to be released.

Lead is classified by USEPA as a Class 2 (probable human) carcinogen based on sufficient animal data; human data are classified as insufficient (USEPA 2019). Although assigned a carcinogenic classification, USEPA's Carcinogen Assessment Group recommends that a numerical estimate of quantitative risk from oral exposure to lead not be used. This is because quantifying cancer risk from lead involves numerous uncertainties such as age, health, nutritional state, body burden and exposure duration influences on the toxicokinetcs (absorption, distribution, metabolism and excretion) of lead. Also, USEPA reports that current knowledge of lead pharmacokinetics indicates that an estimate derived by standard procedures would not truly describe the potential risk. Consequently, USEPA does not report an Oral Slope Factor (SFo) for carcinogenic effects or an Oral Reference Dose (RfD) or Inhalation Reference Concentration (RfC) for non-carcinogenic effects. An RfD and an RfC are typically derived from an analyte concentration less than which no adverse effects have been observed.

The Oak Ridge National Laboratory of the US Department of Energy (USDOE) maintains the Risk Assessment Information System (RAIS) that presents and integrates a variety of USEPA, USDOE and other enterprise risk assessment information, tools and resources (USDOE 2019). For lead, the RAIS has adopted an SFo of 0.0085, published by the California Environmental Protection Agency, for assessing carcinogenic risk. Consequently, the RAIS can be used to evaluate potential carcinogenic risk scenarios for lead exposure with the caveat that such evaluation be used as a screening, or provisional basis, method. In such screening, a predicted risk value of $\leq 1 \times 10^{-6}$ is considered to be nominal and indistinguishable from ambient background risk. A predicted risk value of $\geq 1 \times 10^{-4}$ is indication that some protective or remedial action is warranted. A predicted risk value between 1×10^{-6} and 1×10^{-4} is within the range where issues and factors beyond contaminant concentrations can be considered in decision-making. In some instances, 1×10^{-5} (vs. 1×10^{-6}) is used as the trigger for further inquiry or consideration.

Historically, the principal endpoint metric of concern for lead exposure was its impact (accumulation in blood) in children where deleterious effects can be manifested more severely than in adults. Some subtle neurological effects have been observed in children at low dose exposures. Because the toxicokinetics of lead are well understood, this allowed lead to be regulated based on blood lead concentration. In 1991, the United States Centers for Disease Control and Prevention (CDC) established a Federal upper limit for childhood blood lead concentration of ten (10) micrograms of lead per deciliter of blood (µg/dL) to obviate risks to children's health. However, recent guidance from CDC has lowered this upper limit to five (5) ug/dL to be protective. This was in response to CDC's guidance position that no safe blood lead has been identified.

The Integrated Exposure Uptake Biokinetic Model (IEUBK) has been widely used to evaluate potential outcomes in child lead blood levels due to lead exposure. This model predicts the blood lead levels in children [under seven (7) years old] who are exposed to environmental lead from air, water, soil and other media (*e.g.,* consumption of paint chips via pica). The IEUBK model is used to calculate the predicted risk that a child exposed to specified media lead concentrations will have a blood lead level ≥5 ug/dL. That is, the IEUBK model is an exposure (dose-response) model that incorporates children's exposures to lead in their environments to estimate the risk of elevated blood lead (typically $\geq$ 5 ug/dL) through estimation of lead body burdens in a mass balance framework. (The Adult Lead Model also exists and is used to evaluate non-residential, typically occupational, lead exposure outcomes on the blood level of a fetus.)

4.1 Drinking Water

The potable water treatment processes of coagulation, flocculation and sedimentation have long been regarded as an effective method for the removal of lead and other heavy metals in source waters (Kawamura 2000), with numerous studies demonstrating upwards of 95% removal of lead using these treatment processes (Sorg *et al.* 1977; Naylor and Dague 1975). Fifty eight of 61 surface water treatment plants in the State include some form of coagulation, flocculation and sedimentation in their treatment trains; the other three (3) surface water treatment plants provide some form of membrane filtration.

Exceedances of the lead Action Level (AL) of 0.015 mg/L, established under the Federal Safe Drinking Water Act (SDWA) Lead and Copper Rule (LCR), are typically the result of the corrosion of lead materials in the pipes and plumbing appurtenances at individual residences (ATSDR 2007; USEPA 2016). Water systems may, and some do, add a corrosion inhibitor at the end of their treatment trains to coat the inner linings of pipes and premise plumbing to prevent the corrosion of lead into the drinking water.

The three (3) impaired stations and the LWOC/WOC for lead in the 2018 IR were compared against the locations of surface water treatment plant intakes. Eighteen surface water treatment plant intakes could have potentially been affected by a WOC for lead. Compliance data from 2016 to 2018 under the SDWA LCR from samples collected at residential sites throughout the distribution systems in the 18 systems were reviewed (Figure 5; Table 1). None of the 18 surface water systems reported a lead AL exceedance during this period. This indicated that lead, if at all present in the source water, was successfully removed during the treatment processes. This also indicated by extension that lead AL exceedance(s) at a water system that purchases water from one of these 18 surface water systems would most likely have originated from the corrosion of lead pipes and premise plumbing within that local water system.

The Department recently completed and published a statewide study that examined the occurrence and fate of lead in public drinking water distribution systems (SCDHEC 2018a). This study examined LCR compliance data for 730 public water systems from the beginning of 2011 through the first half of 2018. Of the 40 public water systems with a lead action level exceedance over that period, six (6) purchased water that originated from a surface water treatment plant. However, in each instance a corrosion inhibitor was added and there was no detectable amount of lead at the entry (purchase) point of their distribution systems. The distribution system immediately outside the surface water treatment plant also did not report a lead action level exceedance in each case. Therefore, the lead found at the taps of these purchase water systems most likely originated from the corrosion of lead pipes and premise plumbing.

Based on the literature review, data from surface water treatment plants potentially affected by a WOC, and statewide study described above, the Department concluded that lead in surface waters of the State, if present, would have been removed during the treatment processes at surface water treatment plants and would not have negatively impacted public health through drinking water. Lead found in tap water would most likely originate from some other source than surface waters that feed drinking water plants.

Figure 5.

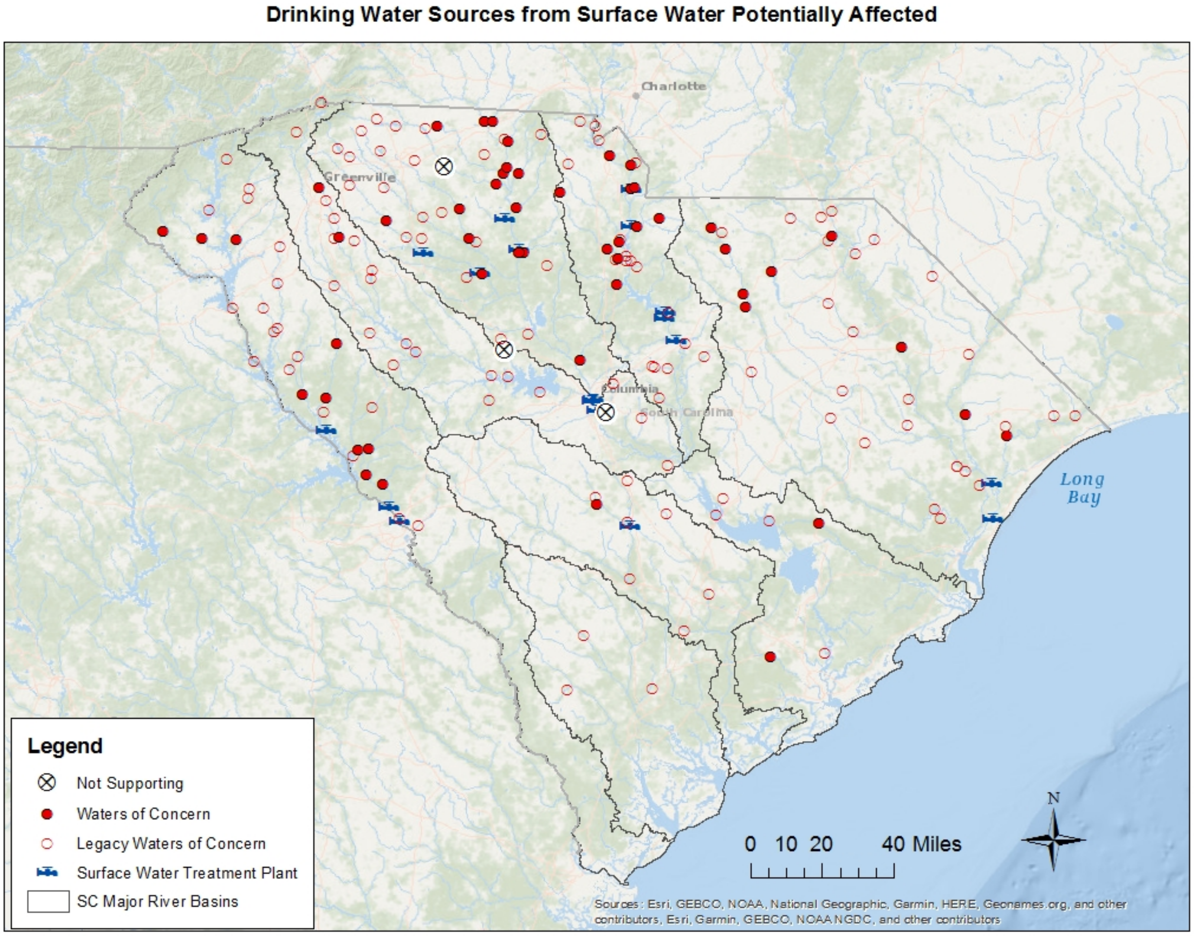


Table 1. Potentially-Affected Drinking Water Systems from Surface Water Sources

Permit ID	Water Treatment Plant	Lead (mg/L)	Year Sampled
SC0210003	City of North Augusta	0.0015	2017
SC1220002	Chester Metropolitan District	0.003	2016
SC1920001	Edgefield County Water & Sewer Authority	0.0017	2016
SC2220010	Georgetown County Water & Sewer District - Waccamaw Neck	0.0026	2018
SC2620004	Grand Strand Water & Sewer Authority - Bull Creek	0.00052	2017
SC2810001	City of Camden	0.0017	2017
SC2820001	Lugoff-Elgin Water Authority	0.0018	2017
SC2830001	Invista (Industry)	0.0058	2017
SC2920002	Catawba River Water Supply Project	0.002	2018
SC3010002	City of Clinton	ND*	2018
SC3210003	City of Cayce	0.0014	2017

SC3210004	City of West Columbia	0.00086	2016
SC3510001	McCormick Commission of Public Works	0.004	2018
SC3610004	Town of Whitmire	0.004	2018
SC3810001	Orangeburg Department of Public Utilities	0.0028	2017
SC4010001	City of Columbia	0.0038	2017
SC4410001	City of Union	0.0017	2016
SC4430003	Carlisle Cone Mills (Industry)	0.0017	2017

*ND = Non-detect

4.2 Fish Consumption

Lead preferentially partitions in fish to bone and scale (Schmitt and McKee 2016) via calcium displacement. Studies have shown lead concentrations in tilapia were highest in the liver, then gills (*i.e.,* non-edible parts) then muscle (*i.e.,* the edible part) (Taweel *et al.* 2012). Upon fish consumption, adults absorb five (5) to 15 percent (%) of the lead present in the tissue; less than 5 % is retained (Thornton *et al.* 2001).

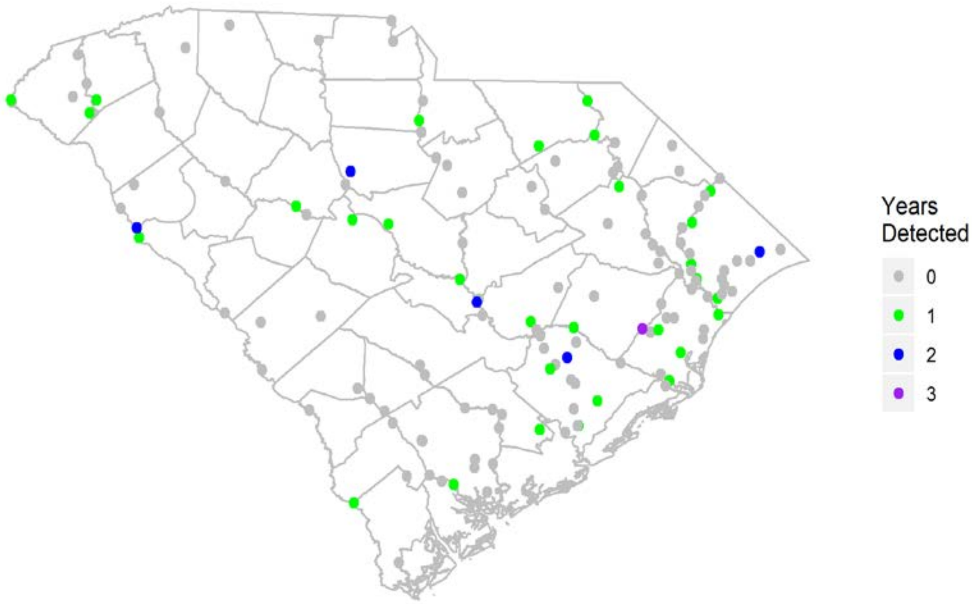
The Department reviewed lead data in fish tissue (filets) from 2006 through 2017. There were 151 locations sampled for lead during this 12-year period that yielded a total of 2,094 samples analyzed for lead. Fifty-five detections at 40 locations were reported during this 12-year period, as presented in Table 2 and depicted in Figure 6. Of the 151 locations where samples were collected over the 12-year period-of-record:

- 111 locations returned no detections
- 34 locations returned a detection for one (1) year only
- Five (5) locations returned a detection for two (2) years
    - CL-097 – Lake Russell (2009, 2013)
    - CSTL-080 – Lake Moultrie (2011, 2016)
    - ST-529 – Lake Marion (2009, 2015)
    - B-327 – Lake Monticello (2013, 2014)
    - CSTL-553 – Waccamaw River (2009, 2013)
- One (1) location returned a detection for three (3) years
    - PD-626 – Black River (2007, 2010, 2012)
- No locations showed detections for four (4) or more years

Basic descriptive statistics of the fish tissue (filet) dataset are summarized in Table 3, with notable observations being:

- Detection frequency of approximately 2.6 %
- Detected concentration range of 1.0 milligrams per kilogram (mg/Kg) to 3.8 mg/Kg
- Mean (± 1 standard deviation) detected concentration of 1.6 mg/Kg (± 0.7)
- Mean (± 1 standard deviation) dataset concentration of 0.04 mg/Kg (± 0.3)
- Large majority of the detections were 2.0 mg/Kg or less:
    - 12.7% of detections were 1.0 mg/Kg
    - 81.8% of detections were up to 2.0 mg/Kg
- Temporal occurrence of detections was consistent across the years (from 1.0% to 4.9% detected each year), except for 2009 (9.3% detections) and 2013 (12.8% detections).

Figure 6. Frequency of Lead Detections in Fish Tissue (Filet) Samples by Location, 2006 – 2017



Thirteen different species (omnivorous, insectivorous and piscivorous) were returned with lead detections. Largemouth bass and bowfin were the more-frequently returned species as was freshwater (vs. saltwater) species (Table 4).

Table 2. Fish Tissue (Filet) Samples with Lead Detections, 2006 - 2017

Location		Collection Date	Species	Length (cm)[a]	Weight (g)[a]	Result (mg/Kg)[a]
Abbeville County						
CL-097F	Lake Russell at Dam	6/3/2009	LARGEMOUTH BASS	38.7	764	1.5
		7/9/2013	LARGEMOUTH BASS	37.8	759	1.2
Berkeley County						
CSTL-080F	Lake Moultrie at Dam	7/19/2011	BOWFIN	59.6	2200	1.1
		3/15/2016	LARGEMOUTH BASS	49.2	1740	1.4
CSTL-564F	E. Fork Cooper River	3/10/2014	BOWFIN	74.6	4640	1.1
MD-042F	Cooper River at Bushy Park	7/10/2013	LARGEMOUTH BASS	51.2	1960	1.2
ST-531F	Lake Moultrie at Hatchery Landing	5/22/2013	LARGEMOUTH BASS	46.3	1400	1.2

Calhoun County						
C-007F	Congaree River at US 601	1/29/2009	BOWFIN	69.6	3270	1.1
ST-529F	Lake Marion at Low Falls Landing	1/29/2009	CHANNEL CATFISH	61	2340	2.1
			BLUE CATFISH	90.7	7718	2.4
		3/24/2015	REDEAR SUNFISH	31.2	667	1.2
Charleston County						
MD-788F	Charleston Harbor	6/9/2009	RED DRUM	51.8	1407	1.3
MD-789F	Ashley River	8/13/2007	RED DRUM	52.3	1427	1.6
MD-790F	Lower Wando River	6/17/2008	SOUTHERN FLOUNDER	45.4	1040	1.0
Chester County						
CW-057F	Fishing Creek Reservoir near Dam	3/9/2009	BLACK CRAPPIE	35.3	900	2.9
Chesterfield County						
PD-012F	Great Pee Dee River at SC 9/US 1	12/7/2010	CHANNEL CATFISH	49.2	1400	1.0
PD-327F	Lake HB Robinson	9/4/2012	LARGEMOUTH BASS	41.4	860	1.6
Clarendon County						
ST-024F	Lake Marion at Wyboo Creek	3/24/2013	LARGEMOUTH BASS	47.1	1540	1.7
Colleton County						
CSTL-098F	Combahee River at US 17	5/6/2009	LARGEMOUTH BASS	40.1	1120	1.6
MD-792F	Combahee River near Cooper River in ACE Basin	5/25/2014	SPOTTED SEA TROUT	34.6	448	1.6
			SOUTHERN FLOUNDER	42.8	888	1.1
Darlington County						
PD-015F	Pee Dee River at US 401	10/30/2007	BLUE CATFISH	64	3310	2.3
			CHANNEL CATFISH	66.9	3650	3.8
Dorchester County						
CSTL-560F	Ashley River at Dorchester State Park	8/19/2016	LARGEMOUTH BASS	39.6	940	1.2
			BOWFIN	58.1	2.2	1.2

Fairfield County						
B-327F	Lake Monticello	10/2/2013	REDEAR SUNFISH	29.4	512	1.2
		3/25/2014	LARGEMOUTH BASS	46.6	1620	3.7
Florence County						
PD-623F	Black Creek at SC 327	1/28/2013	LARGEMOUTH BASS	31.8	408	1.4
Georgetown County						
MD-138F	Waccamaw River at Channel Market 57	4/21/2008	LARGEMOUTH BASS	41.9	980	1.2
PD-628F	Sampit River at international Paper	4/22/2008	BOWFIN	62.1	2220	1.8
PD-659F	Black River at Old Pump Station	9/24/2012	LARGEMOUTH BASS	32.6	459	1.7
ST-005F	North Santee River at Pole Yard	11/15/2006	REDEAR SUNFISH	23.1	244	2.0
Hampton County						
SV-687F	Savannah River at Stokes Bluff Landing	6/5/2012	LARGEMOUTH BASS	41.4	1040	1.6
Horry County						
CSTL-553F	Waccamaw River at SC 31	7/21/2009	BOWFIN	59.3	2310	1.8
			BLUE CATFISH	66	3290	2.2
		9/24/2013	REDEAR SUNFISH	25.8	437	1.1
PD-038F	Lumber River at Ricefield Cove	7/8/2008	LARGEMOUTH BASS	38.6	783	2.2
PD-350F	Little Pee Dee River at Punchbowl Landing	9/22/2009	FLATHEAD CATFISH	90.1	9988	1.8
			BOWFIN	62.1	2790	1.0
PD-620F	Little Pee Dee River at US 378	9/22/2009	REDBREAST SUNFISH	28.6	598	1.2
Lexington County						
S-273F	Lake Murray at Dam	3/17/2014	REDBREAST SUNFISH	27.4	438	1.4

McCormick County						
CL-040F	Lake Thurmond at Bobby Brown State Park	2/27/2013	CHAIN PICKEREL	44.8	526	3.4
Marion County						
PD-619F	Little Pee Dee River at Galivants Ferry	2/4/2013	BOWFIN	69.3	3180	3.3
Newberry County						
S-105F	Saluda River at SC 395	3/20/2013	LARGEMOUTH BASS	42.3	1180	1.0
			CHANNEL CATFISH	67.1	2800	1.3
			BLACK CRAPPIE	33.1	589	1.4
Oconee County						
SV-599F	Tugaloo Lake	8/7/2013	LARGEMOUTH BASS	44.1	1200	1.1
Pickens County						
SV-106F	Lake Hartwell at Martin Creek	6/11/2013	SPOTTED BASS	32.1	385	1.9
SV-107F	Lake Hartwell at 12 Mile Creek	6/11/2013	SPOTTED BASS	49.8	1220	1.1
Richland County						
B-311F	Broad River at I-20	1/21/2015	LARGEMOUTH BASS	51.2	2120	1.0
Williamsburg County						
PD-626F	Black River at Pumphouse Landing	7/7/2007	LARGEMOUTH BASS	40.8	960	1.0
		11/29/2010	BOWFIN	61.2	2420	1.0
		9/24/2012	CHAIN PICKEREL	52.1	840	1.4
ST-528F	Santee River at US 52	9/16/2009	BOWFIN	68.9	3440	1.5

a. cm = centimeters; g = grams; mg/Kg = milligrams per kilogram

Table 3. Basic Descriptive Statistics for Lead in Fish Tissue (Filet) Samples, 2006 - 2017

Number of Samples	Number of Lead Detects	Range of Lead Detects (mg/Kg)	Mean of Detects (mg/Kg)	± 1 Standard Deviation of Detects	Mean of All Samples (mg/Kg)	± 1 Standard Deviation of All Samples
2,094	55	1.0 – 3.8	1.6	0.7	0.04	0.3

Lead Concentration Distribution Frequency				
Interval (mg/Kg)	Count	% of Total by Interval Count	Cumulative Count	% of Total by Cumulative Count
1.0	7	12.7	7	12.7
1.1 – 2.0	38	69.1	45	81.8
2.1 – 3.0	6	10.9	53	92.7
3.1 – 4.0	4	7.3	57	100
≥ 4.1	0	0	57	
Total	55	100	--	--

Total Analyses and Total [and (Percent)] Lead Detections by Year												
2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Totals
224	397	307	140	141	64	103	117	179	162	147	113	2,094
1	4	4	13	2	1	5	15	5	2	3	0	55
(0.4)	(1.0)	(1.3)	(9.3)	(1.4)	(1.6)	(4.9)	(12.8)	(2.8)	(1.2)	(2.0)	(0.0)	(2.6)

Table 4. Occurrence of Lead Detections in Fish Tissue (Filet) by Species, 2006 - 2017

Species	Number of Detects	Range (mg/Kg)	Mean (mg/Kg)	± 1 Standard Deviation
Largemouth Bass	20	1.5 – 3.7	1.5	0.6
Bowfin	10	1.0 – 3.3	1.5	0.7
Channel Catfish	4	1.0 – 3.8	2.0	1.3
Blue Catfish	3	2.2 – 2.4	2.3	0.1
Flathead Catfish	1	1.8	Not Applicable (NA)	NA
Redeared Sunfish	4	1.1 – 2.0	1.4	0.4
Redbreast Sunfish	2	1.2 ; 1.4	NA	NA
Spotted Bass	2	1.1 ; 1.9	NA	NA
Black Crappie	2	1.4 ; 2.9	NA	NA
Red Drum	2	1.3 ; 1.6	NA	NA
Southern Flounder	2	1.0 ; 1.1	NA	NA
Spotted Seatrout	1	1.6	NA	NA
Chain Pickerel	2	1.1; 1.9	NA	NA

In order to evaluate the potential impact of fish consumption on public health, both the RAIS evaluation tool (for carcinogenic effects) and the IEUBK model (for child blood level) were used.

Carcinogenic Effects

A base case was modeled for carcinogenic risk using the RAIS Model. Exposure factors, including differential exposure point concentrations of lead, were then changed to fit alternative cases. The changes in the outcome from the base case were determined by scaling off of the base case because of the direct proportional relationship between exposure factor dynamics, exposure point concentrations and predicted carcinogenic risk. The RAIS Model was configured using the following assumptions/inputs:

- two (2) different default receptor classes were evaluated; namely, a child interval [(zero (0) to six (6) years old] weighing 15 kilograms (kg) [about 33 pounds (lbs)] and a combined child/adult interval [six (6) to 32 years] weighing 80 kg (about 176 lbs)
- an exposure frequency (*i.e.,* day in which a fish meal was eaten) of one (1) and three (3) days per week for 52 weeks per year for both receptor classes
- an ingestion rate (how much fish eaten) of two (2) ounces (oz) per day (56,699 mg/day) for a child; six (6) oz/day (170,097 mg/day) for the combined child/adult
- exposure point concentrations as follows:
    - 1.0 mg/Kg – mean for entire period-of-record dataset (2,094 observations) [1.0 mg/Kg used for actual dataset value of 0.04 mg/Kg]
    - 1.6 mg/Kg – mean of detected samples (55 observations)
    - 2.3 mg/Kg -- mean of detected samples plus one (1) standard deviation
    - 3.8 mg/Kg – maximum detected concentration
- all other factors for the calculation were adopted as defaults set in the RAIS

The resulting risk predictions (summarized in Annex 3) illustrated slight excursions greater than 1.0×10^{-6} for most of the receptor classes. The highest predicted risk observed was 1.1×10^{-5} in the combined child/adult class at the extreme end of the exposure assumptions [fish consumed three (3) days per week for 52 weeks; all fish consumed contained the maximum lead detected in the period-of-record dataset (3.8 mg/Kg)].

Childhood Blood Level

The assumptions/inputs used for the IEUBK Model analysis were the same as used for the carcinogenic risk analysis with the following exceptions:

- seven (7) different receptor classes, by age in years, were used [0-1, 1-2, 2-3, 3-4, 4-5, 5-6 and 6-7; a different body weight was used for each class (ranging from 9.2 kg (0-1) to 31.8 kg (6-7)
- edible exposure (in this case, fish consumption) is spread equally across a week by the model
- only lead impacts due to ingestion of fish tissue were considered in the model runs
- no background or other source(s) lead levels were incorporated into the analysis, i.e., the levels predicted are additive to those resulting from background/other source(s) exposure

The resulting blood level outcome predictions from consumption of fish are also presented in Annex 3. As with the carcinogenic risk outcomes, as the exposure potentials move toward the upper end scenarios, some excursions greater than 5 ug/dL and 10 ug/dL were predicted. Generally, consumption of fish one (1) day per week did not indicate an excursion of 5 ug/dL unless the assumption that all fish consumed contained the maximum amount of lead detected in the dataset (3.8 mg/Kg). That scenario showed predicted blood lead levels ranging from 3.5 ug/dL (0-1 years) to 5.9 ug/dL (2-3 years).

Summary

The screening analysis of incidental and occasional ingestion of fish from the State's surface waters relative to lead did not indicate realistic concerns. The upper-end exposure scenarios (*e.g.*, more frequent meals; all fish contained the maximum level observed) used were conservative (*i.e.,* erring on the side of being health protective) and not completely plausible to occur in actual life circumstances. When more realistic scenarios comprising less frequency and duration of exposure (*i.e.,* the lower end of the scenario band) were considered, consumption of fish was not indicated to be of concern relative to the lead dataset that is the subject of this Report.

Extant Fish Consumption Advisories

The Department maintains a fish tissue monitoring program to provide data for the development and implementation of fish consumption advisories (SCDHEC 2018b). Table 5 summarizes the current advisories (principally driven by mercury) that are in-place and that are co-located with lead detections in the noted species from the 2006-2017 period-of-record lead dataset.

Table 5. Fish Tissue (Filet) Samples with Lead Detections, 2006 - 2017 and Consumption Advisory Areas

Location [a]		Species with Lead Detects	Fish Consumption Advisory? [b]
Abbeville County			
Lake Russell	CL-097F	LARGEMOUTH BASS	Yes; 1 meal [c]/week
Berkeley County			
Lake Moultrie	CSTL-080F	BOWFIN	Yes; 1 meal/week
		LARGEMOUTH BASS	No
E. Fork Cooper River	CSTL-564F	BOWFIN	Yes; 1 meal/week
Cooper River at Bushy Park	MD-042F	LARGEMOUTH BASS	No
Lake Moultrie	ST-531F	LARGEMOUTH BASS	No
Calhoun County			
Congaree River	C-007F	BOWFIN	Yes; 1 meal/week
Lake Marion	ST-529F	CHANNEL CATFISH	No
		BLUE CATFISH	No
		REDEAR SUNFISH	No
Charleston County			
Charleston Harbor	MD-788F	RED DRUM	No
Ashley River	MD-789F	RED DRUM	No
Lower Wando River	MD-790F	SOUTHERN FLOUNDER	No
Chester County			
Fishing Creek Reservoir	CW-057	BLACK CRAPPIE [d]	Yes; 1 meal/month
Chesterfield County			
Great Pee Dee River	PD-012F	CHANNEL CATFISH	No
Lake HB Robinson	PD-327F	LARGEMOUTH BASS	Yes; 1 meal/month
Clarendon County			
Lake Marion	ST-024F	LARGEMOUTH BASS	Yes; 1 meal/week
Colleton County			

Combahee River	CSTL-098F; MD-792F	LARGEMOUTH BASS	Yes; No consumption
		SPOTTED SEA TROUT	No
		SOUTHERN FLOUNDER	No
Darlington County			
Great Pee Dee River	PD-015F	BLUE CATFISH	Yes; 1 meal/month
		CHANNEL CATFISH	No
Dorchester County			
Ashley River	CSTL-560F	LARGEMOUTH BASS	Yes; 1 meal/week
		BOWFIN	Yes; No consumption
Fairfield County			
Lake Monticello	B-327F	REDEAR SUNFISH	No
		LARGEMOUTH BASS	No
Florence County			
Black Creek	PD-623F	LARGEMOUTH BASS	Yes; 1 meal/month
Georgetown County			
Waccamaw River	MD-138F	LARGEMOUTH BASS	No
Sampit River	PD-628F	BOWFIN	Yes; 1 meal/month
Black River	PD-659F	LARGEMOUTH BASS	Yes; No consumption
North Santee River	ST-005F	REDEAR SUNFISH	No
Hampton County			
Savannah River	SV-687F	LARGEMOUTH BASS	Yes; 1 meal/month
Horry County			
Waccamaw River	CSTL-553F	BOWFIN	Yes; No consumption
		BLUE CATFISH	Yes; 1 meal/week
		REDEAR SUNFISH	Yes; 1 meal/week
Lumber River	PD-038F	LARGEMOUTH BASS	Yes; No Consumption
Little Pee Dee River	PD-350F; PD-620F	FLATHEAD CATFISH	Yes; No consumption
		BOWFIN	Yes; No consumption
		REDBREAST SUNFISH	Yes; 1 meal/week
Lexington County			
Lake Murray	S-273F	REDBREAST SUNFISH	No
McCormick County			
Lake Thurmond	CL-040F	CHAIN PICKEREL	No
Marion County			
Little Pee Dee River	PD-619F	BOWFIN	Yes; No consumption
Newberry County			
Saluda River	S-105F	LARGEMOUTH BASS	Yes; 1 meal/week
		CHANNEL CATFISH	No
		BLACK CRAPPIE	No
Oconee County			

Tugaloo Lake	SV-599F	LARGEMOUTH BASS	Yes; 1 meal/month
Pickens County			
Lake Hartwell [d]	SV-106F; SV-107F	SPOTTED BASS	Yes; No consumption
Richland County			
Broad River	B-311F	LARGEMOUTH BASS	No
Williamsburg County			
Black River	PD-626F	LARGEMOUTH BASS	Yes; No consumption
		BOWFIN	Yes; 1 meal/month
		CHAIN PICKEREL	Yes; 1 meal/month
Santee River	ST-528F	BOWFIN	Yes; 1 meal/week

a. waterbody name is where advisory applies; number is station from Table 4 where lead was detected in fish tissue
b. SCDHEC 2018b; all advisories are due to mercury unless otherwise noted
c. one (1) meal is eight (8) ounces of fish
d. advisory for polychlorinated biphenyls in addition to mercury

4.3 Swimming

Ingestion of lead by swallowing water is the principal route of exposure during recreational uses (*e.g.*, wading, swimming, skiing, boating) of waterways. Dermal absorption is a very minor exposure route. Swimming has been selected as the indicator of recreational use risk because of its higher opportunity for incidental ingestion of larger amounts of water than other uses (*e.g.,* skiing, canoeing, *etc.).* Exposure to lead while swimming is likely greater for children than adults but such exposure is typically incidental and infrequent with limited uptake (i.e., ingestion) of water (Dorevitch *et al.* 2011). When these exposure factors align with very low contaminant concentrations, risk of public health impact is typically not of significant concern.

The Department reviewed lead data in water column samples for the dataset covered by the IR reporting period:

- 1,199 analyses were performed from 173 locations
- Detection frequency of approximately 53.7% (644 of the 1,199 analyses)
- The frequency distribution of all maximum concentrations is presented in Table 6.
- Lead was detected in all samples from 21 of the 173 locations (12.1%)
  - Using the maximum concentration reported for each location (n=173), mean (± 1 standard deviation) of 14.7 ug/L (± 44.9)
  - Using the maximum concentration reported for each of the all-detects locations (n=21), mean (± 1 standard deviation) of 11.9 mg/L (± 8.7)
  - Maximum dataset detection (470 ug/L) was at PD-066 (Lynches River at Chesterfield County Road 13) [for period-of-record, lead detection frequency at this location was 5/12]

Table 6. Frequency Distribution of Maximum Lead Concentrations in Water

Maximum Concentration Interval (ug/L)	Count (n=173)	% of Total by Interval Count	% of Total by Cumulative
<u><</u>5.0	72	41.6	41.6
5.1 – 10	55	31.8	73.4
10 -- 15	17	9.8	83.2
16 -- 20	12	6.9	90.1
21 -- 30	7	4.0	94.1
31 -- 40	5	2.9	97.0
41 -- 50	2	1.2	98.2
51 -- 60	0	0.0	98.2
61 -- 70	0	0.0	98.2
71 -- 80	0	0.0	98.2
81 -- 90	0	0.0	98.2
91 – 100	1	0.6	98.8
101 -200	1	0.6	99.4
201 -- 300	0	0.0	99.4
301 -- 400	0	0.0	99.4
401 -- 500	1	0.6	100
<u>></u>501	0	0.0	---

Source: Annex 2

As was done for fish consumption, the potential impact of swimming on public health was evaluated using both the RAIS evaluation tool (for carcinogenic effects) and the IEUBK model (for child blood level).

<u>Carcinogenic Effects</u>
As was done for the fish consumption exposure route, a base case was modeled for carcinogenic risk from swimming using the RAIS Model. Exposure factors, including differential exposure point concentrations of lead, were then changed to fit alternative cases. The changes in the outcome from the base case were determined by scaling off of the base case because of the direct proportional relationship between exposure factor dynamics, exposure point concentrations and predicted carcinogenic risk. The RAIS Model was configured using the following assumptions/inputs:

- two (2) different default receptor classes were evaluated; namely, a child interval [zero (0) to six (6) years old] and a combined child/adult interval [six (6) to 32 years]
- an exposure frequency (*i.e.,* swimming days) of one (1) or three (3) days per week year-round.
- exposure point concentrations as follows:
    - 1.0 ug/L
    - 10 ug/L (per Table 6, 73.4% of the maximum concentrations were less than 10 ug/L)
    - 100 ug/L (per Table 6, 98.8% of the maximum concentrations were less than 100 ug/L)
    - 500 ug/L (maximum detection reported was 470 ug/L)
- only lead impacts due to ingestion of surface water were considered; dermal absorption pathway is negligible

The resulting risk predictions (also summarized in Annex 4) exhibited one (1) excursion greater than 1.0 x 10^{-6} for all of the exposure scenarios (1.3 x 10^{-6} for a child swimming 3 days per week, 52 weeks per year in water with a rounded value used for highest level reported in the dataset (500 ug/L for 470 ug/L). All other risk predictions ranged from 4.0 x 10^{-10} to 4.8 x 10^{-7}.

Childhood Blood Level

The assumptions/inputs used for the IEUBK Model analysis were the same as used for the carcinogenic risk analysis with the following exceptions:

- one (1) receptor age class (6-7 years) was used because swimming exposure factors for younger age groups are not available in the IEUBK Model
- the default drinking water module was used to evaluate incidental ingestion during swimming by using an ingestion rate specific for the age and activity being evaluated (USEPA 2011)
- only lead impacts due to ingestion of surface water were considered in the model runs

The resulting blood level outcome predictions from incidental ingestion of water during swimming are also presented in Annex 4. The predicted impact on blood lead levels for a child (6-7 years old) ranged from 0.0 ug/dL to 1.7 ug/dL.

Summary

The screening analysis of incidental and occasional ingestion of water during swimming in the State's surface waters relative to lead did not indicate a concern. As with the fish tissue consumption analysis, the upper-end exposure scenarios used were conservative (*i.e.,* erring on the side of being health protective) and not completely plausible to occur in actual life circumstances. Nevertheless, application of these extreme exposure scenarios did not translate into a deleterious impact on either risk or blood lead levels due to swimming. Direct contact by swimming is not considered to not have been of concern relative to the lead dataset that is the subject of this Report.

5.0 Provisional Source Review

For the draft 2018 §303(d) List, the Department listed three (3) locations as being impaired due to exceedances of the chronic aquatic life criterion for lead and identified another 169 WOC due to potential exceedances of the chronic aquatic life criterion for lead. This section provides an initial review of the potential source(s) of lead for these three (3) locations.

5.1 Nationwide Total Maximum Daily Loads

According to USEPA, more than half of the states have developed 486 TMDLs for lead. The Department reviewed a subset of these lead TMDLs to determine the types of sources identified. Lead TMDLs developed by states identify a variety of sources including:

- NPDES-permitted wastewater treatment facilities (WWTF)
- urban stormwater
- legacy industrial operations
- legacy mining operations
- natural background

TMDLs have also been developed for lead impairments which simply stated that the cause of the impairment is unknown. In addition, many of the reviewed TMDLs referred to former sources of lead that have since been banned by Federal mandates, *e.g.,* lead-based paints, lead water lines, leaded gasoline and lead shot used for waterfowl hunting.

5.1.1 NPDES Wastewater Treatment Facilities

Alabama Department of Environmental Management - TMDL for Walnut Creek, Metals - September 2010

The Walnut Creek Metals TMDL is for a 3.3-mile river segment. The TMDL concluded that nonpoint sources are not contributing to the lead impairment and that, of the two (2) continuous NPDES discharges, only the Troy Walnut Creek WWTF is considered to be a source. The Troy Walnut Creek WWTF receives wastewater from three (3) industrial users, one (1) of which produces lead from recycled batteries. The TMDL assigns a waste load allocation (WLA) only to the Troy Walnut Creek WWTF. There are no municipal separate storm sewer systems (MS4) areas within the Walnut Creek watershed.

5.1.2 Urban Stormwater

California State Water Resources Control Board – Ballona Creek Metals TMDL and the Ballona Estuary Toxics TMDL – Amended December 2013

Ballona Creek flows for approximately ten (10) miles from Los Angeles through Culver City before reaching the Pacific Ocean. The TMDLs concluded that urban stormwater is a substantial source of metals such as copper, lead and zinc and assigned a WLA to the following point sources: Los Angeles County MS4, the State of California Department of Transportation, Minor NPDES Permits and General Non-Stormwater NPDES Permits and General Industrial and Construction Stormwater Permits.

5.1.3 Former Industrial Sources

Tennessee Department of Environment and Conservation – TMDL for Metals in the Harpeth River Watershed – October 2002

The Harpeth River Metals TMDL addresses antimony, arsenic, cadmium, lead, and zinc impairments for a 2.7-mile segment of the Harpeth River. The TMDL identifies past operations of the General Smelting & Refining facility as the source of the metals impairment and describes historic operations which, among other things, allowed spent battery acid to flow untreated into the Harpeth River.

5.1.4 Legacy Mining

Montana Department of Environmental Quality – Bonita Superior Metals TMDLs - May 2013

The Bonita – Superior TMDL addressed approximately 50 square miles in western Montana near the former Towns of Bonita and Superior. The TMDL comprised three (3) watershed tributaries to the Clark Fork River and included Flat Creek, Hall Gulch, Cramer Creek and Wallace Creek. All streams are impaired for metals including lead. The TMDL stated that there are no NPDES-permitted point sources in the Bonita – Superior project area. It attributes the impairments to human activity related to Montana's mining legacy. These metals sources include adits and seeps, metals-laden floodplain deposits, waste rock and tailings and other features associated with abandoned and inactive mining operations.

5.1.5 Natural Background

Louisiana Department of Environmental Quality – East and West Forks of Six Mile Creek and Six Mile Creek TMDL for Dissolved lead - November 2001

The TMDL addressed lead impairments for the East and West Forks of Six Mile Creek, which are located in central Louisiana and originate near Fort Polk in Vernon Parish. The Forks join downstream to form Six Mile Creek. According to the TMDL, there are no point sources discharging lead to the Six Mile Creek system. A group of reference streams located throughout the state have been established that exhibit near-pristine characteristics and have no man-made sources discharging or contributing runoff into them. Six Mile Creek is one of these reference streams. Therefore, it was concluded by the agency that natural background loading is the most likely source of lead in the Six Mile Creek system.

5.1.6 Unknown Sources

USEPA – TMDL for lead in the Savannah River (Between Butler and McBean Creeks) and Butler Creek – March 2000

The TMDL addressed a 23-mile segment of the Savannah River as well as Butler Creek that are impaired due to lead. The TMDL was developed pursuant to a Consent Decree in the Georgia TMDL lawsuit. According to the TMDL, there are no known permitted point sources of lead and the cause of the lead impairment is not identified.

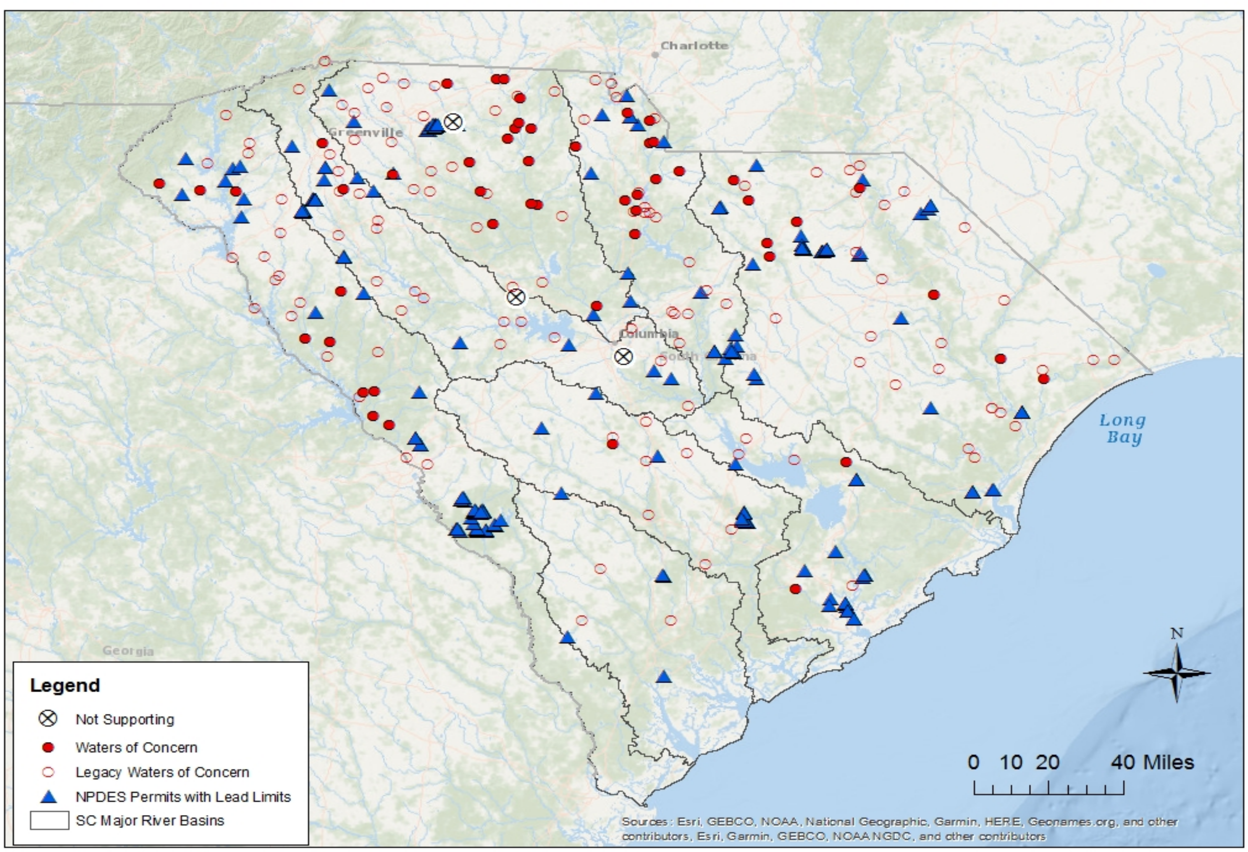
5.2 Review of Statewide Sources

5.2.1 NPDES Municipal and Industrial Wastewater Treatment Facilities

There are 109 NPDES permits (50 are General Permits) for municipal and industrial dischargers in the State that have lead limits (Figure 7). Accordingly, these facilities may be potential source(s) of or contributor(s) to lead impairment. Symbol clusters indicate facilities permitted for several outfalls (*e.g.,* USDOE Savannah River Site).

Figure 7.

NPDES Facilities with Permit Limits for Lead



5.2.2 NPDES MS4 Permits for Stormwater Discharges

An MS4 is a conveyance or system of conveyances that is owned by a state, city, town, village, or other public entity and is designed to collect or convey stormwater that discharges to waters of the state. Operators of large, medium and small MS4s are required to obtain NPDES permit coverage. South Carolina has one (1) large MS4 [the State Department of Transportation (SCDOT)], three (3) medium MS4s (City of Columbia, Greenville County and Richland County) and 72 regulated small MS4s.

5.2.3 NPDES Permits for Industrial Stormwater

Specific categories of industrial activities are required to be covered under NPDES permits for their stormwater discharges. The Department's current Industrial Stormwater General Permit (SCR000000) was issued on September 1, 2016 and covers approximately 1,800 industrial facilities. The permit requires facilities discharging to impaired waters to monitor their stormwater discharges for the pollutant of concern. If water quality standards for the pollutant of concern are exceeded, a required review of the potential problem is triggered to determine what corrective actions are necessary.

5.2.4 Deposition from Air Emissions

Lead in air available for deposition to soils and water is typically present as particulate and is initially deposited near emission sources and is not widely distributed. With respect to sources for lead emissions, Title V of the Clean Air Act (CAA) requires major sources of air pollutants, and certain other sources, to obtain an operating permit and report air emissions. A major source under Title V is one that emits, or has the potential to emit, more than 100 tons per year (tpy) of any air pollutant; or, more than 10 tpy of a single Hazardous Air Pollutant (HAP); or, 25 tpy of a combination of HAPs. SCDHEC Regulation 61-62.1, Section III, requires that facilities submit emissions data for all regulated pollutants (SCDHEC 2017). According to the 2016 Air Emissions report, there were 207 Title V facilities in South Carolina reporting lead air emissions (Figure 8).

5.2.5 Uncontrolled, Abandoned or Other Waste Sites (Legacy Sites)

Under the South Carolina Hazardous Waste Management Act, the Department implements programs to respond to releases of hazardous substances at uncontrolled hazardous waste sites. These sites are addressed under various statutory authority, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Brownfields/Voluntary Cleanup Program, and the Dry Cleaning Restoration Fund. This report on lead focuses on the sites that are commonly referred to as Superfund sites but may be a variety of legacy sites. There are currently 511 legacy sites in South Carolina with known contamination. There are another 141 sites with some residual contamination present where restrictions on land use are in place to prevent exposure but where no other cleanup activities are necessary. Of the 511 legacy sites, former Super Phosphate fertilizer manufacturing sites, battery manufacturing and recycling sites and shooting ranges are known sources of lead contamination.

The Department has identified legacy sites where there is known metals contaminated groundwater, soils and stormwater (Figures 9, 10 and 11, respectively). Figure 12 depicts and Table 7 lists legacy sites with known lead contamination.

Figure 8.

2016 Estimated Lead Emissions from CAA Title V Facilities

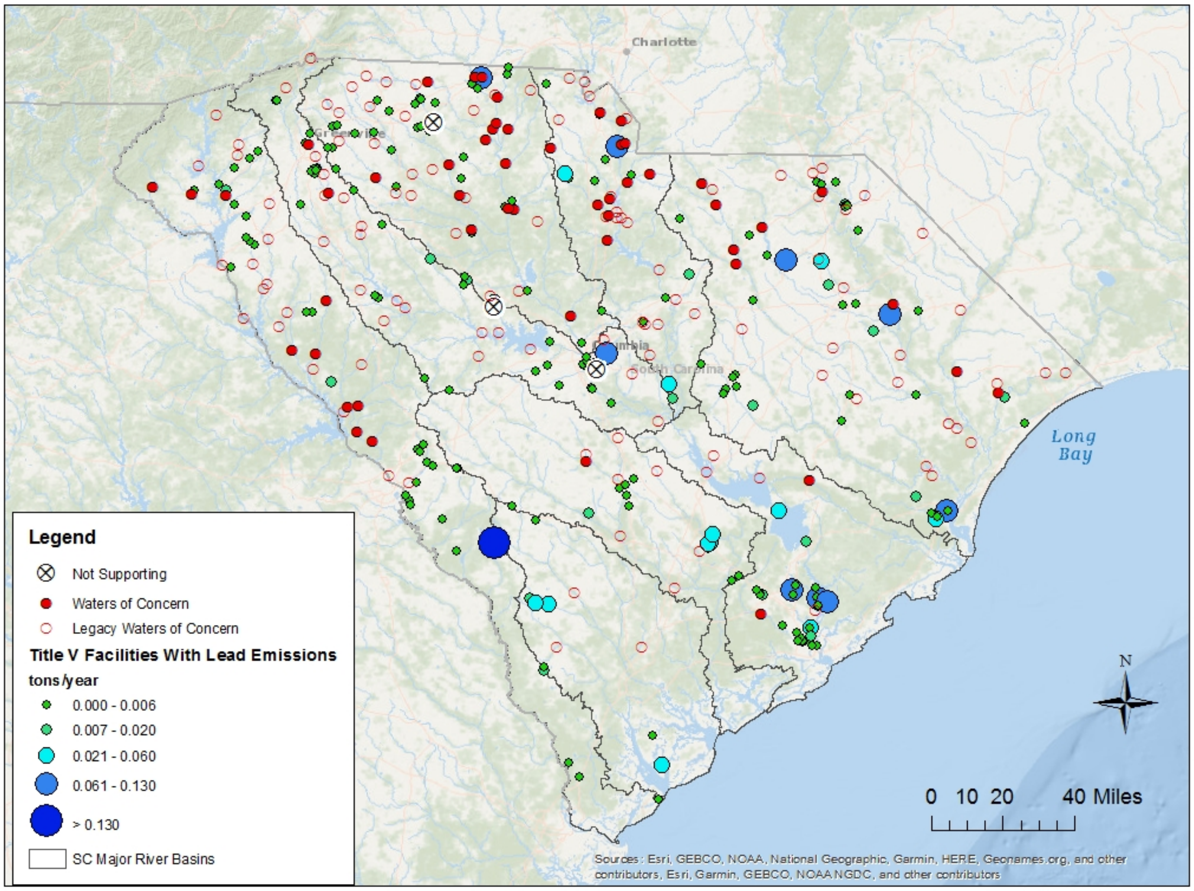


Figure 9.

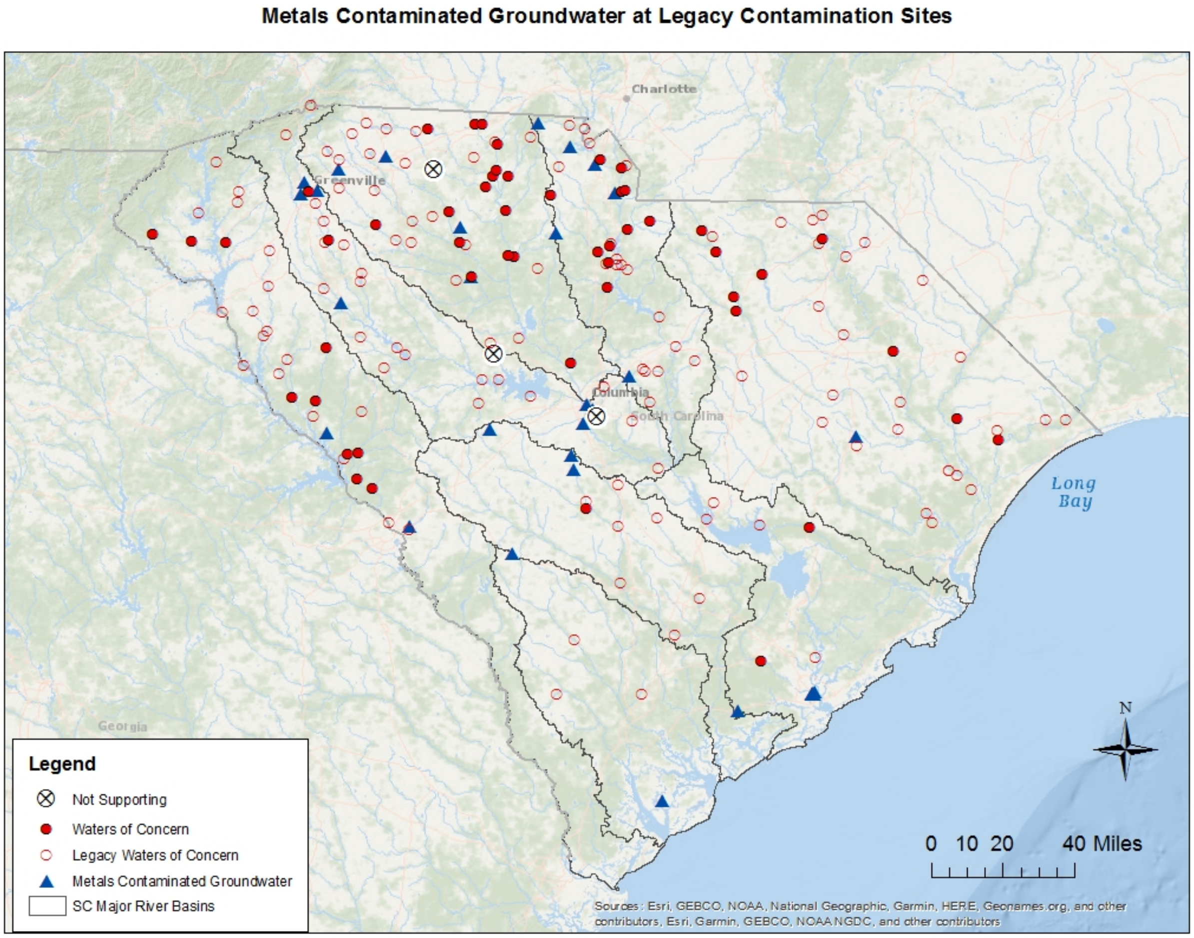

Metals Contaminated Groundwater at Legacy Contamination Sites
Charlotte
Greenville
Columbia
South Carolina
Long Bay
Georgia
Legend
Not Supporting
Waters of Concern
Legacy Waters of Concern
Metals Contaminated Groundwater
SC Major River Basins
N
0 10 20 40 Miles
Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Figure 10.

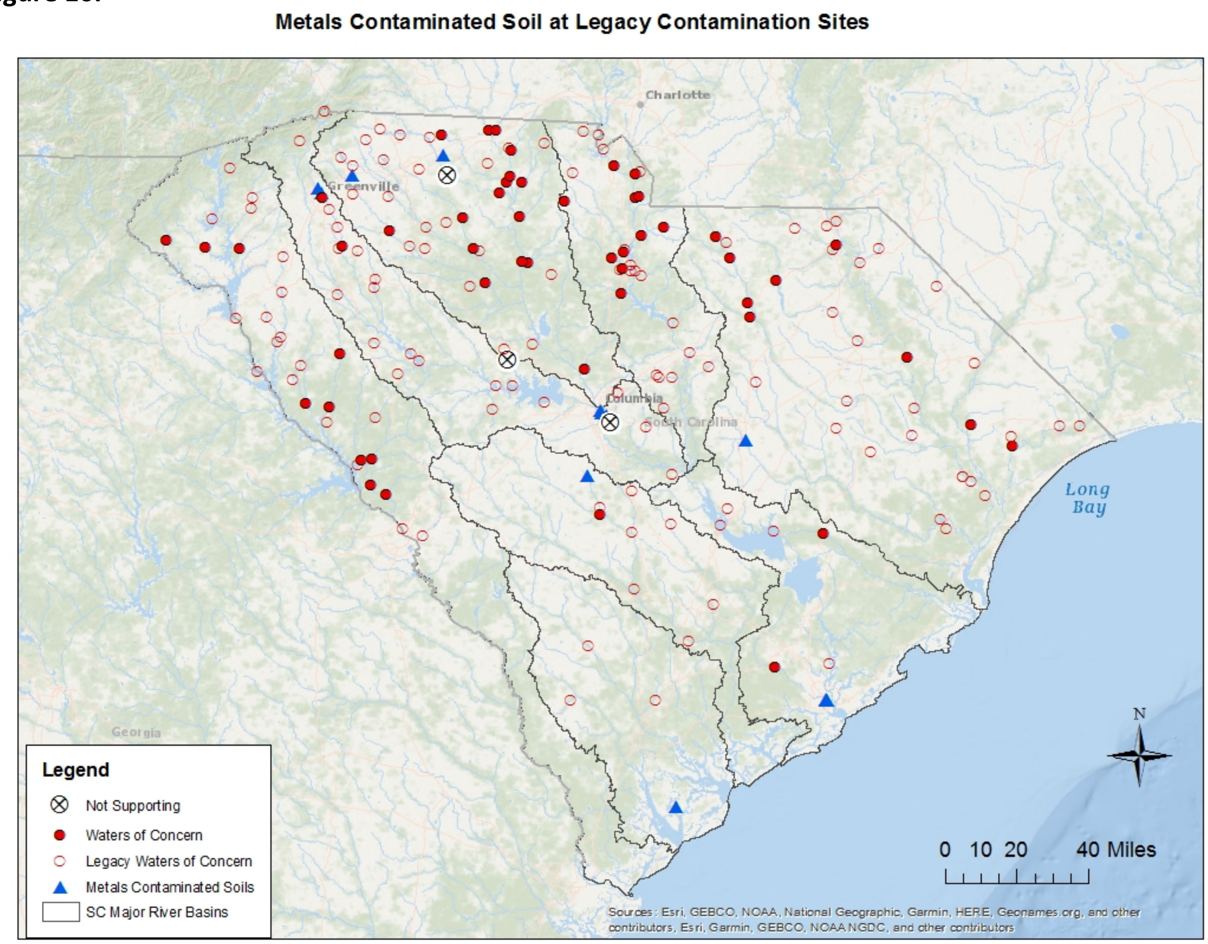

Metals Contaminated Soil at Legacy Contamination Sites
Charlotte
Greenville
Columbia
South Carolina
Georgia
Long Bay
Legend
Not Supporting
Waters of Concern
Legacy Waters of Concern
Metals Contaminated Soils
SC Major River Basins
0 10 20 40 Miles
N
Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Figure 11.

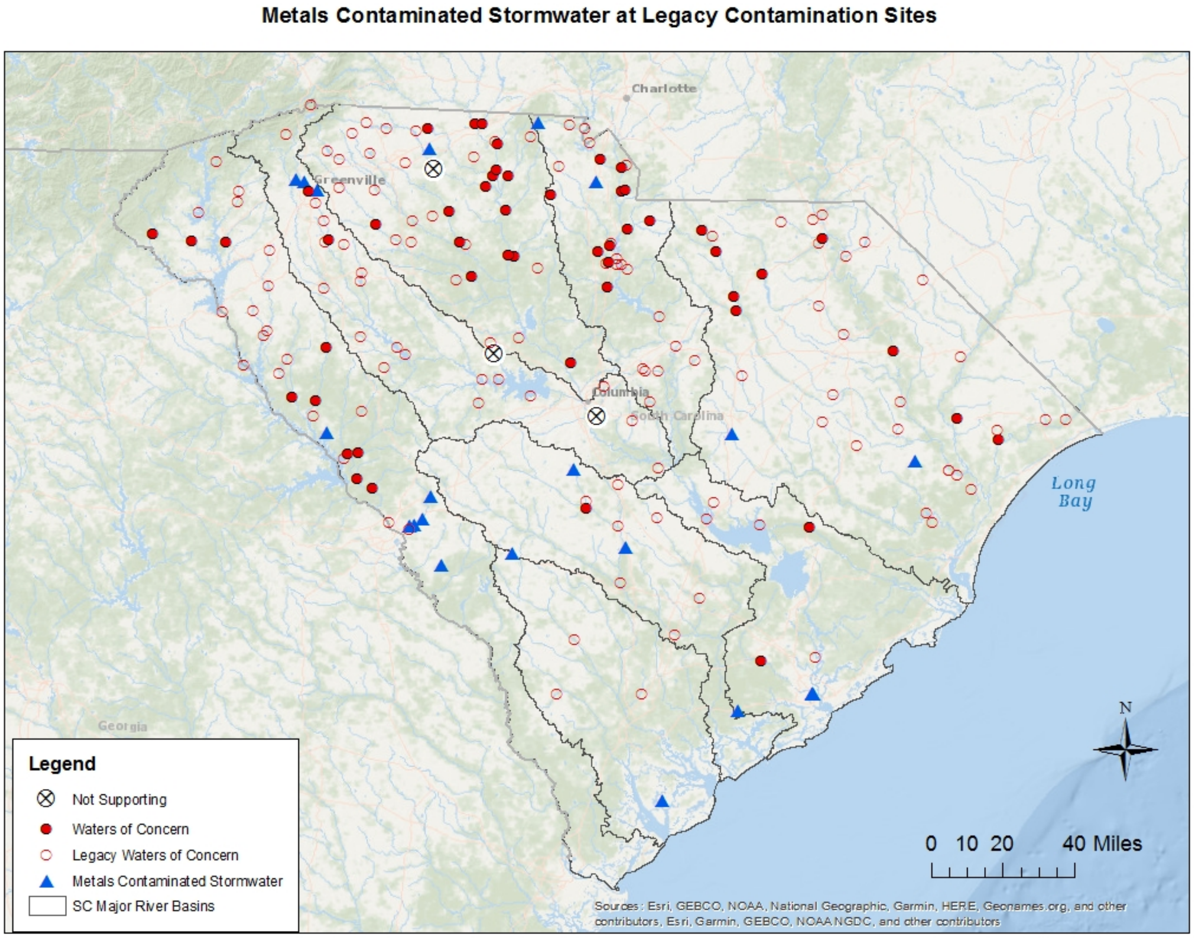

Metals Contaminated Stormwater at Legacy Contamination Sites
Charlotte
Greenville
Columbia
South Carolina
Georgia
Long Bay
N
Legend
Not Supporting
Waters of Concern
Legacy Waters of Concern
Metals Contaminated Stormwater
SC Major River Basins
0 10 20 40 Miles
Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Figure 12.

Lead Contamination at Legacy Contamination Sites

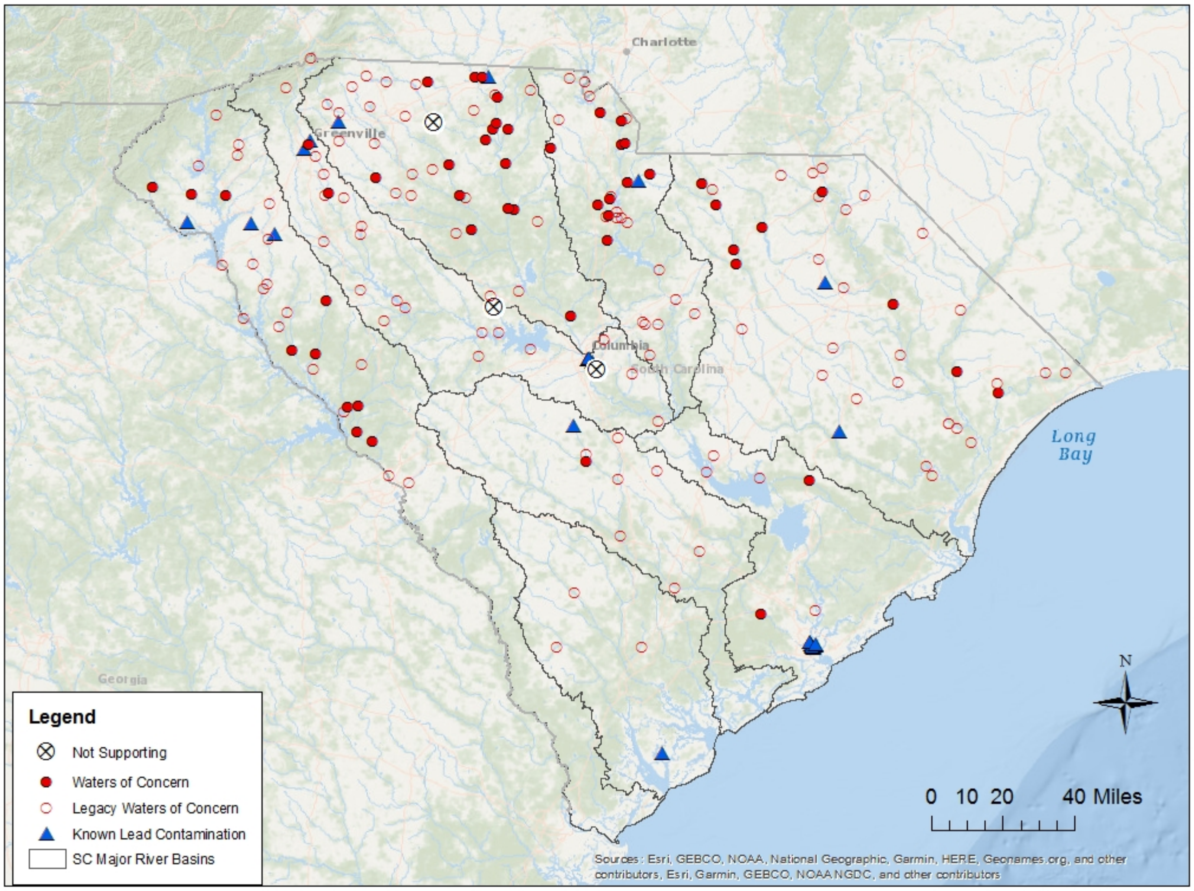


Table 7. Legacy Waste Sites with Known Lead Contamination

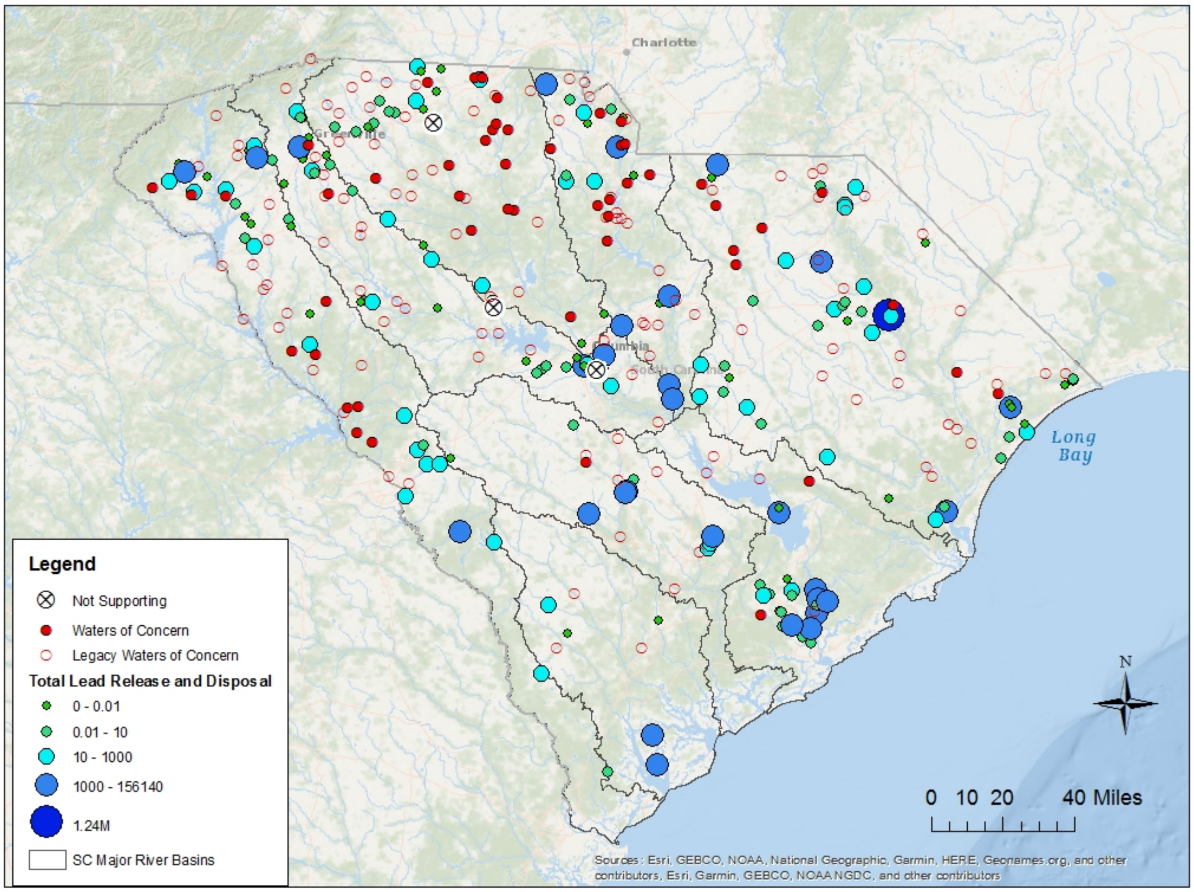
Project Name	Street Address	City
GENERAL BATTERY CORP	OLD CHICK SPRINGS RD S OF SC 101	GREER
SWIFT AGRI-CHEM CORP	2750 SPEISSEGGER DR	CHARLESTON
SOUTHERN AGRICULTURAL PLANT SITE	111 DENNIS ST	KINGSTREE
SOUTHERN SLAG AGGREGATE	HWY 102 - 1316 SAVANNAH HWY	SWANSEA
ASHEPOO PHOSPHATE/FERTILIZER WORKS	BRASWELL ST	CHARLESTON
PACIFIC GUANO	1505 KING ST EXT	CHARLESTON
STONO PHOSPHATE WORKS	2079 AUSTIN AVE	CHARLESTON
ATLANTIC PHOSPHATE WORKS/SCE&G HAGOOD ST	2200 HAGOOD RD	CHARLESTON
KAISER ALUMINUM	1435 BLECKLEY ST	ANDERSON
ETIWAN PHOSPHATE COMPANY	MILFORD ST	CHARLESTON
PORT OF BALDWIN MINES	LADYS ISLAND DR BRIDGE	PORT ROYAL
CATAWBA FERTILIZER	LANDSFORD RD NEAR SPRINGDALE RD	LANCASTER
VIRGINIA-CAROLINA CHEMICAL COMPANY	ANDERSON RD AND SOMERSET ST	GREENVILLE
ASHEPOO/OSWALD	71 BRASWELL ST	CHARLESTON
COLUMBIA PHOSPHATE COMPANY	707 CATAWBA ST	COLUMBIA
GLOBE PHOSPHATE COMPANY	875 CATAWBA ST	COLUMBIA
VIRGINIA CAROLINA CHEMICAL CORPORATION (VCC) BLACKSBURG (FORMER)	OLD SHELBY RD	BLACKSBURG
WANDO PHOSPHATE MILL	BAKER HOSPITAL BLVD	NORTH CHARLESTON
EDISTO PHOSPHATE COMPANY	1884 HERBERT ST	CHARLESTON
WELCH GROUP ENVIRONMENTAL (WGE) BELTON	5043 BELTON HWY	ANDERSON
WELCH GROUP ENVIRONMENTAL (WGE) FAIRPLAY	170 FELTMAN FARM RD	FAIR PLAY
DARLINGTON PHOSPHATE COMPANY	311 WASHINGTON ST	DARLINGTON
ROYSTER GUANO FERTILIZER	2218 COMMERCE DR	COLUMBIA
USC CATAWBA STREET SITE	1301 CATAWBA ST	COLUMBIA
BATTERY & ELECTRIC CO	109 STONE AVE	GREENVILLE

5.2.6 Other Sources

The Toxic Release Inventory (TRI) tracks specific chemicals that may pose a threat to human health and the environment. Lead is a reportable chemical under TRI. Facilities from different industry sectors must report annually how much of each chemical is released. A release means that the chemical is emitted to the air of water or placed in some type of land disposal. In South Carolina, there were 182 facilities that reported TRI data for lead in 2017. The total lead release data are depicted on Figure 13.

Figure 13.

Summary of 2017 TRI Reports for Total Lead Release and/or Disposal



5.3 Review of Ambient Statewide Stream Sediments

For insight into possible natural sources of lead in the State, the Department requested that the South Carolina Geological Survey of the Department of Natural Resource (SCDNR) review available datasets on the geological formations to evaluate the linkage between the composition of soils and stream sediments in the South Carolina and adjacent states. The following is a summary excerpt from that report (SCDNR 2019). The full report is presented in Annex 5.

Note: all literature citations and figure references in the following summary excerpt refer to those documentations in the full State Geological Survey report (SCDNR 2019).

ANALYSIS

Stream and River Sediments

In the 1970's the USGS sampled fluvial sediments across the nation as part of NURE. Geochemical analyses were done, and test results are available through a USGS data portal. These data were interpolated to depict the total (both geogenic and anthropogenic) Pb in river and stream sediments in Georgia, North Carolina, and South Carolina (Figure 10 & 11). The gaps in data shown on Figures 10 and 11, reflect analytical results less than the detectable amount. For this reason, these areas have been left blank on the figure.

It is important to note that NURE samples may include both geogenic and anthropogenic Pb. In rural parts of South Carolina that have a limited history of industrial development, [Pb] likely reflects a high geogenic to anthropogenic [Pb] ratio. In contrast, urban centers with a history of industrial development may contain a significant component of anthropogenic Pb, and this development may be reflected in higher [Pb]. For example, samples collected from Sumter, Columbia, and Rock Hill have [Pb] highs of 1150 ppm, 903 ppm, 427 ppm respectively. The [Pb] highs are particularly visible when viewed in conjunction with a state land-use map (Figure 12; Homer et al., 2015).

The [Pb] highs found in south-central North Carolina could be attributed to high arsenic (As) levels being eroded from sulfide minerals from the Carolina Slate Belt (Figure 10; Pippin et al., 2003). Pb is commonly found in As minerals (Salmien, 2019; Bowell et al., 2014). Along with its association with As, Pb is often found in gold deposits (Feiss et al., 1991; National Academies of Sciences, Engineering, and Medicine, 2017; Svetlitskaya and Nevolko, 2017; Molnar et al. 2015; Hillman et al., 2017). On the river and stream map (Figure 13), it is possible to see a slight increase in [Pb] around historic gold mines in the South Carolina Piedmont, particularly the gold deposits located in Edgefield and McCormick Counties (Maybin, 1997). The reason why there is a correlation between these mines in the stream and river sediments and not in the soils (Figures 5, 7, & 9) is an area of potential future research.

The location of high [Pb] southeast of the Fall Line in the upper Coastal Plain could be related to the transport of Pb from the sialic Piedmont rocks by fluvial processes. The location of this "Pb Line" is slightly northwest of the Orangeburg Scarp, a geologic feature that divides the Upper and Middle Coastal Plain's (Figure 1). The way in which Pb is transported in Coastal Plain sediments and its relation to the Orangeburg Scarp could be another area of future study.

Waters of Concern

As previously stated, the Pb in Georgia, North Carolina, and South Carolina is considered geogenic and related to granitic plutons and felsic metamorphic rocks. The waters of concern (WOC) defined by the South Carolina Department of Health and Environmental Control (DHEC) are scattered throughout the State (Figure 3). Pb anomalies in WOC's that are near granitic plutons most likely have a large component of geogenic lead. Samples collected in proximity to urban areas are more likely to contain a component of anthropogenic Pb (Figure 12). Pb anomalies in WOCs from the Lower Coastal Plain may not be related to geogenic Piedmont sources. The rate at which feldspar breaks down in the weathering environment will cause Pb to disperse. Pb isotope ratios can be used to determine anthropogenic or geogenic origin in the WOCs (Kong et al., 2018).

CONCLUSION

South Carolina has an average [Pb] of 14.4 ppm, which is reflected both in the river and stream sediments (NURE [National Uranium Resource Evaluation]), and soil and rock geochemical datasets. The distribution of South Carolina's [Pb] is similar to Georgia and North Carolina. The southeastern coastal states lack a prevalent history of Pb extraction, and there are no large deposits of galena, anglesite, or minerals in which Pb is a major component. In all three states, the majority of Pb appears to be concentrated in the Piedmont region. The cause of this areal concentration is suggested to be from proximity to numerous granitic plutons and felsic metamorphic rocks found in that region. The area of [Pb] soil anomalies parallels the granitic rocks of all three states. Pb moves from the granitic rocks into the soil through physical and chemical weathering. The subtropical climate in South Carolina limits the mobility of Pb in the sediment and soil profile. However, soft water similar to that found in the Piedmont can increase Pb mobilization in both surface and groundwater. Chemistry of soft water may be the ultimate factor in mobility. But more work needs to be done.

Even if some of the Pb in the WOCs originated from the sialic rocks in the Piedmont of South Carolina [sic]. *However, certain samples collected around urban areas and in the Lower Coastal Plain may be related to anthropogenic sources. Further study on the WOC Pb isotope ratios is needed before a final assessment can be made related to the geochemical nature of South Carolina Pb.*

The SCDNR report aligns with observations made by Canova (1999) on stream sediments and soils for background conditions.

5.4 Review of Potential Sources Specific to the Three Listed Locations

This section provides a provisional discussion of sources that may contribute to indicated lead impairments in Camping Creek in Newberry County (Location S-290) and Gills Creek in Richland County (location C-017) and the ostensible impairment in Lawsons Fork Creek in Spartanburg County (Location BL-001) [As noted earlier, a 2019 benthic assessment indicated that this location was fully-supporting of aquatic life. In order to remain consistent with the Department's 303(d) process, this location will be carried forward and addressed for no listing in a future cycle.]

5.4.1 - Potential Lead Sources for Lawsons Fork Creek at S-42-108 in Spartanburg County (Location BL-001)

NPDES Point Sources

There are 15 NPDES permits in the watershed draining to BL-001. Six (6) of these include lead limits (Figure 14, Table 8). The bulk petroleum storage general permit includes a total lead limit of 0.051 mg/L daily maximum with quarterly monitoring required. The petroleum contaminated groundwater general permit limit for lead is a monthly average of no more than 0.00083 mg/L and a daily maximum of 0.022 mg/L. This permit requires monthly sampling.

Figure 14.

NPDES Permits with Lead Limits - Lawsons Fork Creek

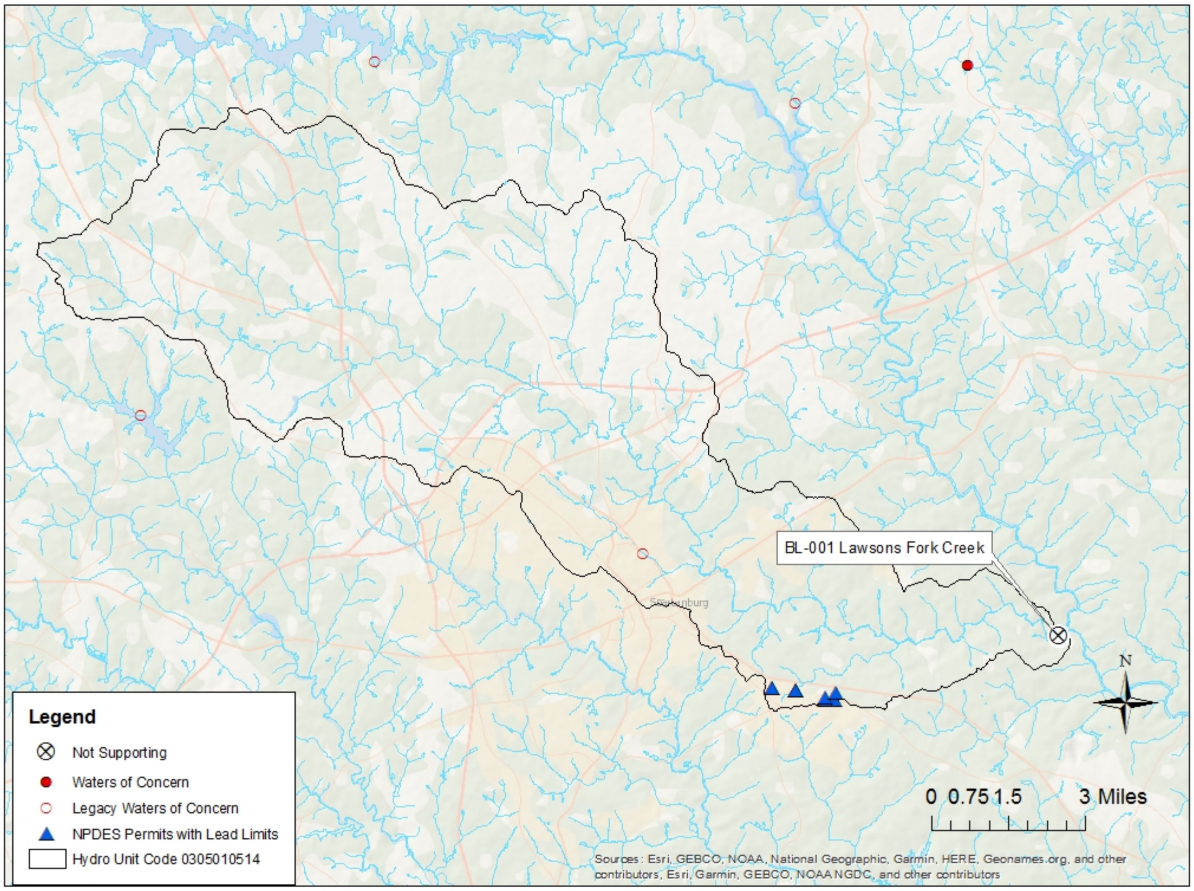


Table 8. NPDES Permits with Lead Limits Upstream of Lawsons Fork Creek (BL-001)

Facility	Permit Number	Description
Magellan Terminal	SCG340006	Bulk Petroleum Storage
Magellan Terminal	SCG340018	Bulk Petroleum Storage
Motiva Enterprises	SCG340001	Bulk Petroleum Storage
Kinder Morgan	SCG340011	Bulk Petroleum Storage
BP Products	SCG340002	Bulk Petroleum Storage
Buckeye Terminals	SCG830033	Petroleum Contaminated Groundwater

The other nine (9) NPDES permittees in the watershed do not have applicable lead limits in their permits and are identified in Table 9. For the City of Inman (SC0021601), lead was analyzed at the correct practical quantitation limit and was not detected in their discharge. The Milliken Dewey Plant (SC0003581) did not have Reasonable Potential to exceed a water quality standard for lead at the time of their last permit reissuance; therefore, that facility does not currently have lead limits. The other seven (7) permittees have coverage under general permits. Three (3) of these are for non-metallic mineral mining which is not considered a source category for lead. The remaining four (4) permittees, which discharge utility water, are not required to sample because their discharge is currently less than a flow that would trigger sampling per the general permit.

Table 9. NPDES Permits without Lead Limits Upstream of Lawsons Fork Creek (BL-001)

Facility	Permit Number	Description
City of Inman WWTP	SC0021601	Wastewater Treatment Facility
Milliken Dewey Plant	SC0003581	Industrial Organic Chemicals
Milliken Dewey Plant	SCG250277	Industrial Organic Chemicals
Inman Stone Company	SCG730084	Crushed and Broken Granite
Associated Asphalt Inman	SCG250297	Bulk Petroleum Station and Terminal
Sloan Construction Valleydale Mine	SCG731201	Non-metallic Minerals
Milliken Roger Milliken Center	SCG250289	Business Services
Mack Molding Company	SCG250235	Plastics Products
Par Grading and Hauling	SCG731330	Non-metallic Minerals

NPDES MS4 Stormwater Discharges

Approximately 70% of the watershed that drains to BL-001 is covered by two (2) small (Phase II) and one (1) large MS4 permits:

- City of Spartanburg SCR038305
- County of Spartanburg SCR038306
- SCDOT (SCS040001) [large MS4 in the watershed]

NPDES Industrial Stormwater Discharges

There are 34 Industrial Stormwater Discharge permits in the watershed upstream of BL-001. (Figure 15, Table 10).

Figure 15.

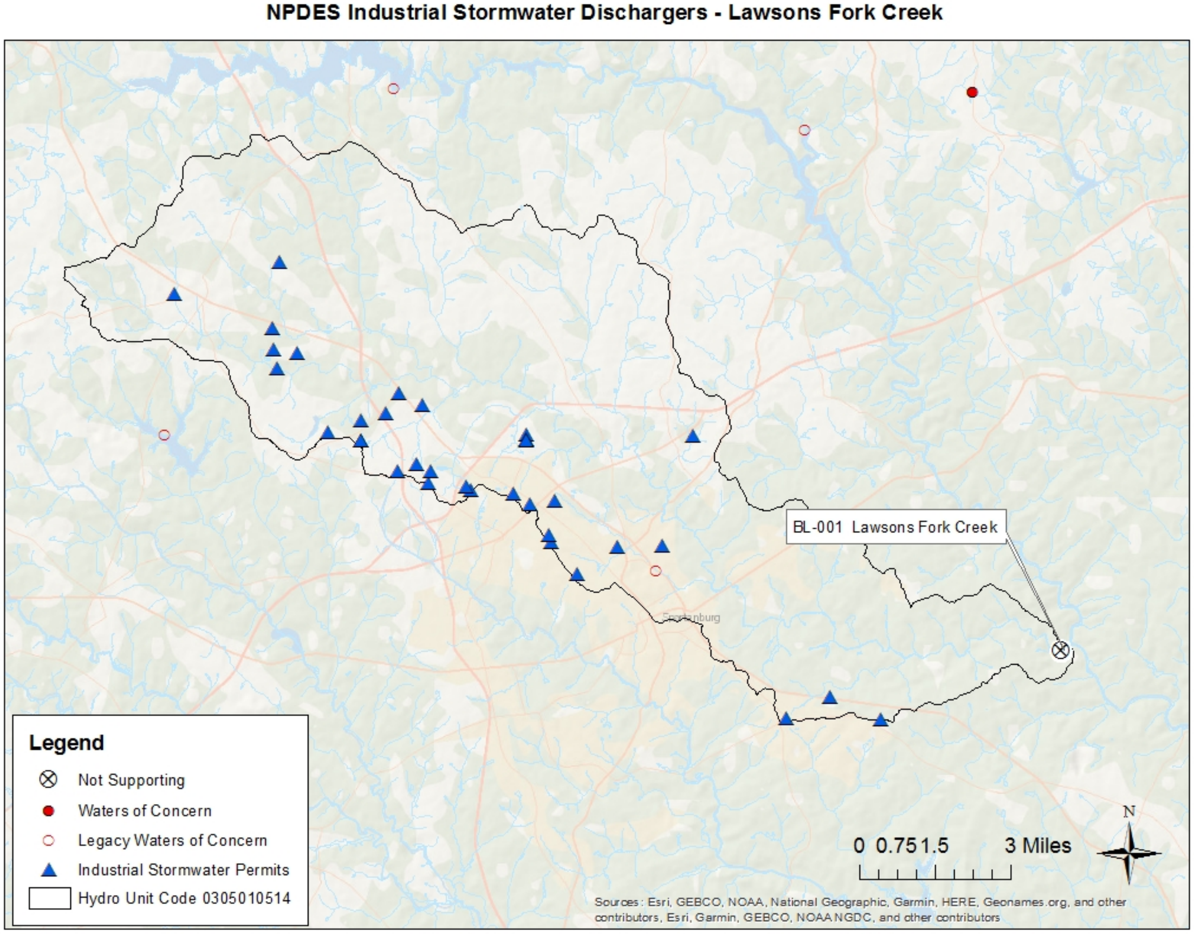


Table 10. NPDES Industrial Stormwater Permits – Lawsons Fork Creek

FACILITY	PERMIT NUMBER
AMAZON.COM.DEDC LLC - GSP1	SCR006020
ANTOLIN INTERIORS USA INC - SPARTANBURG	SCR006042
AURIA	SCR006029
BakeMark	SCR005789
BakeMark	SCR006071
CARSON'S USED AUTO PARTS	SCR003898
CLEMENT LUMBER COMPANY	SCR001062
CMC SPARTANBURG	SCR003722
COMMERCIAL METALS COMPANY DBA CMC RECYCLING	SCR005780
COTTON OWENS ENTERPRISES, INC,	SCR003885
CTMI	SCR005532
DIXIE TOO AUTO PARTS	SCR002148
EAGLE TRANSPORT CORPORATION	SCR002157

HAYNE YARD	SCR002399
HI-BRIDGE AUTOMOTIVE	SCR003913
HIGHLAND BAKING COMPANY	SCR005299
HOME FABRIC FINISHING	SCR005351
INMAN MILLS SAYBROOK PLANT	SCR000325
IWG HPC INC	SCR004562
KOHLER COMPANY	SCR001627
MACK MOLDING COMPANY	SCR004487
MILLIKEN CHEMICAL-DEWEY PLANT	SCR000599
MINTZ SCRAP IRON & METAL INC	SCR000579
MOUNTAIN FREIGHT TRANSPORATION	SCR005416
PINNACLE TRAILER SALES INC	SCR005085
POLAR EXPRESS	SCR005052
ROCK-TENN SOUTHERN CONTAINER SPARTANBURG SHEET PLANT	SCR005303
SIEGWERK USA CO	SCR004222
SOUTHERN WOOD PIEDMONT CO	SCR001881
SPARTAN RECYCLING GROUP LLC	SCR005576
THOMAS CONCRETE OF SOUTH CAROLINA - SPRINGFIELD ROAD	SCR005595
UNITED FOREST PRODUCTS INC	SCR005063
UNITED PARCEL SERVICE INC	SCR000844
WASTE TREATMENT PLANT	SCR002080

Legacy Waste Sites
There are no legacy sites in the watershed with known lead contamination.

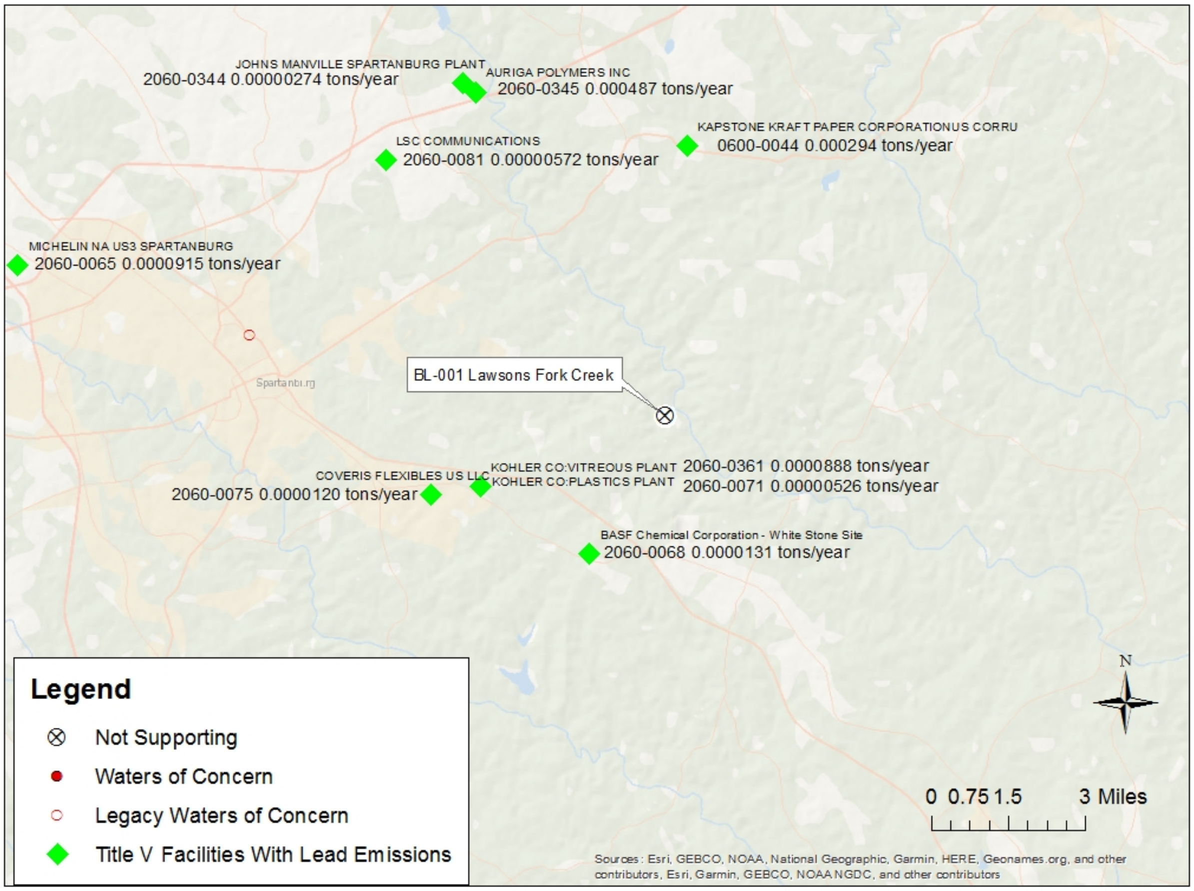
Deposition from Air Emissions
There are nine (9) Title V sources near BL-001 that reported lead emissions in 2016 (Figure 16).

- Auriga Polymers (2060-0345) -- 0.000487 tpy
- BASF Chemical Corporation Whitestone Site (2060-0068) -- 0.0000131 tpy
- Coveris Flexibles US, LLC (2060-0075) -- 0.0000120 tpy
- Johns Manville Spartanburg Plant (2060-0344) -- 0.00000274 tpy
- Kapstone Kraft Paper Corporation (0600-0044) -- 0.000294 tpy
- Kohler Company Plastics Plant (2060-0071) -- 0.00000526 tpy
- Kohler Company Vitreous Plant (2060-0361) -- 0.0000888 tpy
- LSC Communication (2060-0081) -- 0.00000572 tpy
- Michelin North America Inc. (2060-0065) -- 0.0000915 tpy

Combined, these sources reported lead emissions of 0.001 tpy or approximately two (2) lbs in 2016.

Figure 16.

CAA Title V Emissions - Lawsons Fork Creek



Other Sources

Based on the 2017 TRI, there are several facilities near BL-001 that reported lead releases, but only one (1) that released more than ten (10) lbs. (Figure 17).

- Auriga Polymers is approximately eight (8) miles away from BL-001 in an adjacent watershed. This facility reported a total of 85.02 lbs. of lead released. Of the total, 84 lbs. of this was disposed of offsite; one (1) pound was released to air; and, 0.02 pound was released to surface water.

- The IWG High Performance Conductors facility is within the watershed. This facility reported the release of 2.63 lbs. of lead, all of which was disposed of offsite.

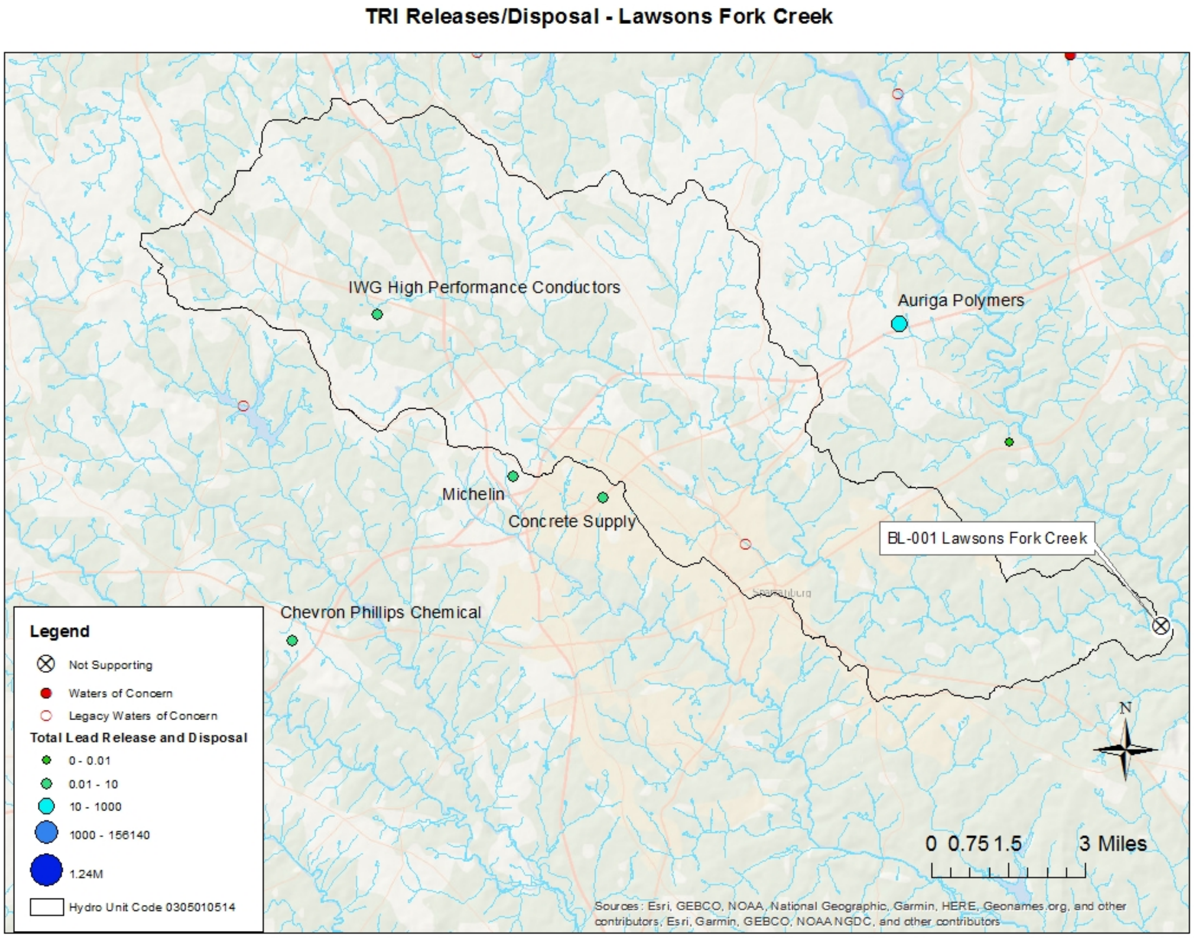
- The Michelin facility at 1000 International Drive in Spartanburg is just outside the watershed. This facility reported release of a total of 1.3 lbs. of lead. Of the total, 0.2 pound was released as air emissions; 1.1 lbs. were released to a waste broker and disposed of offsite.

- Concrete Supply Company, 475 Simuel Road in Spartanburg, also adjacent to but not within the watershed, released a total of 0.0125 pound of lead as air emissions.

- The only other facility in the vicinity that released greater than 0.01 pound of lead is the Chevron Phillips Chemical Supply Company. This facility reported releasing one (1) pound of lead to an offsite landfill.

Combined, these sources reported lead emissions of approximately 90 lbs. in 2016.

Figure 17.



Legacy Mining
Sampling station BL-001 is located on Goldmine Road (S-42-108), an indication that there may have been mining in this area in the past. There are records of a *vein mine* in the Lawsons Fork Creek area as well as placer mining upstream of the sampling station. During the 1800s there were 19 gold mines operating in Spartanburg, Union and York Counties. The Hammett mine in the Lawson Fork Creek area was one of the most productive. Unfortunately, records from the time during which mining was active are incomplete so the exact locations of the mines and what kind of processing was used are unknown (McCauley and Butler 1966; Sloan 1908).

5.4.2 – Potential lead Sources for Camping Creek in Newberry County (Location S-290)
NPDES Wastewater Facilities
There are no NDPES WWTFs discharging upstream from location S-290.

NPDES MS4 Stormwater Discharges

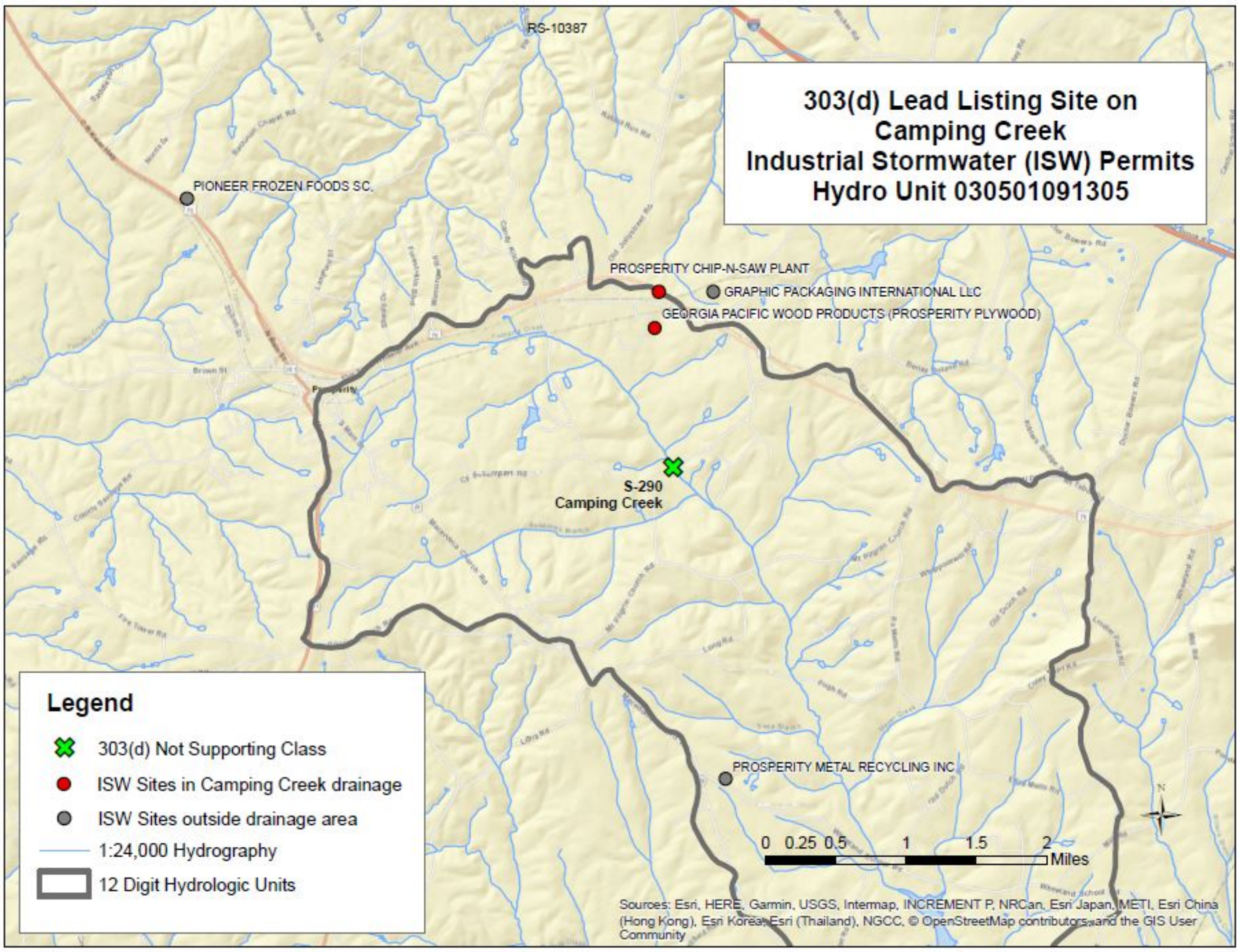
The only MS4 implementing a stormwater program in the vicinity of location S-290 is SCDOT (NPDES SCS040001).

NPDES Industrial Stormwater Discharges

There are two (2) Industrial Stormwater Discharge permits in the Camping Creek watershed upstream from location S-290 (Figure 18):

- Georgia Pacific Wood Products (Prosperity Plywood) - SCR004659
- Prosperity Chip-N-Saw Plant - SCR000108

Figure 18. NPDES Industrial Stormwater Dischargers – Camping Creek



Legacy Waste Sites

There are no legacy waste sites in the vicinity of location S-290.

Deposition from Air Emissions

There are six (6) CAA Title V permitted sources in the vicinity of station S-290 that reported air emissions for lead in 2016 as follows (Figure 19):

- Georgia-Pacific Wood Products, LLC holds two (2) Title V permits (1780-0011 – Georgia Pacific Wood Products LLC – Prosperity Chip-N-Saw; 1780-0008 – Georgia Pacific Wood Products LLC –

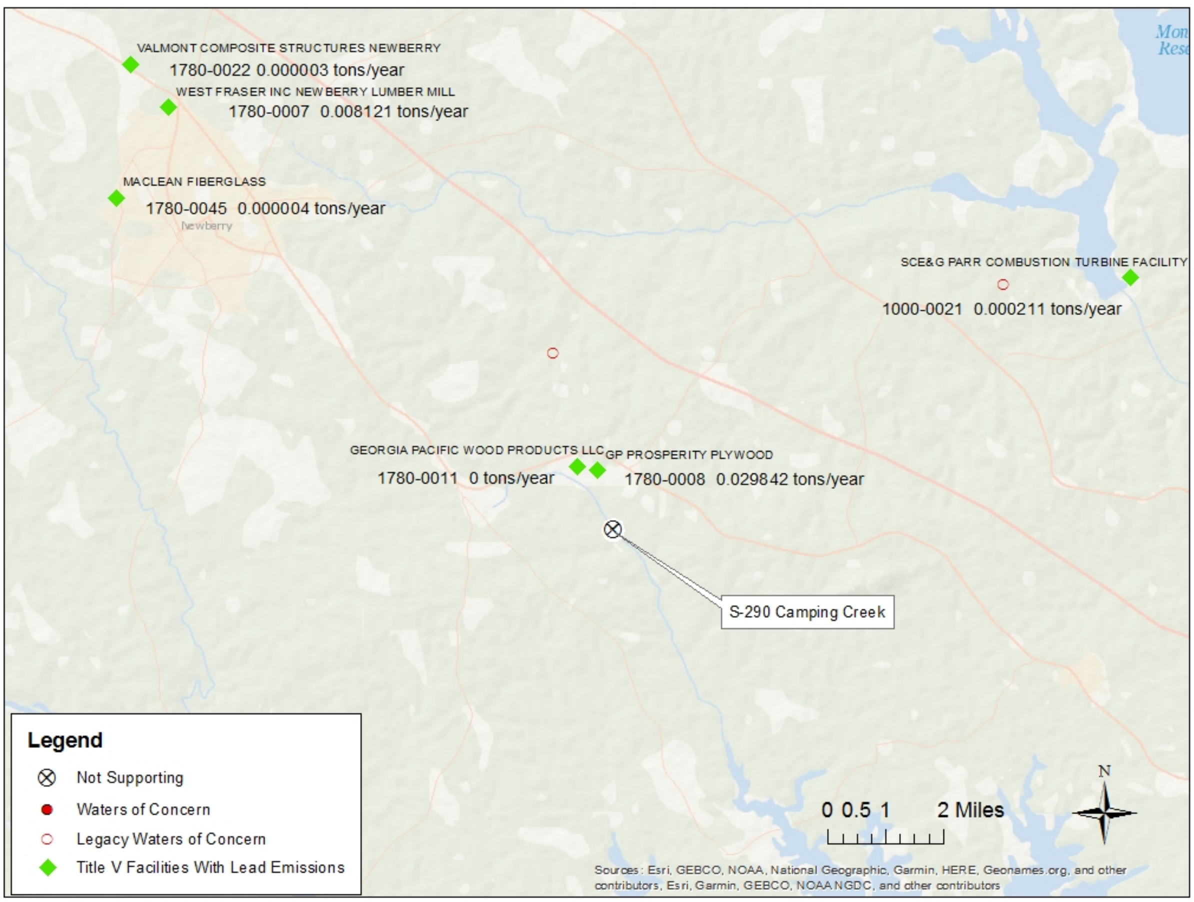
Prosperity Plywood). Combined, these two (2) facilities reported emissions of approximately 0.029842 tpy .

- SCE&G, Parr Combustion Turbine Facility (1000-0021) reported emissions of approximately 0.0002109 tpy.
- MacLean Fiberglass (1780-0045) reported emissions of approximately 0.000004 tpy.
- West Fraser Inc. Newberry Lumber Mill (1780-0007) reported emissions of approximately 0.008121 tpy.
- Valmont Composite Structures Newberry (1780-0022) reported emissions of approximately 0.000003 tpy.

Combined, these sources reported lead emissions of 0.038 tpy or approximately 76 lbs. in 2016.

Figure 19.

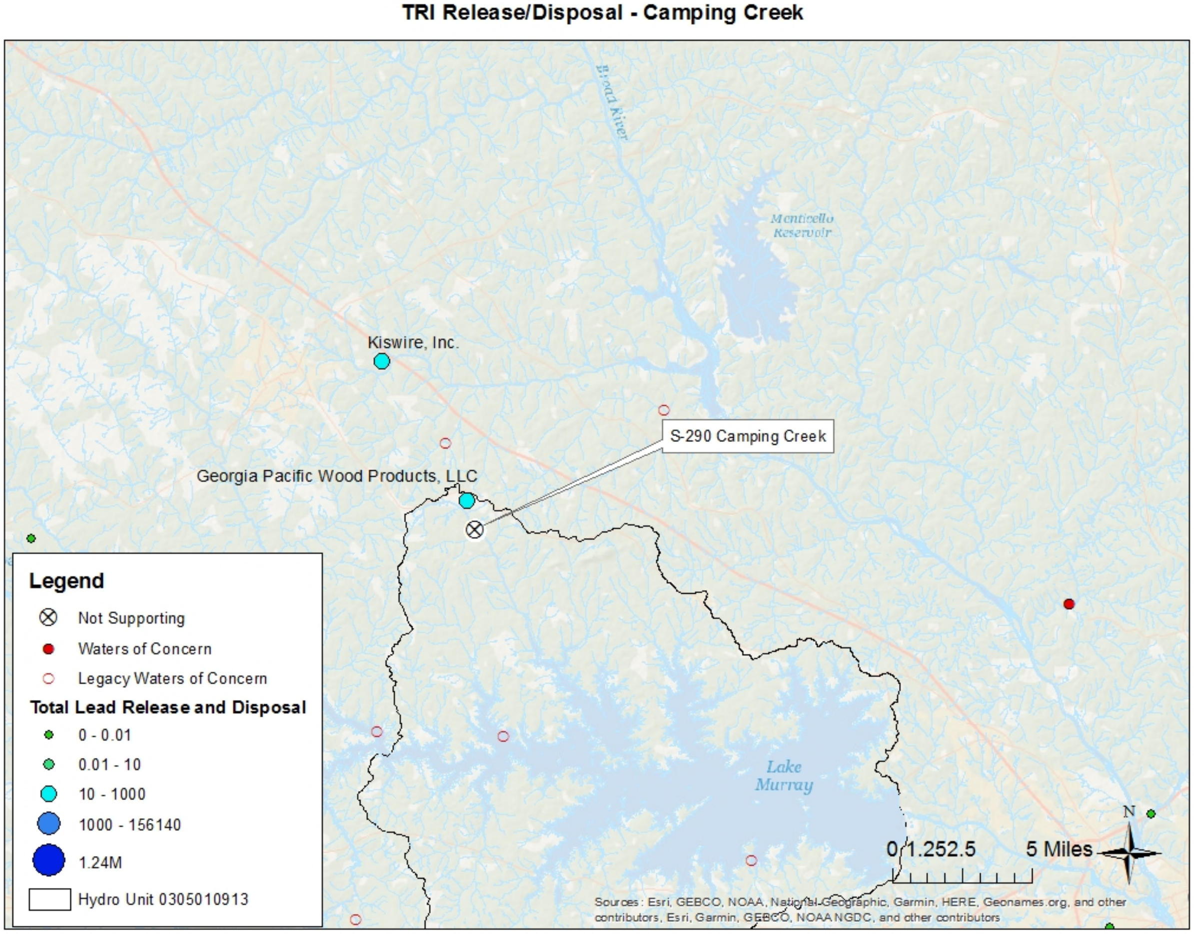
CAA Title V Emissions - Camping Creek



Other Sources

The 2017 TRI reports for facilities releasing greater than ten (10) lbs. of lead in the vicinity of location S-290 were reviewed (Figure 20). In addition to the Georgia Pacific facilities noted above, one (1) other nearby facility, Kiswire Inc., reported 430.2 lbs. of lead released in 2017. Most of these releases (393.8 lbs.) was through disposal at off-site landfills. A total of 36.4 lbs. was released through point source and fugitive air emissions.

Figure 20.



5.4.3 Potential Lead Sources for Gills Creek at Bluff Road in Richland County (Location C-017)

NPDES Wastewater Facilities

Amphenol Corporation (NPDES SC0046264) is the only NPDES WWTF discharging upstream from location C-017. The discharge is the result of a groundwater cleanup for chlorinated solvents. Lead has not been identified as a constituent of concern and the permittee indicated that lead was not present in their discharge at the time of their permit application. Therefore, this facility is not considered a potential source of lead and does not have lead limits.

NPDES MS4 Stormwater Discharges

There are multiple MS4 permittees upstream from location C-017:

- SCDOT (SCS040001) operates a large MS4 in the watershed
- the City of Columbia (SCS79001) and Richland County (SCS400001) and its co-permittees, Arcadia Lakes and the City of Forest Acres are medium MS4s
- Fort Jackson (SCR03901) is a small MS4

NPDES Industrial Stormwater Discharges

There are 24 Industrial Stormwater Discharge permits in the Gills Creek watershed upstream of location C-017 (Table 11; Figure 21).

Figure 21. NPDES Industrial Stormwater Dischargers – Gills Creek

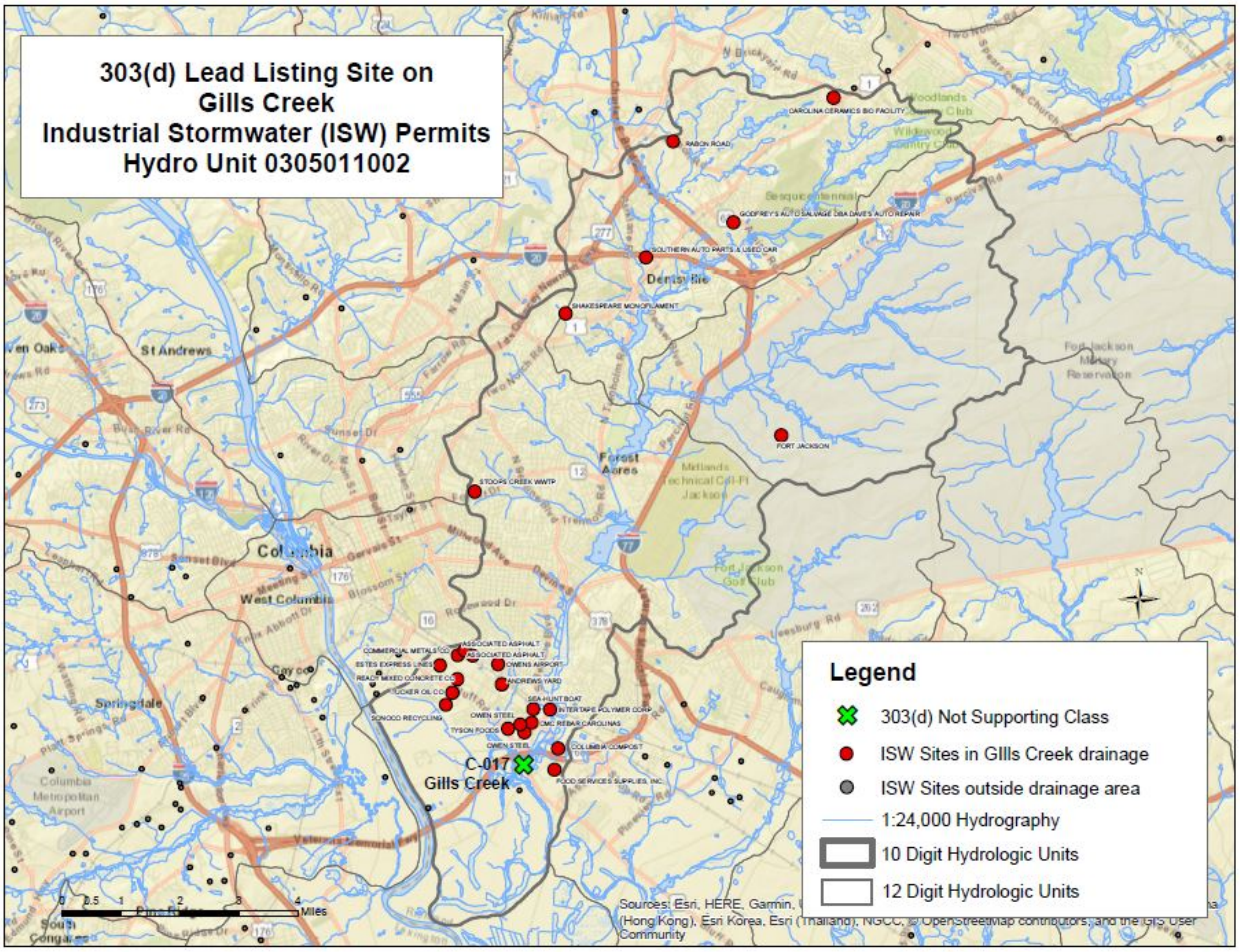


Table 11. NPDES Industrial Stormwater Permits – Gills Creek

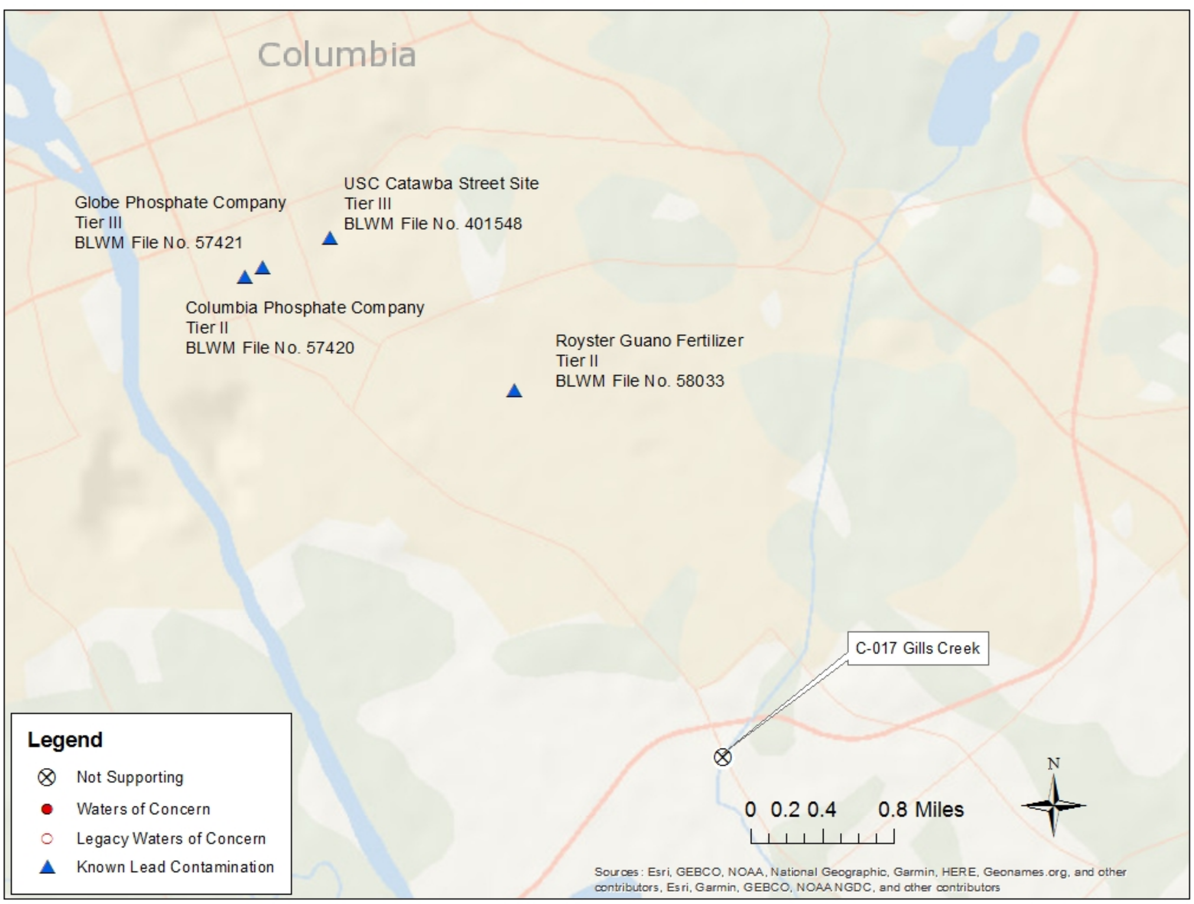
FACILITY	PERMIT NUMBER
ANDREWS YARD (NORFOLK)	SCR004236
ASSOCIATED ASPHALT COLUMBIA	SCR005314
ASSOCIATED ASPHALT COLUMBIA	SCR005315
CAROLINA CERAMICS BIO FACILITY	SCR000029
CITY OF COLUMBIA COMPOST FACILITY	SCR005549
CMC REBAR CAROLINAS	SCR002436
COLUMBIA OWENS AIRPORT	SCR000664
COMMERCIAL METALS COMPANY DBA CMC RECYCLING	SCR005775
ESTES EXPRESS LINES	SCR002169
FOOD SERVICES SUPPLIES, INC,	SCR003373
FORT JACKSON	SCR001892

GODFREY'S AUTO SALVAGE DBA DAVE'S AUTO REPAIR	SCR003781
INTERTAPE POLYMER CORP	SCR005614
OWEN STEEL COMPANY	SCR005773
OWEN STEEL COMPANY	SCR005137
RABON ROAD	SCR005509
READY MIXED CONCRETE COMPANY	SCR004082
SEA-HUNT BOAT	SCR004563
SHAKESPEARE MONOFILAMENT	SCR002535
SONOCO RECYCLING COLUMBIA	SCR004898
SOUTHERN AUTO PARTS & USED CAR	SCR003735
STOOPS CREEK WWTP	SCR003629
TUCKER OIL CO	SCR004505
TYSON FOODS	SCR004017

Legacy Waste Sites
There are four (4) legacy sites in the vicinity of location C-017 with known lead contamination (Figure 22).

Figure 22.

Legacy Waste Sites - Gills Creek

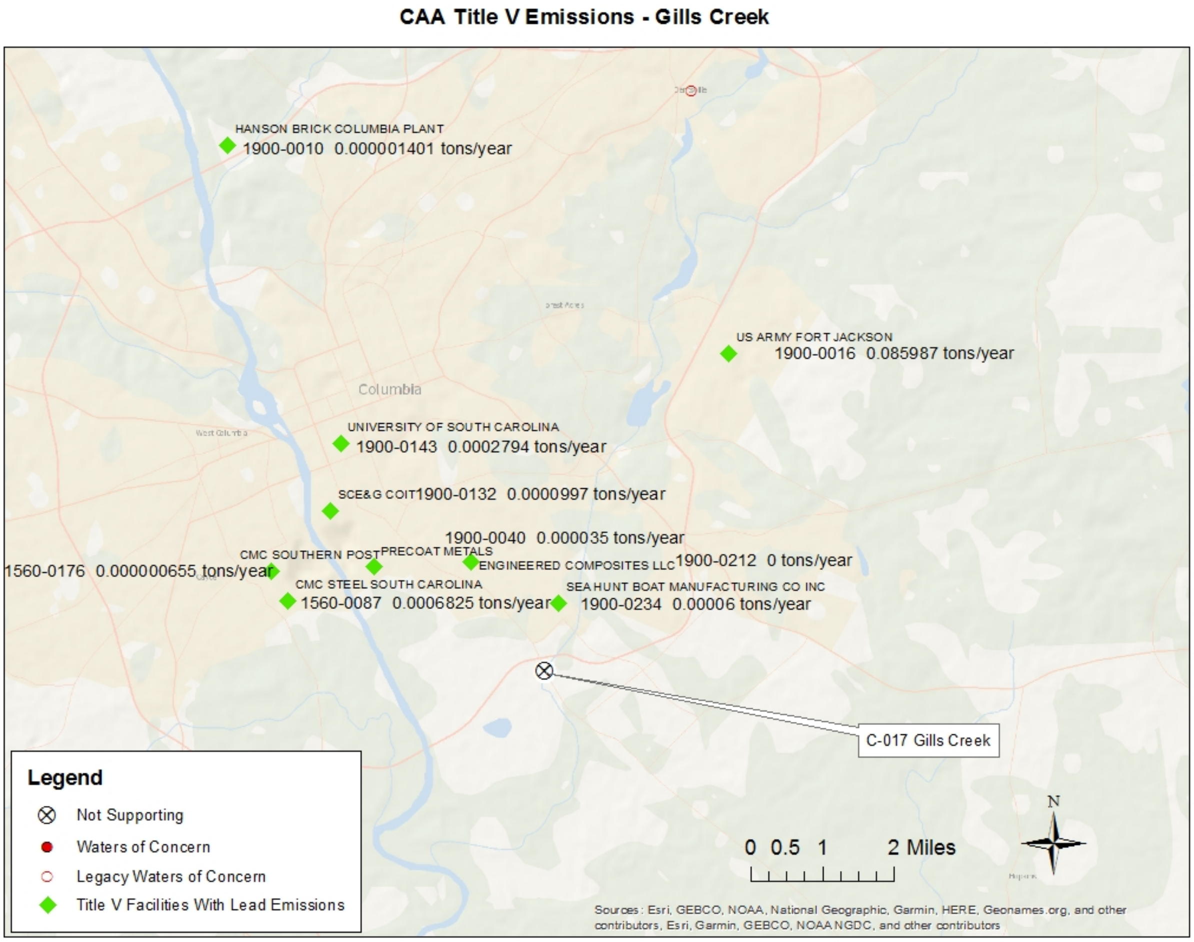


Deposition from Air Emissions
There are nine (9) CAA Title V sources in the vicinity of station C-017 (Figure 23) that reported air emissions for lead in 2016:

- US Army Fort Jackson (1900-0016) reported emissions of 0.085987 tpy
- University of South Carolina (1900-0143) reported emissions of 0.0002794 tpy
- SCE&G Coit (1900-0132) reported emissions of 0.0000997 tpy
- Sea Hunt Boat Manufacturing Co. Inc. (1900-0234) reported emissions of 0.00005961 tpy
- Precoat Metals (1900-0040) reported emissions of 0.00003545 tpy
- Hanson Brick Columbia Plant (1900-0010) reported emissions of 0.000001401 tpy
- Engineered Composites LLC (1900-0212) reported emissions of 4.81E-08 tpy
- CMC Steel South Carolina (1560-0087) reported emissions of 0.0006825 tpy
- CMC Southern Post (1560-0176) reported emissions of 0.000000655 tpy

Combined, these sources reported lead emissions of 0.09 tpy, approximately 180 lbs. in 2016.

Figure 23.



Other Sources

Based on the 2017 TRI, there are five (5) facilities near location C-017 with total lead disposal greater than ten (10) lbs. in 2017 (Figure 24). FN America LLC is located in an adjacent river basin but is near the Gills Creek headwaters. The US Army Fort Jackson base is immediately upstream from location C-017. Precoat Metals and CMC Steel are near the Congaree River upstream from the Gills Creek confluence. Westinghouse Nuclear Fuels is located near the Congaree River downstream from the Gills Creek confluence.

<u>FN America LLC at 797 Old Clemson Road in Columbia, South Carolina</u>

Total On- and Off-site Disposal or Other Releases: 6,726.5 lbs.

- Total On-site Disposal or Other Releases: 2.3 lbs.
- Total Off-site Disposal or Other Releases: 6,724.2 lbs.

<u>US Army Fort Jackson at 2563 Essayons Way in Fort Jackson, South Carolina</u>

Total On- and Off-site Disposal or Other Releases: 101,113.7 lbs.

- Total On-site Disposal or Other Releases: 101,113.7 lbs.
- Total Off-site Disposal or Other Releases: 0 lbs.

<u>Precoat Metals at 650 Rosewood Drive in Columbia, South Carolina</u>

Total On- and Off-site Disposal or Other Releases: 176 lbs.

- Total On-site Disposal or Other Releases: 0 lbs.
- Total Off-site Disposal or Other Releases: 176 lbs.

<u>CMC Steel SC at 310 New State Road in Cayce, South Carolina</u>

Total On- and Off-site Disposal or Other Releases: 7,225 lbs.

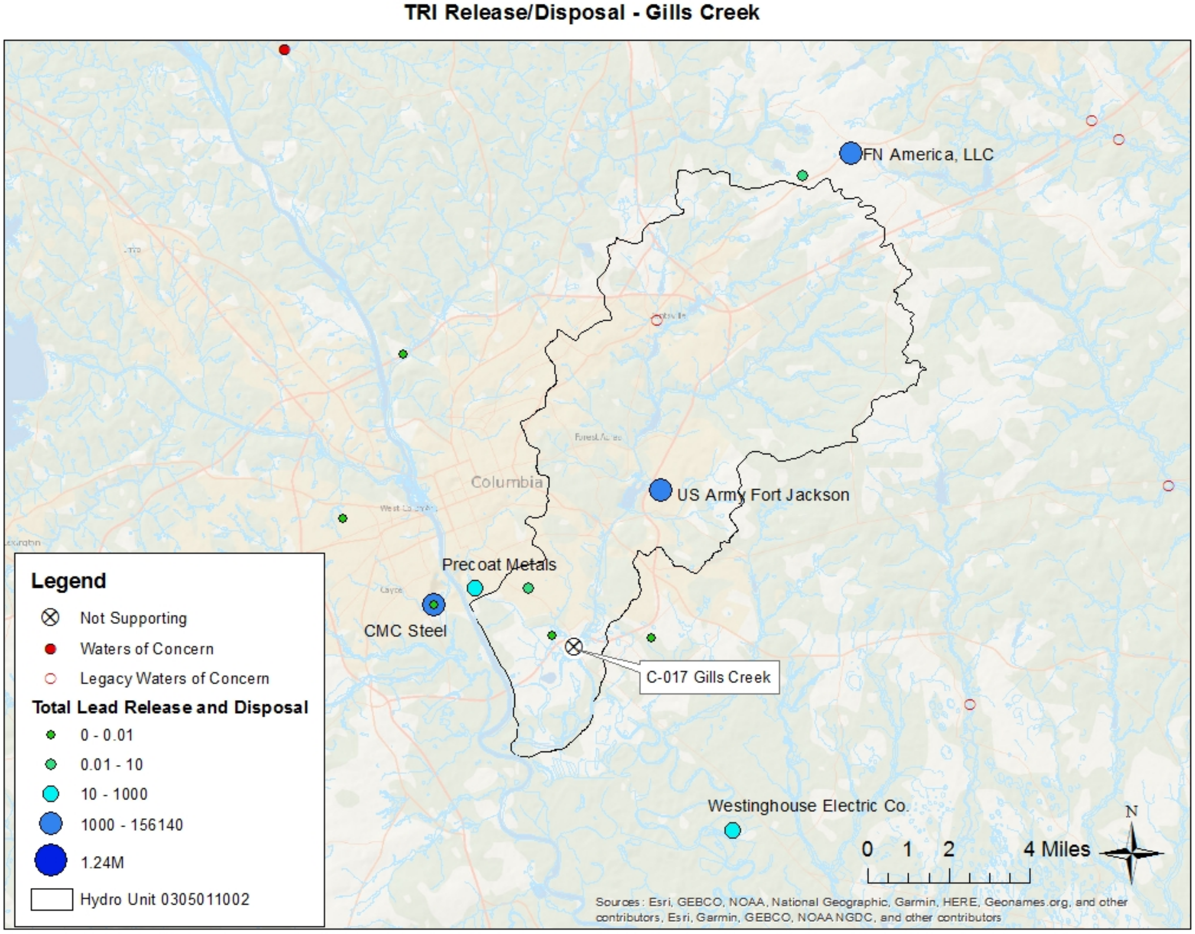
- Total On-site Disposal or Other Releases: 529 lbs.
- Total Off-site Disposal or Other Releases: 6,696 lbs.

<u>Westinghouse Electric Co. LLC at 5801 Bluff Road in Hopkins, South Carolina</u>

Total On- and Off-site Disposal or Other Releases: 280 lbs.

- Total On-site Disposal or Other Releases: 0 lbs.
- Total Off-site Disposal or Other Releases: 280 lbs.

Figure 24.



6.0 Path Forward

6.1 Three Listed Locations

In accordance with the CWA, when a waterbody is placed on the 303(d) List of Impaired Waters, states are required to develop a TMDL. A TMDL limits the amount of point source and nonpoint source pollution that a waterbody can receive so that it can meet applicable water quality standards. TMDLs calculate the pollutant reduction needed and serve as plans to restore the waterbody.

For the three (3) waterbodies identified as impaired due to exceedances of the chronic aquatic life criterion for lead, SCDHEC has prioritized two of these waters for TMDL development. NPDES point source discharges contributing to the impairment will be subject to the WLA reductions identified in the TMDL. Further, during the TMDL development process, SCDHEC will continue to investigate other potential sources identified in this report.

The TMDL development process for impaired waterbodies involves a public engagement process (this is required by TMDL regulations). This will provide the public and other interested parties an opportunity to review and comment on the findings of the TMDL investigations.

6.1.1 Lawsons Fork Creek at Spartanburg County Road 108 (BL-001)

The Department will continue quarterly sampling for lead, TSS and hardness at this location. The 2019 macroinvertebrate assessment indicated that this location was fully supporting of aquatic life. Upon the performance of another bioassessment during an upcoming assessment cycle and evaluation of additional lead sampling results, should those data show that the location is no longer fully supporting, a TMDL will be developed. If a TMDL be issued, the permittees listed below will be subject to the WLA identified in the TMDL.

NPDES Point Sources

The permitted point sources in the watershed (Tables 8 and 9) will be required to comply with the WLA identified as protective if a TMDL is developed.

NPDES MS4 Stormwater Discharges

- Much of the watershed that drains to BL-001 is covered by two (2) small (phase II) MS4 permits (City of Spartanburg and Spartanburg County). If a TMDL is established downstream of their discharges, small MS4 permittees are required to develop a TMDL Monitoring and Assessment Plan to measure pollutant levels discharges from their outfalls. They are also required to develop a plan to implement BMPs that target the WLA.

- SCDOT also manages a large, statewide MS4 within the watershed. If there is a TMDL applicable to their discharges, SCDOT must monitor for the pollutant of concern. SCDOT's current permit is expired and the Department will include provisions in the reissued permit to establish non-numeric effluent limitations necessary to address lead.

6.1.2 Camping Creek at Newberry County Road 202, Downstream from GA Pacific (S-290)

The Department will continue quarterly sampling for lead, TSS and hardness at this location. When a TMDL is issued, the permittee(s) listed below will be subject to the WLA identified in the TMDL.

NPDES MS4 Stormwater Discharges

Currently, the only permittee that would be subject to the WLA identified in the TMDL is SCDOT (NPDES SCS040001). As a statewide MS4 permittee, when there is a TMDL applicable to their discharges, SCDOT must monitor for the pollutant of concern. SCDOT's current MS4 permit is expired and the Department will include provisions in the reissued permit to establish non-numeric effluent limitations necessary to address lead.

6.1.3 C-017 Gills Creek at Bluff Road (SC 48) (C-017)

The Department will continue quarterly sampling for lead, TSS and hardness at this location. When a TMDL is issued, the permittees listed below will be subject to the WLA identified in the TMDL.

NPDES MS4 Stormwater Discharges

- Fort Jackson is a small MS4 (SCR030000) upstream of station C-017. In accordance with the small MS4 permit, when a there is a TMDL downstream from their outfalls, they are required to develop a TMDL Monitoring and Assessment Plan to measure pollutant levels discharged from their outfalls and to develop a plan to implement BMPs to target the WLA.
- There are two (2) medium MS4s (City of Columbia (SCS790001) and Richland County (SCS400001)): upstream from location C-017. Per these MS4 permits, when there is a TMDL downstream from their outfalls, the permitees are required to assess their contribution to the

impairment and evaluate management practices, incorporate structural and non-structural BMPs, control techniques, systems, and other provisions necessary to achieve the WLA.

- SCDOT (NPDES SCS040001) is a statewide MS4 permittee. When there is a TMDL applicable to their discharges, SCDOT must monitor for the pollutant of concern. SCDOT's current MS4 permit is expired and the Department will include provisions in the reissued permit to establish non-numeric effluent limitations necessary to address lead.

6.2 Waters of Concern

In calendar year 2019, TSS has been added to all routine ambient freshwater stream samples that include metals and will continue to be part of the parameter suite in the future. Hardness is already a part of the standard suite of parameters collected with metals samples in freshwaters.

The 88 LWOC, which do not have current data or were missing TSS results, are also being sampled quarterly for lead, TSS and hardness.

There was a total of 30 Lake LWOC sites on 21 different lakes in the State. Nineteen of these lakes have either active fixed monitoring locations (BASE sites) or have had additional statistical survey lake sites since the 2014 assessment cycle (years 2010 through 2012). All of the BASE sites and subsequent statistical survey sites show no current sites qualify as WOC with the exception of one (1) 2013 statistical survey site in Lake Wylie. Lake Wylie continues to have active fixed monitoring BASE locations and a more recent statistical survey site that do not show any standards exceedances since the 2016 assessment cycle.

There are three (3) small reservoirs, Bushy Park (also known as the Back River Reservoir), Lake George Warren and Lake Wallace, that do not have new data since the 2012 assessment cycle (years 2008 through 2010). All of these reservoirs will also have monitoring conducted quarterly for lead, TSS and hardness.

Once the 2019 data have been collected and assessed, it will become part of the dataset for the 2022 303(d) List which will rely on metals data for the three (3)-year assessment window from 2018 through 2020. At that time, the Department will determine whether these WOC need to be listed as impaired and, if so, whether they need to be prioritized for TMDL development.

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Annex 1 Cover Page

Annex 1 Key

SEQ	Sequence number for sorting back to original table order
LISTING CATEGORY	
LIST	List as Impaired based on both the 1984 and 1996 partioning coefficients
LIST_Error	Listed in Error based on 1984 partioning coefficients
WOC_2018	WOC from 2018 §303(d) Assessment Cycles based on both the 1984 and 1996 partioning coefficients
Legacy	WOC from pre-2018 §303(d) Assessment Cycles based on both the 1984 and 1996 partioning coefficients
STAT	Station Number
WBODY	S=Stream, L=Lake or Reservoir, SE=Transitional zone between freshwater and saltwater
DESCRIPT	Description of monitoring site location
STR_NAME	Waterbody Name
CNTY1	First County
CNTY2	Second County if site is on County boundary
CLASS1	First Classification of waterbody at monitoring site location
CLASS2	Second Classification of waterbody at monitoring site location if on boundary between different classifications
PREVCLASS	If Class 1 or 2 is ONRW or ORW, classification of the waterbody immediately prior to reclassification to either ORW or ONRW. Numeric and narrative criteria shall be those of that prior classification.
ECOREGION	Level three ecoregion
LONGITUDE	Longitude of monitoring site location
LATITUDE	Latitude of monitoring site location
HUC_12	12-digit Hydrologic Unit Code

Annex 1

SEQ	LISTING CATEGORY	STAT	WBODY	DESCRIPT	STR_NAME	CNTY1	CNTY2	CLASS1	CLASS2	PREVCLASS	ECOREGION	LONGITUDE	LATITUDE	HUC_12
1	LIST	BL-001	S	LAWSONS FORK CK AT S-42-108	LAWSONS FORK CREEK	SPARTANBURG		FW			PIEDMONT	-81.788548629	34.943700375	030501051402
2	LIST	C-017	S	GILLS CK AT SC 48 -BLUFF ROAD	GILLS CREEK	RICHLAND		FW			SOUTHEASTERN PLAINS	-80.98909610607	33.94813845467	030501100203
3	LIST	S-290	S	CAMPING CK S-36-202 BLW GA PACIFIC	CAMPING CREEK	NEWBERRY		FW			PIEDMONT	-81.48682553185	34.20035806242	030501091305
4	LIST_Error	RS-16312	S	CATTAIL BRANCH AT S-13-54 EVANS MILL ROAD	CATTAIL BRANCH	CHESTERFIELD		FW			SOUTHEASTERN PLAINS	-80.373413	34.74785	030402010602
5	WOC_2018	B-037	S	ENOREE RVR AT S-42-118 SW OF WOODRUFF	ENOREE RIVER	LAURENS	SPARTANBURG	FW			PIEDMONT	-82.06885135327	34.71886999847	030501080106
6	WOC_2018	B-042	S	BROAD RVR AT SC 18 4 MI NE GAFFNEY	BROAD RIVER	CHEROKEE		FW			PIEDMONT	-81.58750986343	35.12414660251	030501051601
7	WOC_2018	B-044	S	BROAD RVR AT SC 211 12 MI SE OF GAFFNEY	BROAD RIVER	CHEROKEE	YORK	FW			PIEDMONT	-81.47996528626	34.93753403462	030501051604
8	WOC_2018	B-046	S	BROAD RVR AT SC 72/215/121 3 MI E OF CARLISLE	BROAD RIVER	CHESTER	UNION	FW			PIEDMONT	-81.41997815791	34.59507898067	030501060305
9	WOC_2018	B-048	S	PACOLET RVR AT SC 105 6 MI AB JCT WITH BROAD RVR	PACOLET RIVER	CHEROKEE	UNION	FW			PIEDMONT	-81.53168277191	34.87366905789	030501051506
10	WOC_2018	B-053	S	ENOREE RVR AT SC 72; 121; and US 176; 1 MI NE WHITMIRE	ENOREE RIVER	NEWBERRY	UNION	FW			PIEDMONT	-81.59853609696	34.50901743088	030501080206
11	WOC_2018	B-057	S	BUFFALO CK AT SC 5 1 MI W OF BLACKSBURG	BUFFALO CREEK	CHEROKEE		FW			PIEDMONT	-81.55014979713	35.1264837918	030501050805
12	WOC_2018	B-062	S	THICKETTY CK AT SC 211 2 MI AB JCT WITH BROAD RVR	THICKETTY CREEK	CHEROKEE		FW			PIEDMONT	-81.49659931954	34.91463503752	030501051004
13	WOC_2018	B-075	S	SANDY RVR AT SC 215 2.5 MI AB JCT WITH BROAD RVR	SANDY RIVER	CHESTER		FW			PIEDMONT	-81.39275525162	34.59329389768	030501060205
14	WOC_2018	B-136	S	TURKEY CK AT SC 9; 14 MI NW OF CHESTER	TURKEY CREEK	CHESTER		FW			PIEDMONT	-81.43240119698	34.77631626459	030501060105
15	WOC_2018	B-159	S	BULLOCK CK AT SC 97 4.8 MI S OF HICKORY GROVE	BULLOCK CREEK	YORK		FW			PIEDMONT	-81.42144998898	34.91549601041	030501051103
16	WOC_2018	B-320	S	BIG CEDAR CK AT SC 215	BIG CEDAR CREEK	RICHLAND		FW			PIEDMONT	-81.11434536601	34.16219291924	030501060603
17	WOC_2018	B-333	S	KINGS CREEK AT S-11-209; 3 MI W OF SMYRNA	KINGS CREEK	CHEROKEE	YORK	FW			PIEDMONT	-81.47575692615	35.04310316276	030501050902
18	WOC_2018	BF-008	S	FAIRFOREST CK AT S-44-16 SW OF UNION	FAIRFOREST CREEK	UNION		FW			PIEDMONT	-81.66133123663	34.64936760015	030501070406
19	WOC_2018	CSTL-102	SE	ASHLEY RVR AT SC 165 4.8 MI SSW OF SUMMERVILLE	ASHLEY RIVER	DORCHESTER		FW	SA		MIDDLE ATLANTIC COASTAL PLAIN	-80.20099229717	32.95836877787	030502010602
20	WOC_2018	CW-014	S	CATAWBA RVR AT US 21	CATAWBA RIVER	YORK		FW			PIEDMONT	-80.97428059949	34.98578068154	030501030602
21	WOC_2018	CW-017	S	CANE CK AT S-29-50	CANE CREEK	LANCASTER		FW			PIEDMONT	-80.83739735892	34.69999272264	030501030305
22	WOC_2018	CW-036	S	SUGAR CREEK AT S-46-36	SUGAR CREEK	LANCASTER	YORK	FW			PIEDMONT	-80.86868032939	34.9507764167	030501030109
23	WOC_2018	CW-041	S	CATAWBA RVR AT SC 5 AB BOWATER	CATAWBA RIVER	LANCASTER	YORK	FW			PIEDMONT	-80.86663144659	34.85375180256	030501030604
24	WOC_2018	CW-072	S	BIG WATEREE CK AT US 21	BIG WATEREE CREEK	FAIRFIELD		FW			PIEDMONT	-80.93885873461	34.46825416369	030501040105
25	WOC_2018	CW-083	S	TWELVEMILE CK AT S-29-55 0.3 MI NW OF VAN WYCK	TWELVEMILE CREEK	LANCASTER		FW			PIEDMONT	-80.85219632038	34.85953120756	030501030204
26	WOC_2018	CW-233	S	FISHING CREEK AT S-12-77	FISHING CREEK	CHESTER		FW			PIEDMONT	-80.92784100391	34.63715722361	030501030410
27	WOC_2018	CW-236	S	ROCKY CK AT S-12-138	ROCKY CREEK	CHESTER		FW			PIEDMONT	-80.93143747808	34.56954212286	030501030505
28	WOC_2018	E-104	S	N FORK EDISTO RVR AT S-38-73	N FORK EDISTO RIVER	ORANGEBURG		FW			SOUTHEASTERN PLAINS	-81.03846568931	33.5765999745	030502030210
29	WOC_2018	MD-107	S	KINGSTON LK NR PUMP STA ON LAKESIDE DR CONWAY	LAKE, KINGSTON	HORRY		FW			MIDDLE ATLANTIC COASTAL PLAIN	-79.04583185583	33.83834315469	030402060803
30	WOC_2018	PD-009	S	LYNCHES RVR AT US 1	LYNCHES RIVER	CHESTERFIELD	KERSHAW	FW			SOUTHEASTERN PLAINS	-80.32161187695	34.42733213107	030402020307
31	WOC_2018	PD-066	S	LYNCHES RVR AT S-13-42	LYNCHES RIVER	CHESTERFIELD	KERSHAW	FW			SOUTHEASTERN PLAINS	-80.4041095123	34.60840334719	030402020305
32	WOC_2018	PD-251	S	BLACK CK AT US 1	BLACK CREEK	CHESTERFIELD		FW-SP			SOUTHEASTERN PLAINS	-80.18003432551	34.51668433272	030402010606
33	WOC_2018	PD-337	S	GREAT PEE DEE RVR AT US 301/76	PEE DEE RIVER	FLORENCE	MARION	FW			SOUTHEASTERN PLAINS	-79.54927014085	34.20357138569	030402011003
34	WOC_2018	PD-338	S	THOMPSON CK AT S-13-148 S OF CHERAW	THOMPSON CREEK	CHESTERFIELD		FW			SOUTHEASTERN PLAINS	-79.88526963585	34.65816464855	030402010411
35	WOC_2018	PD-344	S	LITTLE LYNCHES RIVER AT SC 341; 3.5 MI SE OF BETHUNE	LITTLE LYNCHES RIVER	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.31137166607	34.37145289409	030402020206
36	WOC_2018	PD-370	S	BRUNSON SWAMP AT S-26-99	BRUNSON SWAMP	HORRY		FW			MIDDLE ATLANTIC COASTAL PLAIN	-79.2426000316	33.9264082625	030402040702
37	WOC_2018	RS-14182	S	ZEKIAL CREEK AT SC 110	ZEKIAL CREEK	CHEROKEE		FW			PIEDMONT	-81.82121583	35.10406474	030501051503
38	WOC_2018	RS-14200	S	GILLS CREEK AT S-29-51; CAMP CREEK RD	GILLS CREEK	LANCASTER		FW			PIEDMONT	-80.72874035	34.73507612	IA
39	WOC_2018	RS-14210	S	FAIRFOREST CREEK AT S-44-279 GIST BRIDGE RD	FAIRFOREST CREEK	UNION		FW			PIEDMONT	-81.71179307	34.77157397	030501070405
40	WOC_2018	RS-14216	S	ROCKY CREEK AT SC 901; MOUNTAIN GAP RD	ROCKY CREEK	CHESTER		FW			PIEDMONT	-80.98291183	34.611979	030501030505
41	WOC_2018	RS-15256	S	LYNCHES RIVER AT S-13-823 WINTERTIDE DRIVE/S-13-823	LYNCHES RIVER	Chesterfield	Lancaster	FW			PIEDMONT	-80.475004	34.695632	030402020105
42	WOC_2018	RS-15284	S	CONRAD CREEK AT S-46-1273 HAWLEY ROAD	CONRAD CREEK	YORK		FW			PIEDMONT	-81.215529	34.838726	030501030404
43	WOC_2018	S-072	S	REEDY RVR ON HWY 418 AT FORK SHOALS	REEDY RIVER	GREENVILLE		FW			PIEDMONT	-82.29753152993	34.65271321647	030501090404
44	WOC_2018	S-319	S	REEDY RVR AT RIVERS ST; DOWNTOWN GREENVILLE	REEDY RIVER	GREENVILLE		FW			PIEDMONT	-82.40167687046	34.84489991256	030501090402
45	WOC_2018	ST-016	S	SANTEE RVR AT US 52 6.5 MI NNW OF ST STEPHENS	SANTEE RIVER	BERKELEY	WILLIAMSBURG	FW			MIDDLE ATLANTIC COASTAL PLAIN	-79.96111639535	33.49401928048	030501120106
46	WOC_2018	SV-004	S	CONEROSS CK AT SC 59	CONEROSS CREEK	OCONEE		FW			PIEDMONT	-82.97033183056	34.63661832575	030601010502
47	WOC_2018	SV-192	S	LITTLE RIVER AT S-33-19	LITTLE RIVER	MCCORMICK		FW			PIEDMONT	-82.46532348476	34.01368217022	030601030513
48	WOC_2018	SV-233	S	EIGHTEENMILE CK AT 2-04-279	EIGHTEENMILE CREEK	ANDERSON		FW			PIEDMONT	-82.80447250619	34.63478372625	030601010602
49	WOC_2018	SV-318	S	LONG CANE CK AT S-33-117 7.0 MI NW MCCORMICK	LONG CANE CREEK	MCCORMICK		FW			PIEDMONT	-82.35216303707	34.00041676773	030601030609
50	WOC_2018	SV-344	S	CHAUGA RIVER AT S-37-34	CHAUGA RIVER	OCONEE		FW			PIEDMONT	-83.16065155499	34.66372488669	030601020304
51	WOC_2018	SV-349	S	LONG CANE CREEK AT S-01-159	LONG CANE CREEK	ABBEVILLE		FW			PIEDMONT	-82.30373968	34.21771602699	030601030606
52	WOC_2018	SV-352	S	TURKEY CREEK AT S-33-227/S-19-68	TURKEY CREEK	EDGEFIELD	MCCORMICK	FW			PIEDMONT	-82.14426596193	33.79437322405	030601070208
53	WOC_2018	SV-354	S	STEVENS CREEK AT S-33-88/S-19-143	STEVENS CREEK	EDGEFIELD	MCCORMICK	FW			PIEDMONT	-82.14963668159	33.68862306395	030601070303
54	WOC_2018	SV-365	S	STEVENS CREEK AT S-33-138	STEVENS CREEK	MCCORMICK		FW			PIEDMONT	-82.19665808507	33.79139154006	030601070108
55	WOC_2018	SV-371	S	HORN CK AT S-19-143	HORN CREEK	EDGEFIELD		FW			PIEDMONT	-82.0737226148	33.651441235	030601070305
56	Legacy	CSTL-075	L	LAKE WARREN; BLACK CK ARM; AT S-25-41 5 MI SW OF HAMPTON	LAKE WARREN	HAMPTON		FW			MIDDLE ATLANTIC COASTAL PLAIN	-81.18030838487	32.82681229171	030502080102
57	Legacy	CSTL-124	L	BACK RIVER RES IN FOREBAY EQUIDISTANT FROM DAM AND SHORELINES	LAKE, BACK RIVER RESERVOIR	BERKELEY		FW			MIDDLE ATLANTIC COASTAL PLAIN	-79.93865300904	32.9673585458	030502010704
58	Legacy	CW-021	S	BIG PINE TREE CK AT US 521; NW BRIDGE	BIG PINE TREE CREEK	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.60497429562	34.2265373602	030501040302
59	Legacy	CW-082	S	SWIFT CK AT S-28-12	SWIFT CREEK	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.51027914912	34.17264599184	030501040305
60	Legacy	CW-154	S	KELLY CK AT S-28-367 2.9 MI SE OF ELGIN	KELLY CREEK	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.76605363857	34.13662214109	030501040401
61	Legacy	CW-155	S	SPEARS CK AT SC 12 3.6 MI SE OF ELGIN	SPEARS CREEK	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.75422565771	34.12962984002	030501040402
62	Legacy	CW-166	S	SPEARS CK AT US 601	SPEARS CREEK	KERSHAW		FW			SOUTHEASTERN PLAINS	-80.69075569083	34.12688226144	030501040402
63	Legacy	CW-237	S	GRANNIES QUARTER CK AT SC 97	GRANNIES QUARTER CREEK	KERSHAW		FW			PIEDMONT	-80.68551092785	34.34991270702	030501040202
64	Legacy	CW-243	S	BIG BRANCH AT S-14-41 -SC-047	BIG BRANCH	CLARENDON		FW			SOUTHEASTERN PLAINS	-80.42426766314	33.59749731137	030501110106
65	Legacy	CW-250	S	COLONELS CK AT SC 262	COLONELS CREEK	RICHLAND		FW			SOUTHEASTERN PLAINS	-80.73319386522	34.00541757631	030501040404
66	Legacy	E-014	S	EDISTO RVR AT US 15 S OF ST GEORGE	EDISTO RIVER	COLLETON	DORCHESTER	FW			MIDDLE ATLANTIC COASTAL PLAIN	-80.61295027845	33.06429444656	030502060108
67	Legacy	E-042	S	BULL SWAMP CK AT S-38-189	BULL SWAMP CREEK	ORANGEBURG		FW			SOUTHEASTERN PLAINS	-81.04178555695	33.60318167826	030502030208
68	Legacy	E-105	S	CAW CAW SWAMP AT S-38-1032 -1148?	CAW CAW SWAMP	ORANGEBURG		FW-SP			SOUTHEASTERN PLAINS	-80.8888204124	33.50519079897	030502030306
69	Legacy	MD-124	S	WACCAMAW RVR AT SC 9 7.0 MI W OF CHERRY GROVE	WACCAMAW RIVER	HORRY		FW-SP			MIDDLE ATLANTIC COASTAL PLAIN	-78.71450105039	33.91211246227	030402060704

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70	Legacy	PD-024A	S	BLACK CK AT US 401 and 52 6 MI NW DARLINGTON	BLACK CREEK	DARLINGTON		FW-SP	FW	SOUTHEASTERN PLAINS	-79.90363397336	34.3849166305	030402010709
71	Legacy	PD-027	S	BLACK CK AT S-16-35 5.5 MI SE DARLINGTON	BLACK CREEK	DARLINGTON		FW		SOUTHEASTERN PLAINS	-79.78645668568	34.27074444189	030402010709
72	Legacy	PD-029E	S	LITTLE PEE DEE RVR AT S-17-23	LITTLE PEE DEE RIVER	DILLON		FW		SOUTHEASTERN PLAINS	-79.39512282749	34.4873675468	030402040504
73	Legacy	PD-037	S	WHITE OAK CK AT S-34-31	WHITE OAK CREEK	MARION		FW-SP		SOUTHEASTERN PLAINS	-79.22254911755	34.17261491966	030402040803
74	Legacy	PD-060	S	PEE DEE RVR AT PETERS FIELD LANDING OFF S-22-36 US IP PUMP STATION	PEE DEE RIVER	GEORGETOWN	MARION	FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.24955325124	33.69888998318	030402070204
75	Legacy	PD-063	S	CROOKED CREEK AT SC 912	CROOKED CREEK	MARLBORO		FW		SOUTHEASTERN PLAINS	-79.77110417502	34.58595042078	030402010507
76	Legacy	PD-169	S	BIG SWP AT US 378 and SC 51 0.9 MI W OF SALEM	BIG SWAMP	FLORENCE		FW-SP		MIDDLE ATLANTIC COASTAL PLAIN	-79.52863282443	33.88766424955	030402020703
77	Legacy	PD-170	S	BLACK RVR AT SC 51 11.6 MI NE OF ANDREWS	BLACK RIVER	GEORGETOWN		FW-SP		MIDDLE ATLANTIC COASTAL PLAIN	-79.40106095627	33.54703008284	030402050906
78	Legacy	PD-191	S	WHITE CREEKS AT US 1	WHITES CREEK	MARLBORO		FW		SOUTHEASTERN PLAINS	-79.88312900571	34.75541885359	030402010502
79	Legacy	PD-345	S	LAKE SWAMP AT S-21-38	LAKE SWAMP	FLORENCE		FW-SP		MIDDLE ATLANTIC COASTAL PLAIN	-79.84136108572	34.02793605289	030402020406
80	Legacy	PD-355	S	SCAPE ORE SWAMP AT S-31-108	SCAPE ORE SWAMP	LEE		FW		SOUTHEASTERN PLAINS	-80.28068116753	34.10856188503	030402050105
81	Legacy	PD-363	S	SIMPSON CREEK AT SC 905	SIMPSON CREEK	HORRY		FW		MIDDLE ATLANTIC COASTAL PLAIN	-78.8123318413	33.91515212789	030402060705
82	Legacy	RL-09071	L	COVE OF LAKE MURRAY BETWEEN WISE FERRY ROAD AND BRADY PORTH ROAD 0.75 MILES SOUTH OF THE TIP OF BUNDRICK ISLAND. ON THE BUNDRICK ISLAND SIDE OF THE COVE JUST OFF THE WEST BANK.	LAKE MURRAY	LEXINGTON		FW		PIEDMONT	-81.3127672865	34.0284650565	030501091311
83	Legacy	RL-09084	L	SALUDA RIVER ARM OF LAKE MURRAY 1.2 MILES SOUTHEAST OF S-223 JUST BEFORE THE CONFLUENCE WITH THE LITTLE SALUDIA RIVER ARM.	LAKE MURRAY	NEWBERRY		FW		PIEDMONT	-81.5474140196	34.0943851202	030501091207
84	Legacy	RL-09085	L	J. ROBINSON LAKE 1.2 MILES SOUTHEAST FROM THE BRIDGE	LAKE J. ROBINSON	GREENVILLE		FW		PIEDMONT	-82.3098922262	35.0107359081	030501070301
85	Legacy	RL-09100	L	LAKE WALLACE 0.6 MILES NORTH OF THE SKI IMPOUNDMENT BOAT LANDING. SITE IS LOCATED ABOUT MID CHANNEL OF THE LAKE.	LAKE WALLACE	MARLBORO		FW		SOUTHEASTERN PLAINS	-79.6780450977	34.6426537788	030402010506
86	Legacy	RL-10001	L	LAKE GREENWOOD 1.9MI WSW OF JCT OF SC-39 AND SC-56	LAKE GREENWOOD	NEWBERRY	GREENWOOD	FW		PIEDMONT	-81.9178004077	34.1913450763	030501090808
87	Legacy	RL-10002	L	LAKE SECESSION 3.5MI WSW OF JCT OF SC-28 AND SC-284	LAKE SECESSION	ABBEVILLE		FW		PIEDMONT	-82.594509323	34.2806012835	030601030205
88	Legacy	RL-10004	L	LAKE RUSSELL 100M WNW OF SC END OF US 29 BRIDGE OVER LAKE RUSSELL	LAKE RUSSELL	ANDERSON		FW		PIEDMONT	-82.815910075	34.3548808763	030601030405
89	Legacy	RL-10006	L	LAKE RUSSELL 6MI WSW OF BROWN OAKS CHURCH AT JCT OF SC-81 AND S-01-900	LAKE RUSSELL	ABBEVILLE		FW		PIEDMONT	-82.7042294549	34.1432953452	030601030410
90	Legacy	RL-10009	L	LAKE MURRAY 5.75MI EAST OF NORTH END OF SC-391 BRIDGE OVER LAKE MURRAY	LAKE MURRAY	NEWBERRY	LEXINGTON	FW		PIEDMONT	-81.4679396155	34.092797312	030501091307
91	Legacy	RL-10010	L	LAKE MARION 0.65MI SSE OF SOUTHEAST END OF GREEN ISLAND	LAKE MARION	CLARENDON		FW		SOUTHEASTERN PLAINS	-80.2010905301	33.5049518258	030501110109
92	Legacy	RL-10012	L	LAKE WYLIE 1.15MI NE OF ENDING OF S-46-154 AT SOUTH POINT	LAKE WYLIE	YORK		FW		PIEDMONT	-81.0443190797	35.1067315507	030501011505
93	Legacy	RL-10013	L	LAKE; CLARKS HILL RESERVOIR 2.6MI NNW OF JCT OF US 221 AND SC-23	LAKE, CLARKS HILL RESERVOIR	MCCORMICK		FW		PIEDMONT	-82.2147131753	33.7678050939	030601030713
94	Legacy	RL-10014	L	LAKE MARION 2MI NORTH OF WEST END OF I-95 BRIDGE OVER LAKE MARION	LAKE MARION	ORANGEBURG	CLARENDON	FW		SOUTHEASTERN PLAINS	-80.456384461	33.530564316	030501110109
95	Legacy	RL-10015	L	LAKE BOWEN 2.65MI NE OF JCT OF US 26 AND SC-292	LAKE BOWEN	SPARTANBURG		FW		PIEDMONT	-82.024601303	35.1034841831	030501051302
96	Legacy	RL-10016	L	LAKE KEOWEE 1.25MI SE OF NEW HOPE CHURCH	LAKE KEOWEE	OCONEE		FW		PIEDMONT	-82.94035861	34.7532551273	030601010306
97	Legacy	RL-10017	L	LAKE GREENWOOD 2.95MI WSW OF LAURENS/NEWBERRY COUNTY LINE ON SC-39	LAKE GREENWOOD	LAURENS	GREENWOOD	FW		PIEDMONT	-81.9613053939	34.2212080871	030501090808
98	Legacy	RL-10018	L	LAKE SECESSION 4.75MI WSW OF JCT OF SC-28 AND SC-284	LAKE SECESSION	ABBEVILLE		FW		PIEDMONT	-82.6084560496	34.2626886073	030601030205
99	Legacy	RL-10101	L	LAKE; JUNIPER 1.4MI SSE OF JCT OF US 1 AND US 52	LAKE, JUNIPER	CHESTERFIELD		FW		SOUTHEASTERN PLAINS	-79.9014021362	34.6375237126	030402010410
100	Legacy	RL-10102	L	LAKE; CEDAR CK RESERVOIR 2.60MI SSE OF JCT OF US 21 AND SC-97 ON EAST SIDE OF GREAT FALL RESERVOIR	LAKE, CEDAR CREEK RESERVOIR	LANCASTER	CHESTER	FW		PIEDMONT	-80.870518041	34.5608118388	030501030606
101	Legacy	RL-10103	L	LAKE BLALOCK 450M ENE OF BUCK CREEK CHURCH	LAKE BLALOCK	SPARTANBURG		FW		PIEDMONT	-81.8800029606	35.0929425321	030501051501
102	Legacy	RL-10105	L	LAKE; BROADWAY 1.3MI SW OF JCT OF US 76 AND US 178	LAKE BROADWAY	ANDERSON		FW		PIEDMONT	-82.5933660041	34.4604174751	030601030202
103	Legacy	RL-10107	L	LAKE CUNNINGHAM 2.1MI NNE OF JCT OF SC-101 AND SC-290	LAKE CUNNINGHAM	GREENVILLE		FW		PIEDMONT	-82.2516693837	34.9769882064	030501070302
104	Legacy	RL-10109	L	LAKE RABON 3.75MI SE OF HICKORY TAVERN AT JCT OF US 76 AND SC-101	LAKE RABON	LAURENS		FW		PIEDMONT	-82.1395606151	34.4858916495	030501090502
105	Legacy	RL-10110	L	LAKE COOLEY 2.75MI SSW OF JCT OF US 176 AND SC-292	LAKE COOLEY	SPARTANBURG		FW		PIEDMONT	-82.1034201009	35.0030523225	030501070201
106	Legacy	RL-11113	L	LAKE RABON NEAR NORTH RABON CREEK INFLOW	LAKE RABON	LAURENS		FW		PIEDMONT	-82.1338208506	34.5181462055	030501090502
107	Legacy	RL-11117	L	GREAT FALLS RESERVOIR 40 YARDS FROM DAM AND 70 YARDS WEST OF SHORE OF POINT	GREAT FALL RESERVOIR	CHESTER		FW		PIEDMONT	-80.8911178735	34.5595890969	030501030606
108	Legacy	RL-11119	L	GREAT FALLS RESERVOIR 1.0 MILES SOUTH OF SC 97 IN THE MIDDLE OF THE RESERVOIR.	GREAT FALL RESERVOIR	CHESTER		FW		PIEDMONT	-80.8907775355	34.5825478908	030501030606
109	Legacy	RL-13088	L	TORRENCE BRANCH ARM OF LAKE WYLIE EVEN WITH CUL-DE-SAC AT END OF WTER TRACE DR	LAKE WYLIE	YORK		FW		SOUTHERN COASTAL PLAIN	-81.023349996	35.0510533378	030501011508
110	Legacy	RS-01021	S	MACK BRANCH AT SC 6; 5.5 M W OF ST MATHEWS	MACK BRANCH	CALHOUN		FW		SOUTHEASTERN PLAINS	-80.8887452	33.6719164	030502030305
111	Legacy	RS-04377	S	PEE DEE RIVER AT PORTS HILL LANDING AT THE END OF CO RD S-22-753 9.5 MI SE OF HEMINGWAY SAMPLE SHOULD BE COLLECTED AS FAR OUT IN THE RIVER AS POSSIBLE	PEE DEE RIVER	GEORGETOWN	MARION	FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.28706974	33.71754096	030402070204
112	Legacy	RS-04544	S	UNNAMED TRIBUTARY TO THE SAVANNAH RIVER AT RIVER BLUFF RD IN THE RAPIDS S/D IN NORTH AUGUSTA. SAMPLE AT THE END OF SERVICE RD FOR TELEPHONE LINES. SEND MORE DETAILED DIRECTIONS TO DISTRICT.	UNNAMED TRIBUTARYUTARYUTARY TO SAVANNAH RIVER	AIKEN		FW		PIEDMONT	-81.99088995	33.51610045	030601060601

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113	Legacy	RS-06007	S	SOUTH FORK DUNCAN CREEK AT GRAVEL RD -LITTLE N CAROLINA RD- NEXT TO SEABOARD COAST LINE RR ENTER LITTLE N CAROLINA RD FROM SC 72 11.8 MI E OF CLINTON 3.5 MI W OF WHITMIRE	SOUTH FORK DUNCAN CREEK	LAURENS		FW		PIEDMONT	-81.6747672674	34.4932461782	030501080302
114	Legacy	RS-06157	S	PEE DEE RIVER AT PORTS HILL LANDING AT THE END OF PORTS HILL RD S-22-753 9.5 MI SE OF HEMINGWAY SAMPLE SHOULD BE COLLECTED AS FAR OUT IN THE RIVER AS POSSIBLE	PEE DEE RIVER	GEORGETOWN		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.2870785426	33.7174953862	030402070204
115	Legacy	RS-09114	S	LICK CK AT BRIDGE ON S-41-189	LICK CREEK	SALUDA		FW		PIEDMONT	-81.55999656	33.99692847	030501091003
116	Legacy	RS-09284	S	BRUSHY CK AT BRIDGE ON S-42-194	BRUSHY CREEK	SPARTANBURG		FW		PIEDMONT	-82.0792446857	34.8531759769	030501070305
117	Legacy	RS-09286	S	VALL BRANCH AT BRIDGE ON SC 28	VALL BRANCH	MCCORMICK		FW		PIEDMONT	-82.3619666808	33.9401760077	030601030711
118	Legacy	RS-09304	S	CULVERT OVER FALL CREEK AT S-23-17	FALL CREEK	GREENVILLE		ORW	FW	BLUE RIDGE	-82.394492877	35.1929515375	030501090101
119	Legacy	RS-09312	S	CEDAR CREEK AT BRIDGE ON S-40-2561 NEAR BEULAH CHURCH AND GATE TO MCINTYRE AIRBASE; ROAD NOT ON COUNTY MAP	CEDAR CREEK	RICHLAND		FW		SOUTHEASTERN PLAINS	-80.8190737342	33.927223408	030501100306
120	Legacy	RS-09316	S	CHINQUAPIN CK AT BRIDGE ON GARNER RD NEAR N PINE ST	CHINQUAPIN CREEK	SPARTANBURG		FW		PIEDMONT	-81.9308142332	34.9654687696	030501051402
121	Legacy	RS-09322	S	HENLEY CREEK AT BRIDGE ON SC 248	HENLEY CREEK	GREENWOOD		FW		PIEDMONT	-82.0252070304	34.1382689089	030501090703
122	Legacy	RS-09323	S	LIGHTWOOD KNOT BRANCH AT TRENHOLM RD EXTENSION	LIGHTWOOD KNOT BRANCH	RICHLAND		FW		SOUTHEASTERN PLAINS	-80.9535666706	34.0652509361	030501100201
123	Legacy	RS-10331	S	HODGES BRANCH AT S-12-354	HODGES BRANCH	CHESTER		FW		PIEDMONT	-80.94118196	34.56548693	030501030505
124	Legacy	RS-10334	S	UNNAMED TRIB TO UNNAMED TRIB TO EDISTO RVR AT S-38-63	UNNAMED TRIBUTARYUTARY	ORANGEBURG		FW		MIDDLE ATLANTIC COASTAL PLAIN	-80.8740187	33.27286893	030502060103
125	Legacy	RS-10336	S	BULLOCK CK AT S-46-889. THIS IS THE SECOND BRIDGE COMING FROM S-46-1052	BULLOCK CREEK	YORK		FW		PIEDMONT	-81.31176514	35.07396684	030501051102
126	Legacy	RS-10339	S	WEIR CK AT S-20-90	WEIR CREEK	FAIRFIELD		FW		PIEDMONT	-81.27838922	34.54483573	030501060503
127	Legacy	RS-10341	S	FOUR HOLE SWAMP AT S-09-90	FOUR HOLE SWAMP	CALHOUN		FW-SP		SOUTHEASTERN PLAINS	-80.70055589	33.53828245	030502050102
128	Legacy	RS-10348	S	ALEXANDER CK AT SC HWY 11	ALEXANDER CREEK	SPARTANBURG		FW		PIEDMONT	-82.12213602	35.12867096	030501051302
129	Legacy	RS-10349	S	LANES CK AT SC 51 JUST NORTH OF OATLAND	LANES CREEK	GEORGETOWN		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.37189201	33.50675856	030402050909
130	Legacy	RS-10356	S	UNNAMED TRIB TO BLACK CK AT S-15-193	UNNAMED TRIBUTARYUTARYUTARY	COLLETON		FW		MIDDLE ATLANTIC COASTAL PLAIN	-80.771898	32.82759439	030502070701
131	Legacy	RS-10361	S	LITTLE FORK CK AT DIRT RD -S-13-151- OFF OF S-13-39. -DREW BAKER RD ACCORDING TO MAP NOT AT STOP SIGN	LITTLE FORK CREEK	CHESTERFIELD		FW		PIEDMONT	-80.42054854	34.67350849	030402020301
132	Legacy	RS-10365	S	PEE DEE RVR AT DE WITT BLUFF LANDING	PEE DEE RIVER	FLORENCE		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.51803544	33.99546799	030402011201
133	Legacy	RS-10373	S	BIG BRANCH AT S-18-378	BIG BRANCH	DORCHESTER		FW		MIDDLE ATLANTIC COASTAL PLAIN	-80.49239822	33.21147264	030502060204
134	Legacy	RS-10375	S	BRUSHY CK AT S-23-1973 -DRY POCKET RD	BRUSHY CREEK	GREENVILLE		FW		PIEDMONT	-82.25083695	34.86314808	030501080102
135	Legacy	RS-10377	S	INDIAN CK AT SCOTCH ROAD JUST OFF OF SC 102	INDIAN CREEK	CHESTERFIELD		FW		SOUTHEASTERN PLAINS	-80.0850477	34.72902306	030402010408
136	Legacy	RS-10380	S	UNNAMED TRIB TO MOTLOW CK AT S-42-869	UNNAMED TRIBUTARYUTARY	SPARTANBURG		FW		PIEDMONT	-82.19276502	35.08109612	030501051301
137	Legacy	RS-10381	S	KINGSTREE SWAMP AT S-21-514	KINGSTREE SWAMP CANAL	FLORENCE		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.89732411	33.91970229	030402050702
138	Legacy	RS-10387	S	KERR CK AT S-36-436	KERR CREEK	NEWBERRY		FW		PIEDMONT	-81.50525206	34.24492598	030501060405
139	Legacy	RS-10389	S	BROWN SWAMP AT US 701	BROWN SWAMP	HORRY		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.04900121	33.87649706	030402060803
140	Legacy	RS-10394	S	PAYNE BRANCH AT S-23-451	PAYNE BRANCH	GREENVILLE		FW		PIEDMONT	-82.22496029	34.63610724	030501090501
141	Legacy	RS-10397	S	LONG BRANCH AT CULVERT AT MOULDS RD. THIS CULVERT IS AT THE END OF PAVEMENT COMING FROM BEULAH RD	LONG BRANCH	WILLIAMSBURG	FLORENCE	FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.73234748	33.82064766	030402020602
142	Legacy	RS-10402	S	CLEAR CK AT S-01-163	CLEAR CREEK	ABBEVILLE		FW		PIEDMONT	-82.53461211	34.11089257	030601030508
143	Legacy	RS-10403	S	CEDAR SHOALS CK AT S-42-204	CEDAR SHOALS CREEK	SPARTANBURG		FW		PIEDMONT	-81.89507159	34.64765639	030501080203
144	Legacy	RS-10408	S	BUCKHEAD CK AT SC-419	BUCKHEAD CREEK	CALHOUN		FW		SOUTHEASTERN PLAINS	-80.69154815	33.73596339	030501100402
145	Legacy	RS-10410	S	SALKEHATCHIE RVR AT SC-641	SALKEHATCHIE RIVER	BAMBERG	ALLENDALE	FW		MIDDLE ATLANTIC COASTAL PLAIN	-81.0975352184	33.0456811745	030502070603
146	Legacy	RS-11002	S	MILL CREEK AT CULVERT ON OLD OLD HWY 11 ROAD -SIDE ROAD OFF CURRENT SC 11-; 3.75 MI N OF MARIETTA	MILL CREEK	GREENVILLE		FW		BLUE RIDGE	-82.5134224205	35.0732147281	030501090203
147	Legacy	RS-11004	S	GOODMANS CREEK AT US 52; BEST ON DOWNSTREAM SIDE; 3.8 MI NW OF CHERAW	GOODMANS CREEK	CHESTERFIELD		FW		SOUTHEASTERN PLAINS	-79.933433846	34.7351494546	030402010501
148	Legacy	RS-11005	S	CUFFYTOWN CREEK AT SC 67; 10.2 MI ENE OF MCCORMICK	CUFFYTOWN CREEK	MCCORMICK		FW		PIEDMONT	-82.1272140413	33.9640980341	030601070106
149	Legacy	RS-11009	S	TWELVEMILE CREEK AT S-39-267; 3.5 MI SW OF PICKENS	TWELVEMILE CREEK	PICKENS		FW		PIEDMONT	-82.7457193041	34.8428887608	030601010407
150	Legacy	RS-11018	S	ENOREE RIVER AT S-30-112 -BEAVERDAM CREEK RD- 1 LANE GIRDER BRIDGE; 0.3 MI W OF US 221	ENOREE RIVER	LAURENS	SPARTANBURG	FW		PIEDMONT	-81.969952574	34.6555343789	030501080106
151	Legacy	RS-11034	S	TYGER RIVER AT S-42-113; 8.3 MI E OF WOODRUFF	TYGER RIVER	SPARTANBURG		FW		PIEDMONT	-81.8903812873	34.7344402816	030501070503
152	Legacy	RS-11039	S	UNNAMED TRIB TO THE PEE DEE RIVER AT US 701; 0.6 MI NE OF YAUHANNAH	UNNAMED TRIBUTARYUTARYUTARY TO PEE DEE	GEORGETOWN		FW		MIDDLE ATLANTIC COASTAL PLAIN	-79.1824551722	33.6372209828	030402070206
153	Legacy	RS-11041	S	CRIMS CREEK AT BRIDGE AT S-36-170; 2.7 MI E OF POMARIA	CRIMS CREEK	NEWBERRY		FW		PIEDMONT	-81.3685574027	34.2624817863	030501060701
154	Legacy	RS-11045	S	BEAVERDAM CREEK AT LONG ROAD S-04-18; OFF SC 81; 8.1 MI NE OF ANDERSON	BEAVERDAM CREEK	ANDERSON		FW		PIEDMONT	-82.5866094891	34.6074165861	030601030201
155	Legacy	RS-11050	S	NELLS BRANCH AT S-11-44; 9.1 MI ESE OF GAFFNEY	NELLS BRANCH	CHEROKEE		FW		PIEDMONT	-81.4903588603	35.0528511773	030501050902
156	Legacy	RS-11053	S	WILSON CREEK AT OLD BRIDGE ON S-04-30 -FRED BRADFORD RD- WHICH IS BETWEEN SC 81 AND S-04-668 AND SOUTH OF S-04-156; 2.1 MI SE OF STARR	WILSON CREEK	ANDERSON		FW		PIEDMONT	-82.6644592256	34.3614215151	030601030206
157	Legacy	RS-11054	S	CORONACA CREEK AT S-24-39; 5.1 MI NNE OF GREENWOOD	CORONACA CREEK	GREENWOOD		FW		PIEDMONT	-82.1407016196	34.2643737468	030501090701
158	Legacy	RS-11056	S	FISHING CK AT S-46-1172; 4.7 MI SE OF YORK	FISHING CREEK	YORK		FW		PIEDMONT	-81.1748971616	34.9545953455	030501030402
159	Legacy	RS-13114	S	BRIDGE OVER MORRIS BRANCH AT S-44-163 -DEEP WATER ROAD	MORRIS BRANCH	Union		FW		PIEDMONT	-81.6284344645	34.6391278034	030501070406
160	Legacy	RS-13136	S	BRIDGE OVER CROWDERS CREEK AT S-46-152 -RIDDLE MILL ROAD	CROWDERS CREEK	York		FW		PIEDMONT	-81.1204535329	35.1244001313	030501011505
161	Legacy	RS-13144	S	BRIDGE AT SC HWY 97 OVER CEDAR CREEK -CEDAR CREEK ROAD	CEDAR CREEK	Lancaster		FW		PIEDMONT	-80.8393364643	34.5373161807	030501040101
162	Legacy	RS-13146	S	SUGAR CREEK AT S-44-223 -BOGAN RD- BRIDGE	SUGAR CREEK	Union		FW		PIEDMONT	-81.7934545988	34.7536380806	030501070404
163	Legacy	RS-13152	S	DAIRY BRANCH AT DEER BRANCH RD OFF US 21	DAIRY BRANCH	Chester		FW		PIEDMONT	-80.9194360486	34.6469457074	030501030410

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164	Legacy	RS-13162	S	GILKEY CREEK AT S-11-92 -BRIDGE HOUSE RD	GILKEY CREEK	Cherokee	FW	PIEDMONT	-81.5898666114	34.9927805526	030501051003
165	Legacy	RS-13168	S	SIXMILE CREEK AT S-29-126 -COLLINS ROAD	SIXMILE CREEK	Lancaster	FW	PIEDMONT	-80.8432179651	34.9594970876	030501030203
166	Legacy	S-013	S	REEDY RVR AT S-23-30 3.9 MI SE GREENVILLE	REEDY RIVER	GREENVILLE	FW	PIEDMONT	-82.36454392095	34.79931621846	030501090402
167	Legacy	S-178	S	HUFF CK AT SC 418 1.6 MI NW FORK SHOALS	HUFF CREEK	GREENVILLE	FW	PIEDMONT	-82.3202773591	34.64386669497	030501090403
168	Legacy	S-304	S	BROAD MOUTH CK AT S-01-111	BROAD MOUTH CREEK	ABBEVILLE	FW	PIEDMONT	-82.31774047671	34.4560625348	030501090802
169	Legacy	S-323	S	REEDY RVR AT S-23-316 3.5 MI SSW OF MAULDIN	REEDY RIVER	GREENVILLE	FW	PIEDMONT	-82.3254037736	34.72684910821	030501090404
170	Legacy	SV-072	S	HORSE CK AT S-02-145	HORSE CREEK	AIKEN	FW	SOUTHEASTERN PLAINS	-81.89616937842	33.48552047506	030601060205
171	Legacy	SV-230	S	EASTATOE CREEK AT S-39-143	EASTATOE CREEK	PICKENS	TPGT	BLUE RIDGE	-82.8531903584	34.95812944847	030601010202
172	Legacy	SV-348	S	LITTLE RIVER AT S-01-32	LITTLE RIVER	ABBEVILLE	FW	PIEDMONT	-82.4953971793	34.16707309212	030601030512
173	Legacy	SV-362	S	TWELVE MILE CK AT S-39-137	TWELVE MILE CREEK	PICKENS	FW	PIEDMONT	-82.74991378808	34.80114432272	030601010407

Annex 2 Cover Page

Annex 2 Key

SEQ	Sequence number for sorting back to original table order
LISTING CATEGORY	
LIST	List as Impaired based on both the 1984 and 1996 partioning coefficients
LIST_Error	Listed in Error based on 1984 partioning coefficients
WOC_2018	WOC from 2018 §303(d) Assessment Cycles based on both the 1984 and 1996 partioning coefficients
Legacy	WOC from pre-2018 §303(d) Assessment Cycles based on both the 1984 and 1996 partioning coefficients
STAT	Station Number
N	Total number of Lead Results
N_EXC_NEW	Number of Lead Results that Exceed the criterion based on the 1996 partioning coefficients
N_EXC_OLD	Number of Lead Results that Exceed the criterion based on the 1984 partioning coefficients
N_LT_RL	Number of Lead Results below Reporting Limit
MIN	Minimum Lead Result (µg/L)
MAX	Maximum Lead Result (µg/L)
CYCLE	§303(d) Assessment Cycle resulting in WOC designation or listing as Impaired
NEW	Assessment Conclusion based on the 1996 partioning coefficients
OLD	Assessment Conclusion based on the 1984 partioning coefficients
COMPARE	Comparison of Assessment Conclusions between the 2 partitioning coefficient assessments
WBODY	S=Stream, L=Lake or Reservoir, SE=Transitional zone between freshwater and saltwater
PB RANGE	Range of Lead Results greater than reporting limit (µg/L)
TSS RANGE	Range of TSS Results greater than reporting limit (mg/L)
HARD RANGE	Range of Hardness Results greater than reporting limit (mg/L)

Annex 2

SEQ	LISTING CATEGORY	STAT	N	N_EXC_NEW	N_EXC_OLD	N_LT_RL	MIN	MAX	CYCLE	NEW	OLD	COMPARE	WBODY	PB RANGE	TSS RANGE	HARD RANGE
1	LIST	BL-001	12	3	2	8	0	12	2018	List	WOC	Different	S	2.2-12	4.6-230	12-21
2	LIST	C-017	12	3	10	2	0	3.4	2018	List	List	Equal	S	2.1-3.4	3.6-13	10-17
3	LIST	S-290	4	3	3	1	0	12	2012	List	List	Equal	S	5.2-12	2.6-31	36-56
4	LIST_Error	RS-16312	6	0	2	2	0	3.2	2018	F	List	Different	S	2.2-3.2	4.9-39	16-56
5	WOC_2018	B-037	4	2	2	2	0	5	2018	WOC	WOC	Equal	S	2.8-5	All Missing	16-16
6	WOC_2018	B-042	12	2	2	10	0	14	2018	WOC	WOC	Equal	S	9.6-14	2.8-15	11-16
7	WOC_2018	B-044	11	3	3	8	0	11	2018	WOC	WOC	Equal	S	3.1-11	3.1-13	15-19
8	WOC_2018	B-046	12	4	3	7	0	36	2018	WOC	WOC	Equal	S	2.2-36	3.7-140	15-36
9	WOC_2018	B-048	12	1	2	10	0	20	2018	F	WOC	Different	S	2.1-20	12-32	13-41
10	WOC_2018	B-053	15	2	2	13	0	5.8	2018	WOC	WOC	Equal	S	2.7-5.8	7.1-50	18-33
11	WOC_2018	B-057	10	2	1	7	0	5.4	2018	WOC	F	Different	S	2.6-5.4	5.6-160	18-26
12	WOC_2018	B-062	11	3	3	8	0	21	2018	WOC	WOC	Equal	S	2.5-21	4-13	16-34
13	WOC_2018	B-075	9	4	4	5	0	23	2018	WOC	WOC	Equal	S	3.5-23	7.1-9.2	23-48
14	WOC_2018	B-136	9	3	3	5	0	6.3	2018	WOC	WOC	Equal	S	2.5-6.3	170-170	21-35
15	WOC_2018	B-159	11	2	2	9	0	8.2	2018	WOC	WOC	Equal	S	5.6-8.2	2-13	21-36
16	WOC_2018	B-320	12	2	2	10	0	2.8	2018	WOC	WOC	Equal	S	2.6-2.8	1.7-4	18-24
17	WOC_2018	B-333	9	2	2	7	0	14	2018	WOC	WOC	Equal	S	5-14	35-35	29-49
18	WOC_2018	BF-008	12	3	4	8	0	21	2018	WOC	WOC	Equal	S	3.2-21	2.9-16	16-40
19	WOC_2018	CSTL-102	9	2	3	6	0	6.4	2018	WOC	WOC	Equal	SE	2.1-6.4	All Missing	All Missing
20	WOC_2018	CW-014	10	2	2	8	0	21	2018	WOC	WOC	Equal	S	6.3-21	4.9-15	18-27
21	WOC_2018	CW-017	11	4	5	6	0	16	2018	WOC	WOC	Equal	S	2.7-16	2.6-22	23-44
22	WOC_2018	CW-036	10	3	5	3	0	8.2	2018	WOC	WOC	Equal	S	2.1-8.2	117-250	55-94
23	WOC_2018	CW-041	8	3	3	4	0	45	2018	WOC	WOC	Equal	S	2.7-45	6.3-69	29-34
24	WOC_2018	CW-072	11	2	2	9	0	2.4	2018	WOC	WOC	Equal	S	2.2-2.4	16.6-43	31-63
25	WOC_2018	CW-083	10	2	3	6	0	12	2018	WOC	WOC	Equal	S	2.1-12	3.8-200	34-55
26	WOC_2018	CW-233	9	2	2	7	0	4.2	2018	WOC	WOC	Equal	S	2.8-4.2	11.1-11.1	34-47
27	WOC_2018	CW-236	11	2	2	9	0	2.6	2018	WOC	WOC	Equal	S	2.5-2.6	16-16	27-50
28	WOC_2018	E-104	12	2	2	10	0	4.8	2018	WOC	WOC	Equal	S	2.3-4.8	All Missing	4.9-10
29	WOC_2018	MD-107	11	1	2	9	0	8.9	2018	F	WOC	Different	S	2-8.9	4.3-4.6	27-68
30	WOC_2018	PD-009	16	7	7	8	0	19	2018	WOC	WOC	Equal	S	2.2-19	7.4-66	13-16
31	WOC_2018	PD-066	12	4	5	7	0	470	2018	WOC	WOC	Equal	S	2.2-470	3.4-30	18-80
32	WOC_2018	PD-251	11	4	4	7	0	18	2018	WOC	WOC	Equal	S	5.7-18	5.4-8.7	2.6-4.6
33	WOC_2018	PD-337	12	2	3	9	0	4.6	2018	WOC	WOC	Equal	S	2.1-4.6	17-17	18-25
34	WOC_2018	PD-338	10	4	4	6	0	30	2018	WOC	WOC	Equal	S	2.9-30	14.3-65	6.8-11
35	WOC_2018	PD-344	12	5	5	7	0	37	2018	WOC	WOC	Equal	S	2.8-37	6-22	5.6-6.6
36	WOC_2018	PD-370	12	2	2	9	0	7	2018	WOC	WOC	Equal	S	2.6-7	6.3-42	23-81
37	WOC_2018	RS-14182	6	3	3	3	0	20	2018	WOC	WOC	Equal	S	2.8-20	All Missing	All Missing
38	WOC_2018	RS-14200	5	4	4	1	0	19	2018	WOC	WOC	Equal	S	6.5-19	All Missing	All Missing
39	WOC_2018	RS-14210	8	5	5	3	0	23	2018	WOC	WOC	Equal	S	3.3-23	All Missing	All Missing
40	WOC_2018	RS-14216	5	3	3	2	0	9.9	2018	WOC	WOC	Equal	S	3.2-9.9	All Missing	All Missing
41	WOC_2018	RS-15256	12	3	3	9	0	3.3	2018	WOC	WOC	Equal	S	2.7-3.3	All Missing	25-48
42	WOC_2018	RS-15284	6	1	2	4	0	2.4	2018	F	WOC	Different	S	2.1-2.4	All Missing	32-33
43	WOC_2018	S-072	11	2	2	9	0	3.2	2018	WOC	WOC	Equal	S	2.2-3.2	3.1-6.6	32-56
44	WOC_2018	S-319	12	2	1	10	0	5.2	2018	WOC	F	Different	S	3.3-5.2	4-62	12-20
45	WOC_2018	ST-016	11	2	2	9	0	3	2018	WOC	WOC	Equal	S	2.8-3	3.4-4.8	15-90
46	WOC_2018	SV-004	11	3	4	7	0	6.1	2018	WOC	WOC	Equal	S	2-6.1	9-12	11-16
47	WOC_2018	SV-192	12	3	3	9	0	4.9	2018	WOC	WOC	Equal	S	2.6-4.9	4.8-16	14-24
48	WOC_2018	SV-233	12	2	2	10	0	4.3	2018	WOC	WOC	Equal	S	3.9-4.3	8.9-58	11-19
49	WOC_2018	SV-318	12	2	2	10	0	4.9	2018	WOC	WOC	Equal	S	4.1-4.9	4.4-39	18-44
50	WOC_2018	SV-344	11	2	2	9	0	3.5	2018	WOC	WOC	Equal	S	2.8-3.5	1-4.3	6.5-8.6
51	WOC_2018	SV-349	4	2	2	2	0	13	2018	WOC	WOC	Equal	S	3-13	All Missing	23-43
52	WOC_2018	SV-352	12	8	8	4	0	150	2018	WOC	WOC	Equal	S	2.3-150	6.2-15	20-42
53	WOC_2018	SV-354	10	5	5	5	0	330	2018	WOC	WOC	Equal	S	2.3-330	4.2-4.2	22-46
54	WOC_2018	SV-365	12	2	3	9	0	4.6	2018	WOC	WOC	Equal	S	2.7-4.6	2.8-5	26-56
55	WOC_2018	SV-371	12	2	2	10	0	5.8	2018	WOC	WOC	Equal	S	2.2-5.8	2.6-6.4	15-24
56	Legacy	CSTL-075	8	2	2	6	0	2.9	2012	WOC	WOC	Equal	L	2.7-2.9	All Missing	23-28
57	Legacy	CSTL-124	8	2	2	6	0	3.5	2012	WOC	WOC	Equal	L	2.4-3.5	All Missing	23-27
58	Legacy	CW-021	8	3	3	5	0	4.4	2012	WOC	WOC	Equal	S	3.3-4.4	All Missing	1-8.1
59	Legacy	CW-082	6	2	2	4	0	4.1	2012	WOC	WOC	Equal	S	3.6-4.1	All Missing	4.9-7.4
60	Legacy	CW-154	4	3	3	1	0	4.4	2012	WOC	WOC	Equal	S	3.2-4.4	All Missing	4.7-6.6
61	Legacy	CW-155	4	3	3	1	0	7	2012	WOC	WOC	Equal	S	3.2-7	All Missing	5.5-7.7
62	Legacy	CW-166	8	3	3	5	0	3	2012	WOC	WOC	Equal	S	2.2-3	All Missing	1-12
63	Legacy	CW-237	8	3	3	5	0	9.5	2012	WOC	WOC	Equal	S	4.7-9.5	All Missing	1-15
64	Legacy	CW-243	7	2	2	5	0	4.8	2012	WOC	WOC	Equal	S	2.7-4.8	All Missing	12-24
65	Legacy	CW-250	8	2	2	6	0	93	2012	WOC	WOC	Equal	S	4.3-93	All Missing	1.9-3.2
66	Legacy	E-014	7	3	3	4	0	4.6	2014	WOC	WOC	Equal	S	2.3-4.6	All Missing	16-16
67	Legacy	E-042	8	2	2	6	0	3	2012	WOC	WOC	Equal	S	2.9-3	5.5-5.5	5.1-6.1
68	Legacy	E-105	8	3	3	5	0	5	2012	WOC	WOC	Equal	S	2.2-5	3.7-3.7	21-22
69	Legacy	MD-124	4	2	2	2	0	5	2012	WOC	WOC	Equal	S	3-5	All Missing	All Missing
70	Legacy	PD-024A	8	3	3	5	0	2.8	2012	WOC	WOC	Equal	S	2.2-2.8	All Missing	All Missing
71	Legacy	PD-027	8	2	2	6	0	4.3	2012	WOC	WOC	Equal	S	3.7-4.3	1.5-8.4	All Missing
72	Legacy	PD-029E	8	2	2	6	0	5.5	2012	WOC	WOC	Equal	S	4.5-5.5	All Missing	All Missing
73	Legacy	PD-037	8	2	2	6	0	6.5	2012	WOC	WOC	Equal	S	3.4-6.5	All Missing	All Missing

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74	Legacy	PD-060	4	2	2	2	0	5.7	2012	WOC	WOC	Equal	S	3.4-5.7	All Missing	All Missing
75	Legacy	PD-063	7	2	2	5	0	5.4	2012	WOC	WOC	Equal	S	2.4-5.4	All Missing	5.8-9.4
76	Legacy	PD-169	3	2	2	1	0	3.8	2012	WOC	WOC	Equal	S	3.2-3.8	All Missing	All Missing
77	Legacy	PD-170	4	2	3	1	0	4.6	2012	WOC	WOC	Equal	S	2.1-4.6	All Missing	All Missing
78	Legacy	PD-191	7	2	2	5	0	6.3	2012	WOC	WOC	Equal	S	3-6.3	All Missing	2.8-3.7
79	Legacy	PD-345	4	2	2	2	0	4	2012	WOC	WOC	Equal	S	2.8-4	All Missing	All Missing
80	Legacy	PD-355	4	3	3	1	0	5.5	2012	WOC	WOC	Equal	S	2.4-5.5	All Missing	All Missing
81	Legacy	PD-363	4	2	2	2	0	4.7	2012	WOC	WOC	Equal	S	2.4-4.7	All Missing	All Missing
82	Legacy	RL-09071	4	2	2	2	0	4.8	2012	WOC	WOC	Equal	L	2.1-4.8	All Missing	14-16
83	Legacy	RL-09084	4	2	2	2	0	4.5	2012	WOC	WOC	Equal	L	3.4-4.5	All Missing	18-23
84	Legacy	RL-09085	4	2	2	2	0	2.5	2012	WOC	WOC	Equal	L	2.2-2.5	All Missing	9.7-9.7
85	Legacy	RL-09100	4	2	2	2	0	3	2012	WOC	WOC	Equal	L	2.8-3	All Missing	All Missing
86	Legacy	RL-10001	7	5	5	2	0	34	2014	WOC	WOC	Equal	L	4.1-34	All Missing	13-16
87	Legacy	RL-10002	4	4	4	0	4	8.7	2014	WOC	WOC	Equal	L	4-8.7	All Missing	9.8-9.8
88	Legacy	RL-10004	4	4	4	0	2.1	4.7	2014	WOC	WOC	Equal	L	2.1-4.7	All Missing	7.4-7.4
89	Legacy	RL-10006	4	2	2	2	0	4	2014	WOC	WOC	Equal	L	2.5-4	All Missing	6.8-6.8
90	Legacy	RL-10009	4	3	3	1	0	6.6	2014	WOC	WOC	Equal	L	3.2-6.6	All Missing	17-17
91	Legacy	RL-10010	13	4	4	9	0	7.1	2014	WOC	WOC	Equal	L	2.2-7.1	4-5.85	5.3-21
92	Legacy	RL-10012	7	6	6	1	0	8.6	2014	WOC	WOC	Equal	L	3.3-8.6	All Missing	All Missing
93	Legacy	RL-10013	7	4	4	3	0	5	2014	WOC	WOC	Equal	L	2.6-5	All Missing	11-11
94	Legacy	RL-10014	10	2	2	8	0	9.1	2014	WOC	WOC	Equal	L	3.1-9.1	4-6.2	17-23
95	Legacy	RL-10015	4	3	3	1	0	4.8	2014	WOC	WOC	Equal	L	3.9-4.8	All Missing	9.9-9.9
96	Legacy	RL-10016	4	3	3	1	0	7.9	2014	WOC	WOC	Equal	L	3.3-7.9	All Missing	All Missing
97	Legacy	RL-10017	7	7	7	0	2.6	7.4	2014	WOC	WOC	Equal	L	2.6-7.4	All Missing	13-16
98	Legacy	RL-10018	4	4	4	0	3.2	8.4	2014	WOC	WOC	Equal	L	3.2-8.4	All Missing	13-13
99	Legacy	RL-10101	5	3	3	2	0	4.3	2014	WOC	WOC	Equal	L	2.1-4.3	All Missing	All Missing
100	Legacy	RL-10102	7	4	4	3	0	10	2014	WOC	WOC	Equal	L	3.5-10	4.7-4.7	All Missing
101	Legacy	RL-10103	4	3	3	1	0	4.7	2014	WOC	WOC	Equal	L	2.9-4.7	All Missing	10-10
102	Legacy	RL-10105	4	3	3	1	0	8.7	2014	WOC	WOC	Equal	L	5-8.7	All Missing	12-12
103	Legacy	RL-10107	4	4	4	0	3	7.5	2014	WOC	WOC	Equal	L	3-7.5	All Missing	11-11
104	Legacy	RL-10109	5	5	5	0	2.2	12	2014	WOC	WOC	Equal	L	2.2-12	All Missing	11-11
105	Legacy	RL-10110	4	3	3	1	0	4.6	2014	WOC	WOC	Equal	L	2.9-4.6	All Missing	15-15
106	Legacy	RL-11113	4	3	3	1	0	3.3	2014	WOC	WOC	Equal	L	2.2-3.3	All Missing	14-14
107	Legacy	RL-11117	8	3	3	5	0	6.6	2014	WOC	WOC	Equal	L	2.9-6.6	All Missing	All Missing
108	Legacy	RL-11119	4	2	2	2	0	4.3	2014	WOC	WOC	Equal	L	2-4.3	All Missing	All Missing
109	Legacy	RL-13088	8	3	3	5	0	16	2016	WOC	WOC	Equal	L	11-16	All Missing	All Missing
110	Legacy	RS-01021	4	2	2	2	0	5.6	2014	WOC	WOC	Equal	S	5-5.6	All Missing	14-14
111	Legacy	RS-04377	6	6	6	0	2.5	4.8	2014	WOC	WOC	Equal	S	2.5-4.8	All Missing	All Missing
112	Legacy	RS-04544	4	2	2	2	0	2.9	2012	WOC	WOC	Equal	S	2.2-2.9	All Missing	15-15
113	Legacy	RS-06007	3	2	2	1	0	12	2012	WOC	WOC	Equal	S	3.4-12	All Missing	24-36
114	Legacy	RS-06157	6	6	6	0	2.5	4.8	2014	WOC	WOC	Equal	S	2.5-4.8	All Missing	All Missing
115	Legacy	RS-09114	4	2	2	2	0	2.8	2012	WOC	WOC	Equal	S	2.7-2.8	All Missing	20-20
116	Legacy	RS-09284	4	1	2	2	0	2.8	2014	F	WOC	Different	S	2-2.8	All Missing	All Missing
117	Legacy	RS-09286	4	2	2	2	0	3.9	2012	WOC	WOC	Equal	S	3.4-3.9	All Missing	All Missing
118	Legacy	RS-09304	3	2	2	1	0	2.7	2012	WOC	WOC	Equal	S	2.2-2.7	All Missing	5.8-5.8
119	Legacy	RS-09312	4	2	2	2	0	3	2012	WOC	WOC	Equal	S	2.3-3	All Missing	3.2-6.3
120	Legacy	RS-09316	4	0	2	2	0	2.4	2012	F	WOC	Different	S	2.1-2.4	All Missing	31-31
121	Legacy	RS-09322	4	2	2	2	0	8.2	2012	WOC	WOC	Equal	S	7.3-8.2	All Missing	37-37
122	Legacy	RS-09323	3	1	2	1	0	2.7	2012	F	WOC	Different	S	2-2.7	All Missing	13-19
123	Legacy	RS-10331	4	4	4	0	8.5	17	2014	WOC	WOC	Equal	S	8.5-17	All Missing	All Missing
124	Legacy	RS-10334	3	3	3	0	4.4	9.5	2014	WOC	WOC	Equal	S	4.4-9.5	All Missing	27-27
125	Legacy	RS-10336	7	7	7	0	3.1	16	2014	WOC	WOC	Equal	S	3.1-16	All Missing	All Missing
126	Legacy	RS-10339	3	3	3	0	6.1	17	2014	WOC	WOC	Equal	S	6.1-17	All Missing	30-30
127	Legacy	RS-10341	4	2	2	2	0	6.9	2014	WOC	WOC	Equal	S	4.3-6.9	All Missing	38-38
128	Legacy	RS-10348	4	3	3	1	0	8	2014	WOC	WOC	Equal	S	5.6-8	All Missing	11-11
129	Legacy	RS-10349	6	6	6	0	2.8	7.3	2014	WOC	WOC	Equal	S	2.8-7.3	All Missing	All Missing
130	Legacy	RS-10356	5	5	5	0	2.3	14	2014	WOC	WOC	Equal	S	2.3-14	All Missing	6.2-6.2
131	Legacy	RS-10361	8	6	6	2	0	4.7	2014	WOC	WOC	Equal	S	2.5-4.7	All Missing	All Missing
132	Legacy	RS-10365	7	5	5	2	0	10	2014	WOC	WOC	Equal	S	2.2-10	All Missing	All Missing
133	Legacy	RS-10373	6	5	5	1	0	20	2014	WOC	WOC	Equal	S	2.2-20	All Missing	40-40
134	Legacy	RS-10375	5	4	4	1	0	9.4	2014	WOC	WOC	Equal	S	2.4-9.4	All Missing	14-14
135	Legacy	RS-10377	4	4	4	0	3.8	5.7	2014	WOC	WOC	Equal	S	3.8-5.7	All Missing	All Missing
136	Legacy	RS-10380	4	3	3	1	0	5.2	2014	WOC	WOC	Equal	S	4.1-5.2	All Missing	10-10
137	Legacy	RS-10381	5	3	3	2	0	4.4	2014	WOC	WOC	Equal	S	4.2-4.4	All Missing	All Missing
138	Legacy	RS-10387	4	4	4	0	4.2	20	2014	WOC	WOC	Equal	S	4.2-20	All Missing	34-35
139	Legacy	RS-10389	3	2	2	1	0	4	2014	WOC	WOC	Equal	S	2.7-4	All Missing	All Missing
140	Legacy	RS-10394	5	4	4	1	0	11	2014	WOC	WOC	Equal	S	4.2-11	All Missing	11-11
141	Legacy	RS-10397	3	2	2	1	0	6.5	2014	WOC	WOC	Equal	S	4.7-6.5	All Missing	All Missing
142	Legacy	RS-10402	3	2	3	0	8.5	13	2014	WOC	WOC	Equal	S	8.5-13	All Missing	170-170
143	Legacy	RS-10403	4	4	4	0	2.7	12	2014	WOC	WOC	Equal	S	2.7-12	All Missing	13-13
144	Legacy	RS-10408	4	2	2	2	0	5.8	2014	WOC	WOC	Equal	S	4-5.8	All Missing	6.4-6.4
145	Legacy	RS-10410	10	8	8	2	0	8.7	2014	WOC	WOC	Equal	S	2.2-8.7	All Missing	25-31
146	Legacy	RS-11002	3	1	2	1	0	2.4	2014	F	WOC	Different	S	2.1-2.4	All Missing	5.1-5.1
147	Legacy	RS-11004	8	2	2	6	0	3	2014	WOC	WOC	Equal	S	2.5-3	All Missing	All Missing

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148	Legacy	RS-11005	4	1	2	2	0	4.5	2014	F	WOC	Different	S	2.1-4.5	All Missing	29-54
149	Legacy	RS-11009	4	1	2	2	0	5.7	2014	F	WOC	Different	S	2.1-5.7	All Missing	10-10
150	Legacy	RS-11018	4	2	2	2	0	3.9	2014	WOC	WOC	Equal	S	3.2-3.9	All Missing	All Missing
151	Legacy	RS-11034	4	0	2	2	0	2.1	2014	F	WOC	Different	S	2-2.1	All Missing	All Missing
152	Legacy	RS-11039	3	3	3	0	3.2	4	2014	WOC	WOC	Equal	S	3.2-4	All Missing	All Missing
153	Legacy	RS-11041	4	3	3	1	0	12	2014	WOC	WOC	Equal	S	2.5-12	All Missing	44-44
154	Legacy	RS-11045	4	3	3	1	0	6.5	2014	WOC	WOC	Equal	S	3.2-6.5	All Missing	14-14
155	Legacy	RS-11050	8	6	6	2	0	36	2014	WOC	WOC	Equal	S	3-36	All Missing	All Missing
156	Legacy	RS-11053	3	2	2	1	0	13	2014	WOC	WOC	Equal	S	5-13	All Missing	11-11
157	Legacy	RS-11054	4	3	3	1	0	4.6	2014	WOC	WOC	Equal	S	4.2-4.6	All Missing	22-22
158	Legacy	RS-11056	8	6	6	2	0	14	2014	WOC	WOC	Equal	S	2.5-14	All Missing	All Missing
159	Legacy	RS-13114	4	2	2	2	0	6.4	2016	WOC	WOC	Equal	S	2.2-6.4	All Missing	All Missing
160	Legacy	RS-13136	8	5	5	3	0	10	2016	WOC	WOC	Equal	S	2.3-10	All Missing	All Missing
161	Legacy	RS-13144	4	1	2	2	0	4.3	2016	F	WOC	Different	S	2-4.3	All Missing	All Missing
162	Legacy	RS-13146	7	4	4	3	0	9.1	2016	WOC	WOC	Equal	S	7.6-9.1	All Missing	All Missing
163	Legacy	RS-13152	7	4	4	3	0	24	2016	WOC	WOC	Equal	S	8.2-24	All Missing	All Missing
164	Legacy	RS-13162	7	4	4	3	0	8.6	2016	WOC	WOC	Equal	S	2.6-8.6	All Missing	All Missing
165	Legacy	RS-13168	8	5	5	3	0	10	2016	WOC	WOC	Equal	S	2.5-10	All Missing	All Missing
166	Legacy	S-013	8	2	2	6	0	5.3	2012	WOC	WOC	Equal	S	2.3-5.3	1.3-7.5	22-22
167	Legacy	S-178	8	2	2	6	0	3.4	2012	WOC	WOC	Equal	S	2.5-3.4	All Missing	11-11
168	Legacy	S-304	5	4	5	0	2.1	13	2014	WOC	WOC	Equal	S	2.1-13	All Missing	8.4-8.4
169	Legacy	S-323	8	0	2	6	0	2.3	2012	F	WOC	Different	S	2.2-2.3	1.7-4.8	38-38
170	Legacy	SV-072	4	2	2	2	0	2.8	2012	WOC	WOC	Equal	S	2.2-2.8	All Missing	5.2-5.2
171	Legacy	SV-230	8	2	2	6	0	6.4	2012	WOC	WOC	Equal	S	4.4-6.4	1-25	5-6.6
172	Legacy	SV-348	3	3	3	0	6.2	44	2014	WOC	WOC	Equal	S	6.2-44	All Missing	14-14
173	Legacy	SV-362	4	3	3	1	0	8.2	2014	WOC	WOC	Equal	S	2.8-8.2	All Missing	9.9-9.9

Annex 3

Calculated Carcinogenic Risk and Blood Lead Level from Fish Consumption

Exposure Assumptions (see additional below)			**Predicted Outcome by Age (years)**									
Exposure Point Concentration	**Exposure Fequency**		**Endpoint**		**0 -1**	**1 -2**	**2 -3**	**3 -4**	**4 -5**	**5 -6**	**6 -7**	**7-32**
Lead Concentration in Fish (mg/Kg) [a]	**Number of Meals per Week [b]**	**Weeks of Exposure per Year**	**Parameter**	**Model**	**Predicted Blood Lead Level (ug/dL)[a] and Carcinogenic Risk (unitless)**							
1.0	1	52	Blood Lead Level	IEUBK	1.0	1.5	1.7	1.6	1.6	1.5	1.6	
			Carcinogenic Risk	RAIS	3.9E-07							
											9.6E-07	
	3		Blood Lead Level	IEUBK	2.8	4.3	4.7	4.6	4.4	4.2	4.7	
			Carcinogenic Risk	RAIS	1.2E-06							
											2.9E-06	
1.6	1		Blood Lead Level	IEUBK	1.6	2.4	2.7	2.6	2.4	2.3	2.6	
			Carcinogenic Risk	RAIS	6.3E-07							
											1.5E-06	
	3		Blood Lead Level	IEUBK	4.4	6.5	7.1	7.0	6.7	6.4	7.1	
			Carcinogenic Risk	RAIS	1.9E-06							
											4.6E-06	
2.3	1		Blood Lead Level	IEUBK	2.3	3.3	3.7	3.4	3.2	3.2	3.6	
			Carcinogenic Risk	RAIS	9.0E-07							
											2.2E-06	
	3		Blood Lead Level	IEUBK	6.1	8.8	9.7	9.5	9.2	8.7	9.7	
			Carcinogenic Risk	RAIS	2.7E-06							
											6.6E-06	
3.8	1		Blood Lead Level	IEUBK	3.5	5.3	5.9	5.7	5.4	5.1	5.7	
			Carcinogenic Risk	RAIS	1.5E-06							
											3.6E-06	
	3		Blood Lead Level	IEUBK	9.2	13.1	14.2	14.1	13.7	13.1	14.5	
			Carcinogenic Risk	RAIS	4.5E-06							
											1.1E-05	

a. mg/Kg = milligram(s) per kilogram
b. child meal = two (2) ounces; adult meal = six (6) ounces; IEUBK default

Receptor and Exposure Assumptions										
Characteristic	**Model**	**Source**	**Values Used**							
Age (years)	Both	(1)	0 -1	1 -2	2 -3	3 -4	4 -5	5 -6	6 -7	7-32
Body Weight (kilograms)	IEUBK	(1)	9.2	11.4	13.8	18.6	18.6	18.6	31.8	
	RAIS	(2)	15						80	
Fish Ingestion Rate (grams per kilogram per day)	IEUBK	(3)	2.9	4.9	4.9	3.6	3.6	3.6	2.9	
Fish Ingestion Rate (milligrams per day)	RAIS	(4)	26,680	55,860	67,620	99,690	66,690	66,690	92,220	
Fish Ingestion Rate (milligrams per day)			56,699						170,097	
Duration (years)	RAIS	(5)	6						26	
Avearging Time (years)	RAIS	(5)	70							

(1) model default
(2) Table 8-1 (USEPA 2011; *Exposure Factors Handbook* . EPA 600-R09-052F)
(3) Table 10 (USEPA 2011; *Exposure Factors Handbook* . EPA 600-R09-052F) [95-percentile value used vs. mean value]
(4) conversion from g/kg-day) from (3)
(4) model default (from USEPA 1989; *Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A)* . Interim Final. EPA 540-1-89-02)

Annex 4

Calculated Carcinogenic Risk and Blood Lead Level from Incidental Water Ingestion During Swimming

Exposure Assumptions (see additional below)			Predicted Outcome by Age (years)									
Exposure Point Concentration	**Exposure Fequency**		**Endpoint**		**0 -1**	**1 -2**	**2 -3**	**3 -4**	**4 -5**	**5 -6**	**6 -7**	**7-32**
Lead Concentration in Water (ug/L) [a]	**Days of Exposure per Week** [b]	**Weeks of Exposure per Year**	**Parameter**	**Model**	**Predicted Blood Lead Level (ug/dL)[a] and Carcinogenic Risk (unitless)**							
1	1	52	Blood Lead Level	IEUBK							0.0	
			Carcinogenic Risk	RAIS [c]	8.3E-10							
											4.0E-10	
	3		Blood Lead Level	IEUBK							0.0	
			Carcinogenic Risk	RAIS	2.5E-09							
											9.7E-10	
10	1		Blood Lead Level	IEUBK							0.0	
			Carcinogenic Risk	RAIS	8.3E-09							
											4.0E-09	
	3		Blood Lead Level	IEUBK							0.0	
			Carcinogenic Risk	RAIS	2.5E-08							
											9.7E-09	
100	1		Blood Lead Level	IEUBK							0.1	
			Carcinogenic Risk	RAIS	8.3E-08							
											4.0E-08	
	3		Blood Lead Level	IEUBK							0.4	
			Carcinogenic Risk	RAIS	2.5E-07							
											9.7E-08	
500	1		Blood Lead Level	IEUBK							0.6	
			Carcinogenic Risk	RAIS	4.2E-07							
											2.0E-07	
	3		Blood Lead Level	IEUBK							1.7	
			Carcinogenic Risk	RAIS	1.3E-06							
											4.8E-07	

a. ug/dL = microgram(s) per deciliter; ug/L = microgram(s) per liter
b. duration of daily event = one (1) hour
c. one (1) base scenario was run for child and adult receptors, then alternatives to the bases were developed by scaling the other exposure scenarios

Receptor and Exposure Assumptions										
Characteristic	**Model**	**Source**	**Values Used**							
Age (years)	Both	(1)	0 -1	1 -2	2 -3	3 -4	4 -5	5 -6	6 -7	7-32
Body Weight (kilograms)	IEUBK	(1)	9.2	11.4	13.8	18.6	18.6	18.6	31.8	
	RAIS	(2)	15						80	
Surface Water Ingestion (liters per day)	IEUBK	(1)							0.096	
	RAIS	(3)	0.12						0.071	
Duration (years)	RAIS	(4)	6						26	
Avearging Time (years)	RAIS	(4)	70							

(1) = model default
(2) Table 8-1 (USEPA 2011; *Exposure Factors Handbook* . EPA 600-R09-052F)
(3) Table 3-7 (USEPA 2011, February 2019 update; *Exposure Factors Handbook* . EPA 600-R09-052F) [95-percentile value used vs. mean value]
(4) model default (from USEPA 1989; *Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part A)* . Interim Final. EPA 540-1-89-02)

Annex 5

LEAD IN THE GEOLOGIC ENVIRONMENT

A report detailing the potential geologic origins of Lead
in South Carolina and neighboring states

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June 4, 2019

INTRODUCTION

Lead (Pb)

Lead (Pb), atomic number 82, is in group 14 and period 6 on the periodic table. Pb is a heavy, metallic element and has an atomic mass of 207.2 amu. Its name is derived from the Latin word plumbum. Krauskopf (1967) classified Pb as a chalcophile element, or an element that tends to concentrate in sulfide minerals and ores. Pb has an ionic radius of 119 pm, which is between potassium's (K) and calcium's (Ca) respective ionic radii of 133 pm and 101 pm (Heier, 1962). Because the size of a Pb ion is comparable to both K and Ca, it can substitute for those elements in feldspar minerals. Ionic substitution is responsible for Pb's abundance in K-rich rocks, and its problematic occurrence in the human body when it replaces Ca (Smallwood, 2019; Spiro and Stigliani, 1996; Salminen, 2019). Pb has a melting point of 327.4° Celsius (Table 1). This melting point is lower than most common crustal metals (Lovering, 1976; Table 1).

Several studies have consistently shown similar numbers of Pb concentration ([Pb]) in the crust. Pb is abundant in the crust and ranges from 12 to 15 parts per million (ppm) (Salminen, 2019; National Academies of Sciences, Engineering, and Medicine, 2017; Lovering, 1976; Tables 2, 3). [Pb] has been used as a proxy in paleoclimatic reconstructions. In cores collected from lacustrine and glacial deposits, seasonal and climatic variations in [Pb] can be documented in an area over time (Boutron et al., 1988; More et al., 2017).

Pb has four naturally occurring isotopes: ^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb (Reimann et al., 2016; Millot and Negrel, 2015). Of these isotopes, three (^{206}Pb, ^{207}Pb, and ^{208}Pb) are radiogenic (Reimann et al., 2016). The most common Pb isotopes is ^{208}Pb which makes up 52.4% of all Pb in nature (Reimann et al., 2016).The other isotopes of Pb are distributed as follows: ^{206}Pb makes up 24.1%, ^{207}Pb is 22.1%, and ^{204}Pb is the least common only consisting of 1.4% of all natural Pb (Reimann et al., 2016).

Pb in the Historical Record

Evidence of anthropogenic and geogenic Pb can be found in both historical and geologic records (Boutron et al. 1988; More et al. 2017; Cloy et al. 2008; Hillman et al. 2017; Drewniak et al. 2011; Ettler et. Al. 2006). Anthropogenic Pb has been occurring in Europe for the past 2500 years. Beginning around the first century C.E., the Romans mined Pb ores at an industrial scale in northern Spain to produce pipes for their water systems (Hillman et al., 2017; Lovering, 1976). Studies in Europe of [Pb] in ice records show a slowdown in Pb extraction during the mid-14th century that correlates with the outbreak of bubonic plague (More et al., 2017).

A similar record of Pb production can be found in the Americas in the past 500 years. In the United States, Pb extraction has historically been concentrated in Missouri, Alaska, Idaho, and Washington. In a comparable study, Juan (1994) concluded that high [Pb] in Washington soil could be attributed to automobile exhaust. These states produced 260,000 metric tons of Pb in 2018 (Klochko, 2019). The most common Pb mineral is galena (PbS); however, other sources of Pb are mined (National Academies of Sciences, Engineering, and Medicine, 2017). Sloan (1908) reported galena only occurring in small veins in South Carolina, and no other significant references to Pb deposits have been made since the early 1900s (Feiss et al. 1991; Singh and Callaghan, 2013). With the exception of one small pre-Civil War mine in Cherokee County, South Carolina, the three-state region of SC, GA, and NC have no

Common Metals in Crusts			
Element	**Symbol**	**Crustal Abundance (ppm)**	**Melting Point (C)**
Aluminum	Al	8.20E+04	660.3
Iron	Fe	5.60E+04	1,538
Magnesium	Mg	2.30E+04	650
Potassium	K	2.10E+04	63.5
Titanium	Ti	5,700	1,668
Manganese	Mn	950	1,246
Lead	Pb	12.5	327.4

Table 1. Selected common metals found in earth's crust. Crustal abundance and melting points are provided. Lead (in red) is not particularly common in the crust and has been put out of order for organizational purposes. Information taken from Lovering (1976) and Krauskopf (1967).

Top Five Most Abundant Elements in Crust						
Element	**Symbol**	**Crust (ppm)**	**Granite (ppm)**	**Basalt (ppm)**	**Shale (ppm)**	**Seawater (ppm)**
Oxygen	O	4.64E+05	NA	NA	NA	857000
Silicon	Si	2.82E+05	3.23E+05	2.40E+05	2.38E+05	3
Aluminum	Al	8.2 E+04	7.70E+04	8.80E+04	8.00E+04	0.01
Iron	Fe	5.60E+04	2.70E+04	8.60E+04	4.70E+04	0.01
Calcium	Ca	4.10E+04	1.60E+04	6.70E+04	2.50E+04	400
Lead	Pb	12	20	5	20	.00003

Table 2. Five most abundant elements in the crust and their distribution in common rock types and seawater. Lead (in red) has been added for comparison. Information taken from Krauskopf (1967).

Post-Transition Metals in Crust						
Element	**Symbol**	**Crust (ppm)**	**Granite (ppm)**	**Basalt (ppm)**	**Shale (ppm)**	**Seawater (ppm)**
Lead	Pb	12.5	20	5	20	0.00003
Aluminum	Al	8.2 E+04	7.70E+04	8.80E+04	8.00E+04	0.01
Gallium	Ga	15	18	12	19	0.00003
Indium	In	0.1	0.1	0.1	0.05	<.02
Tin	Sn	2	3	1	6	0.0008
Thallium	Tl	0.45	0.75	0.1	1	<.00001
Bismuth	Bi	0.17	0.18	0.15	0.01	0.00002

Table 3. The post-transition metals and their distribution throughout the crust, common rock types, and seawater. Information taken from Krauskopf (1967).

significant history of Pb extraction (Singh and Callaghan, 2013; Mittwede, 1989; Keith, 1931; Feiss et al. 1991).

Pb in Minerals

Pb is the dominant cation in the following minerals: galena (PbS), cerussite ($PbCO_3$), anglesite ($PbSO_4$), litharge (PbO), jamesonite ($Pb_4FeSb_6S_{16}$), mimetite ($Pb_5(AsO_4)_3Cl$), minium (Pb_3O_4), phosgenite ($Pb_2CO_3Cl_2$), plagionite ($Pb_5Sb_8S_{17}$), pyromorphite ($Pb_5(PO_4)_3Cl$), stolzite ($PbWO_4$), vanadinite ($Pb_5(VO4)_3Cl$), wulfenite ($PbMnO_4$), crocoite ($PbCrO_4$), and bournonite ($PbCuSbS_3$). The most common and economically important Pb minerals are: galena, cerussite, and anglesite (National Academies of Sciences, Engineering, and Medicine, 2017). Trace amounts of Pb also can be found in K-feldspar, plagioclase, mica group minerals, zircon, and magnetite. Trace amounts of an element in a crystal usually consist of less than 1% of the materials concentration and may appear as impurities in the rock (Gill, 1989). These trace minerals, in this case Pb, attach to a crystal structure via cation exchange, a process in which a positive ion attaches to a negative particle setting some of it "free" while also being absorbed into the crystal structure (Krauskopf, 1967; Neuendorf, 2011). It is probable that Pb in Georgia, North Carolina, and South Carolina soils are derived from those minerals because they are common in crystalline Piedmont rocks (Figures 1 – 9).

Pb in Rocks

The sedimentary rock with the highest [Pb] are shales. This concentration is a result of organic marine organisms preserved during formation of the fine-grained deposits (Salminen, 2019; Table 3). These organisms would have absorbed Pb from various sources. Sedimentary rocks with high carbonate and low iron-sulfide concentrations also can retain Pb because those rocks lack an acid neutralizing capacity (National Academies of Sciences, Engineering, and Medicine, 2017).

Pb is closely associated with igneous processes and is concentrated in late-stage granitic magmas (Salminen, 2019). These magmas form sialic igneous rocks (K-Al rich, felsic composition), such as granite, and these rocks are more likely to host Pb than basic igneous rocks (Fe-Mg-rich, mafic composition) (Salminen, 2019; Heier, 1962; Cocker, 1998). Pb has a lower melting point than Fe and Mg, and its ionic size makes it more conducive to be incorporated into minerals such as K-feldspar that form in sialic igneous rocks (Table 1).

As previously mentioned, one of the most prominent Pb-bearing minerals is K-feldspar, especially in sialic igneous rocks. In K-feldspar, [Pb] will vary depending on the temperature and pressure at the time of formation. K-feldspar found in granodiorite and granite have a [Pb] of 20 ppm (Heier, 1962; Krauskopf, 1967; Table 3). K-feldspar, however, in pegmatite has a [Pb] of 100 ppm (Heier, 1962; Krauskopf, 1967). Hydrothermal systems produce the K-feldspar mineral adularia with a [Pb] of 62 ppm (Heier, 1962; Krauskopf, 1967). In the high temperature form of K-feldspar, sanidine, [Pb] is 21 ppm (Heier, 1962; Krauskopf, 1967). Within K-feldspar, Pb^{2+} has a larger electronegativity value, which increases the strength of the covalent Pb-O bonds, compared to the preexisting K-O bonds (Heier, 1962). Granitic rocks range between 40 – 80 percent feldspar-group minerals (Neuendorf et al., 2011; Mottana et al., 1977).

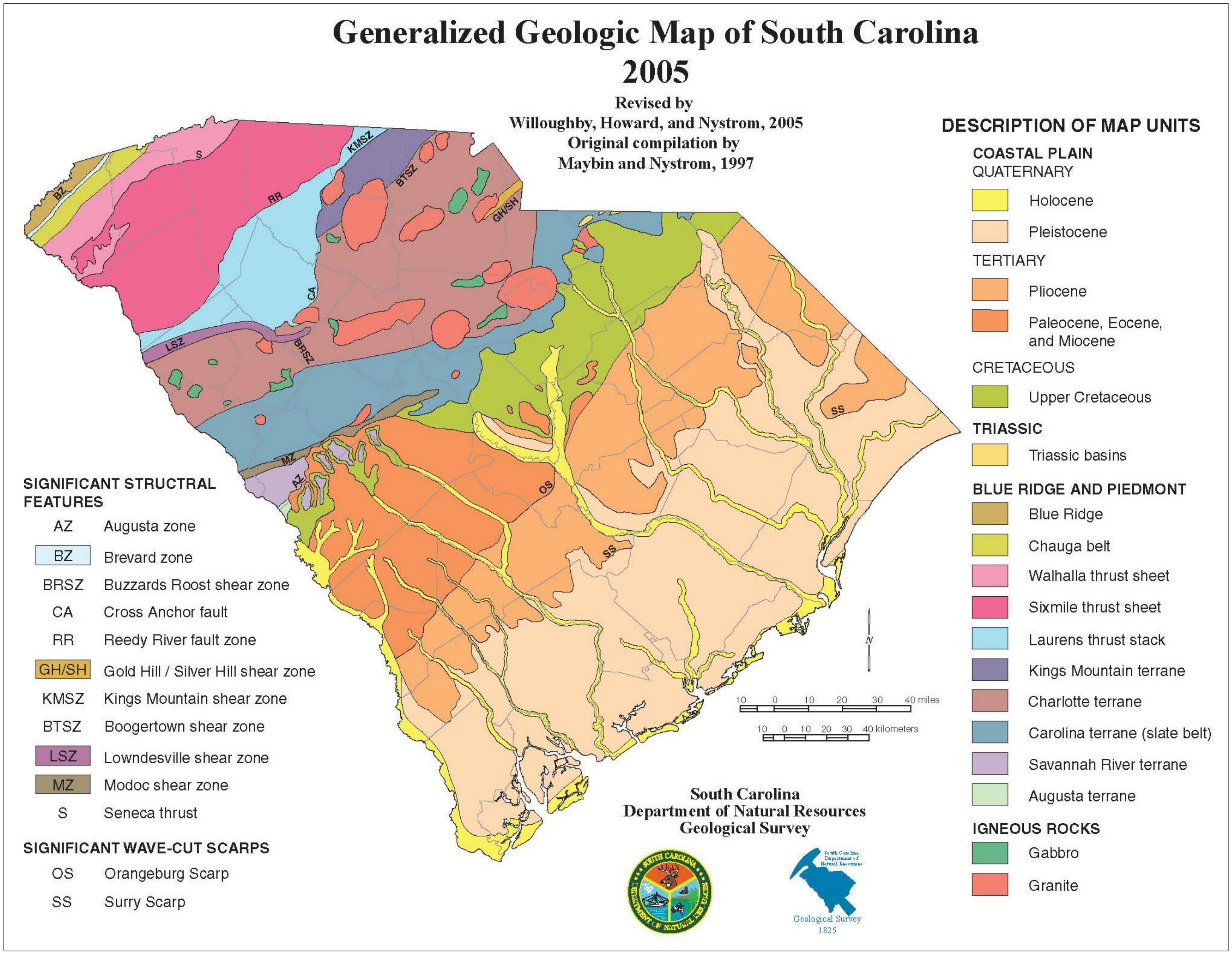

Figure 1. Generalized Geologic Map of South Carolina. Available from: http://www.dnr.sc.gov/geology/Pubs/GGMS/GGMS1.pdf

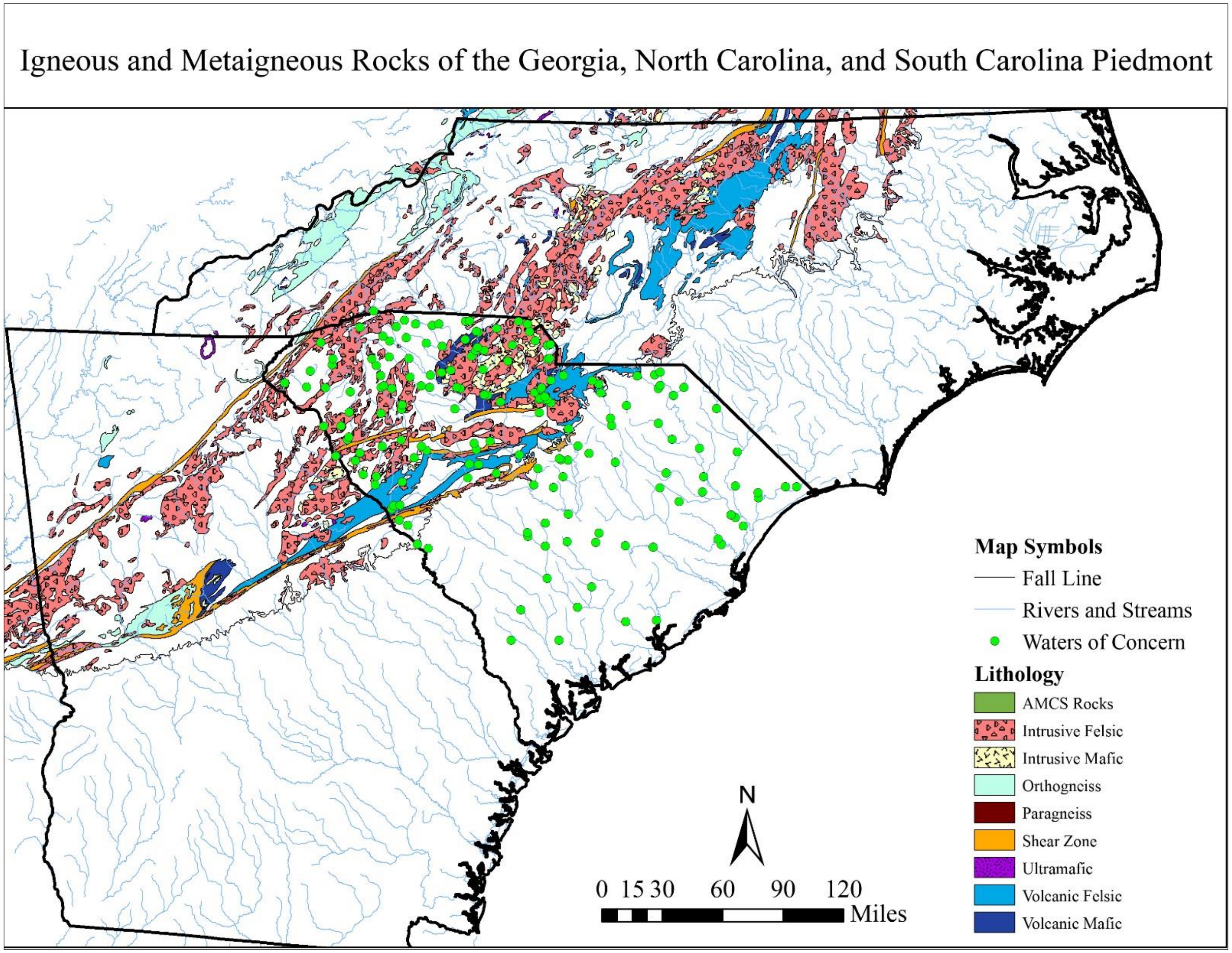

Figure 2. Image depicts the crystalline geology of the piedmont regions within Georgia, North Carolina, and South Carolina. Geology has been adapted from Hibbard et al. (2006), Rivers and streams are depicted by blue lines, and green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

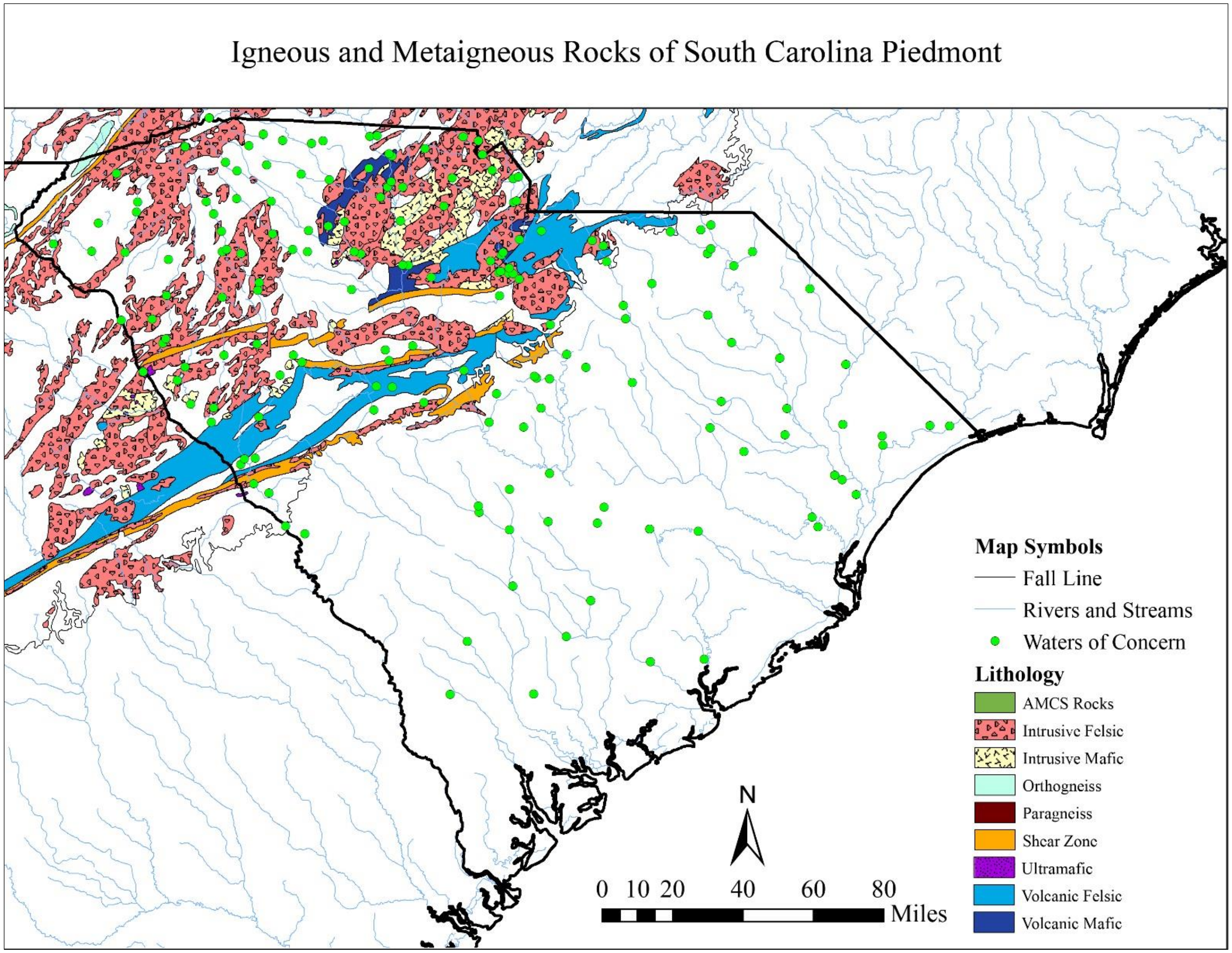

Figure 3. Image depicts the majority of crystalline rocks in the South Carolina piedmont. Geology has been modified from Hibbard et al. (2006), rivers and streams are depicted by blue lines, and green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

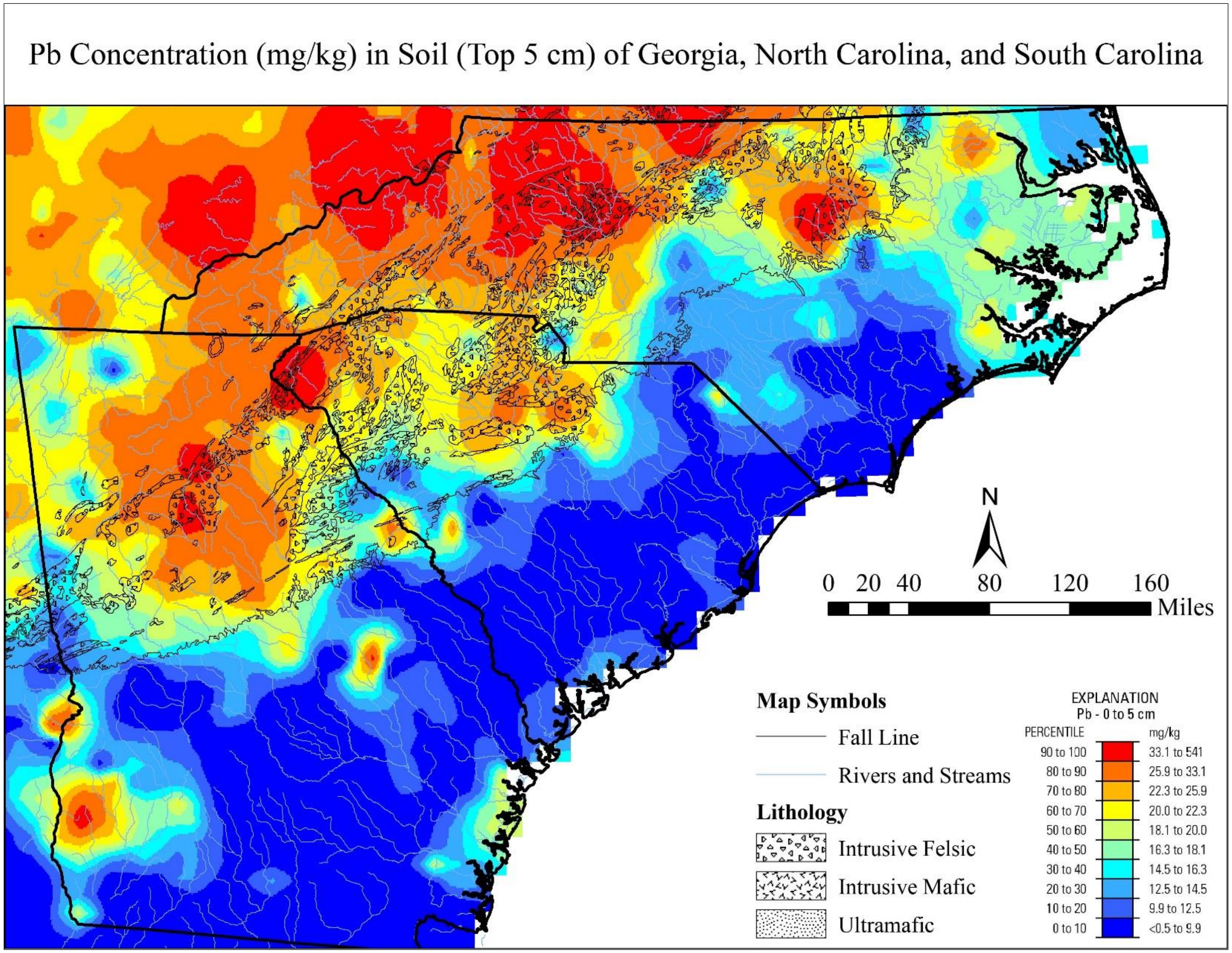

Figure 4. Depiction of the [Pb] (mg/kg) in the first 5 cm of soil within Georgia, North Carolina, and South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid, and rivers/streams are depicted by blue lines.

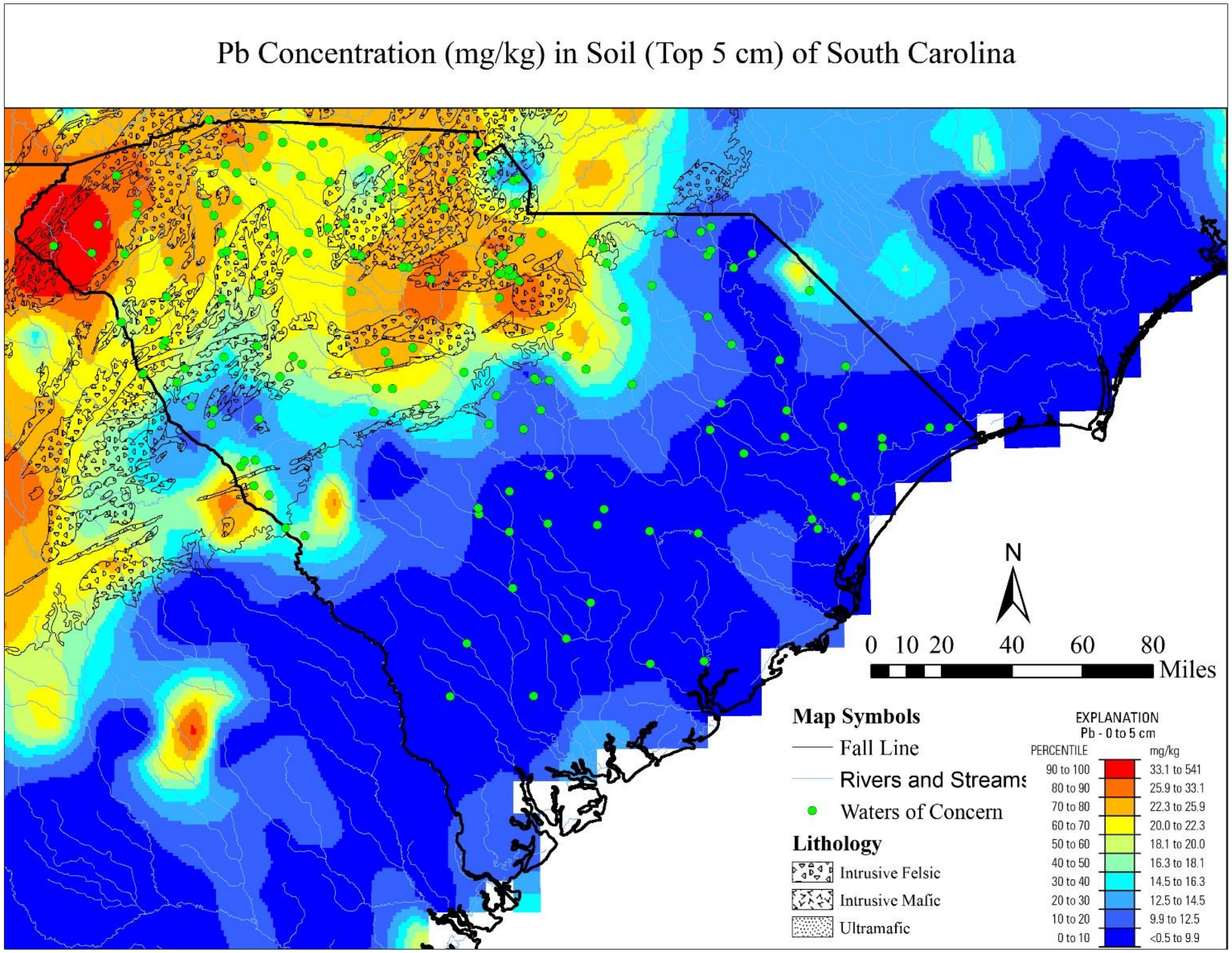

Figure 5. Depiction of the [Pb] (mg/kg) in the first 5 cm of soil within South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic intrusive rocks in the Piedmont has been overlaid, and rivers/streams are depicted by blue lines. Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

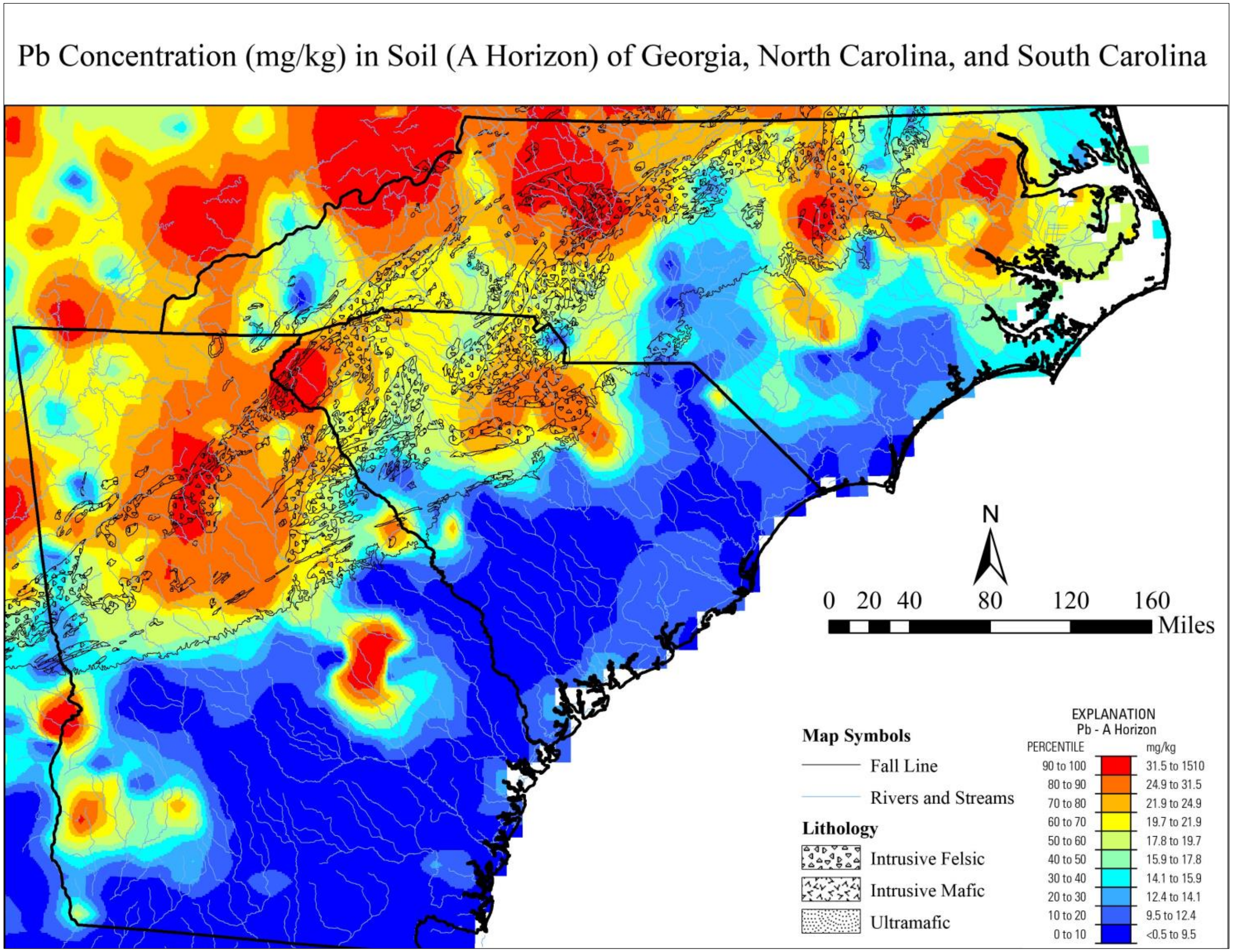

Figure 6. Depiction of the [Pb] (mg/kg) in the A Horizon of soil within Georgia, North Carolina, and South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid, and rivers/streams depicted by blue lines.

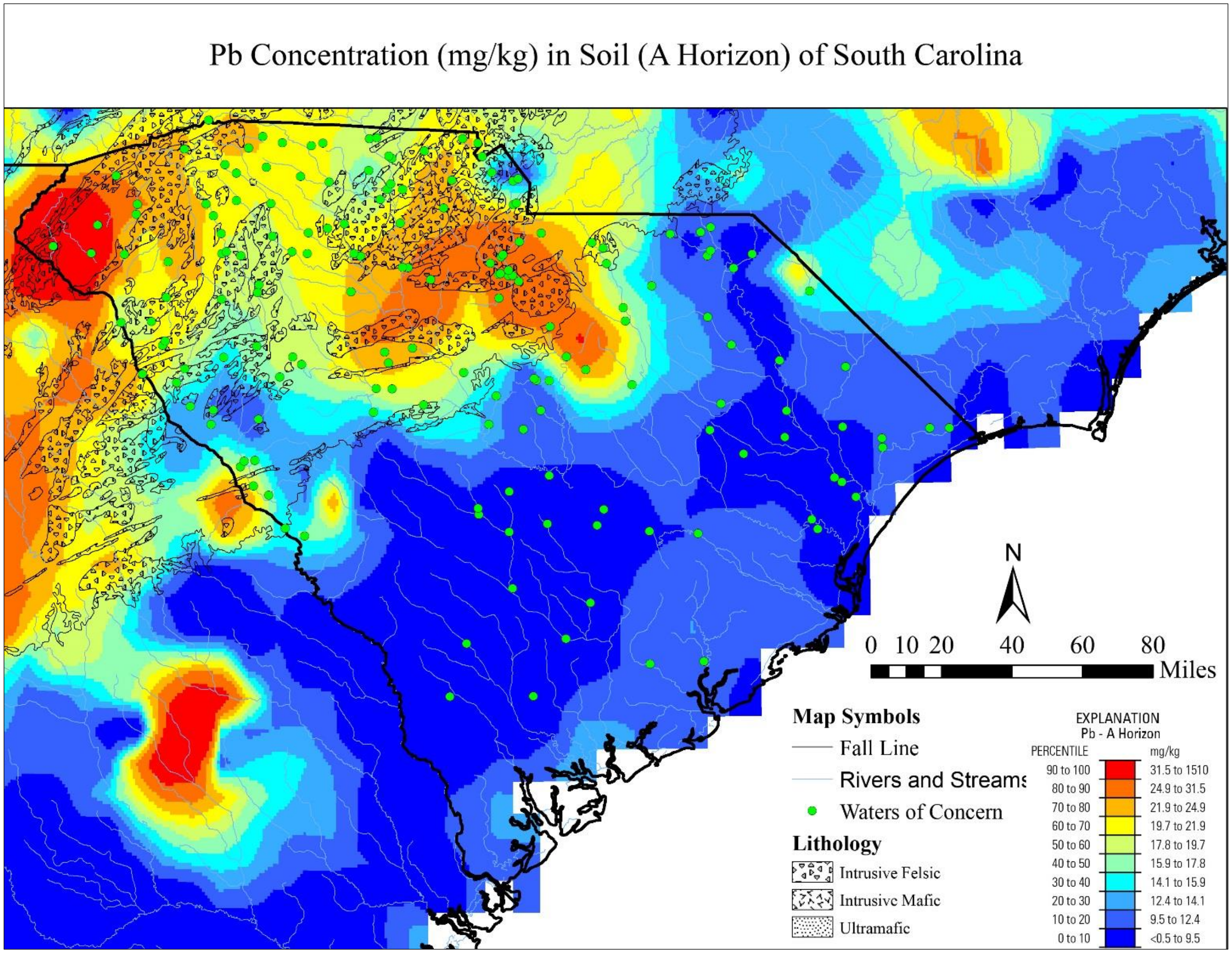

Figure 7. Depiction of the [Pb] (mg/kg) in the A Horizon of soil within South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid. Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

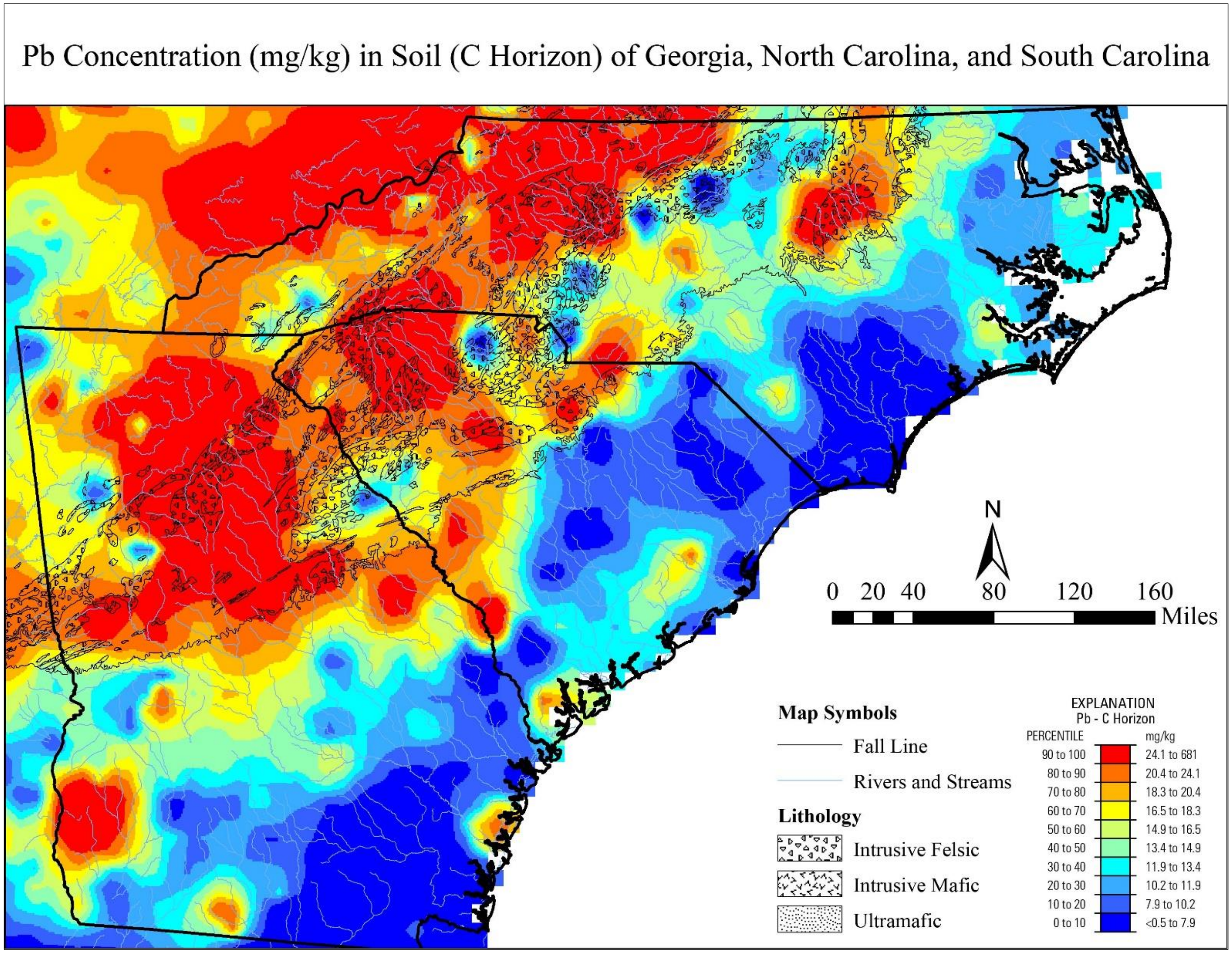

Figure 8. Depiction of the [Pb] (mg/kg) in the C Horizon of soil within Georgia, North Carolina, and South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid. Rivers/streams are depicted by blue lines.

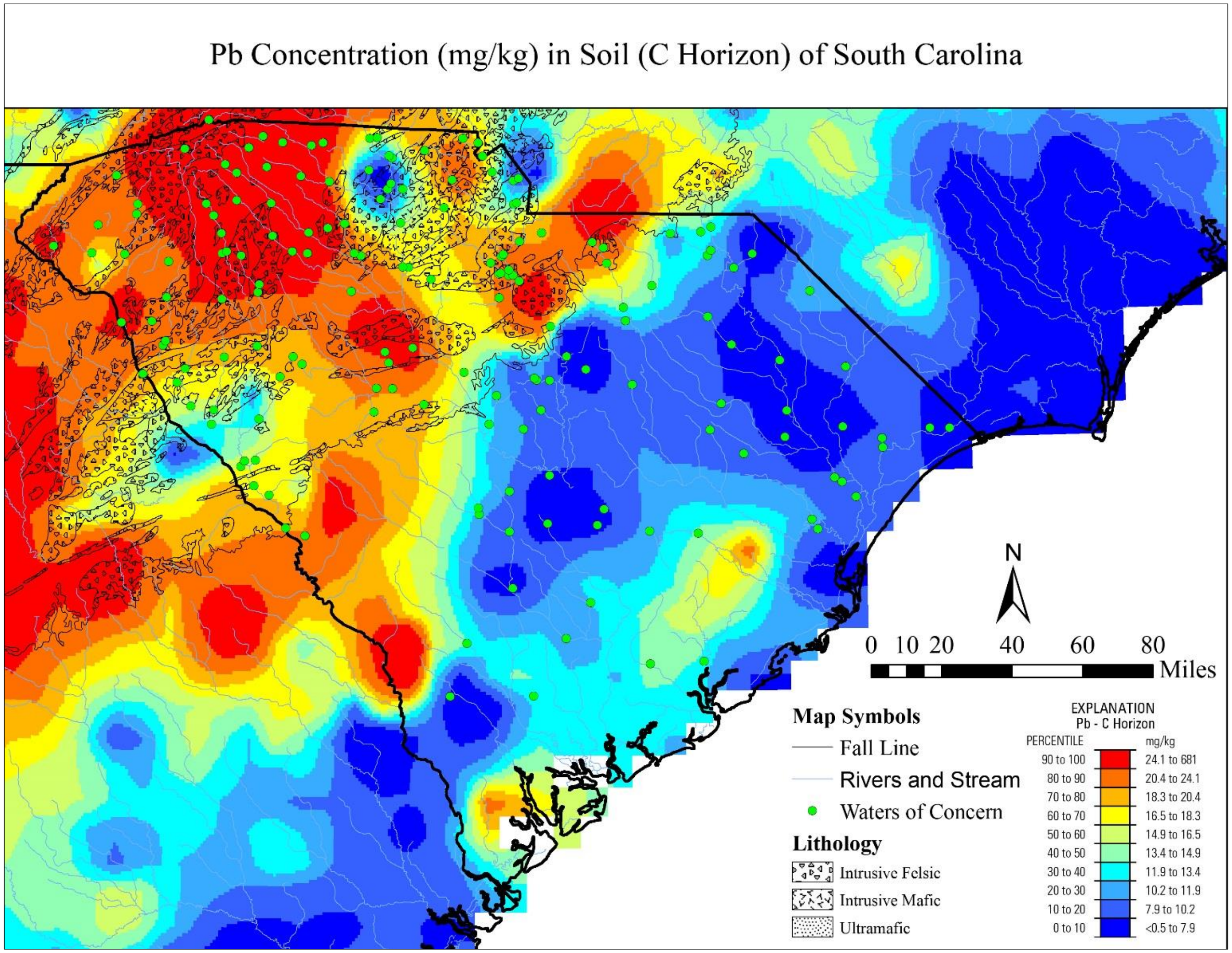

Figure 9. Depiction of the [Pb] (mg/kg) in the C Horizon of soil within South Carolina. Soil data taken from Smith et al. (2014). The ratio mg/kg is equal to ppm. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid. Rivers/streams are depicted by blue lines. Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

Geochemical data of South Carolina rock sample show that there are high levels of [Pb] in certain igneous and metamorphic rocks (Table 4; U.S. Geological Survey, 2008). It is important to note that felsic rocks ([Pb] of 45.02 ppm) of South Carolina have on average 63% more Pb then the states mafic rocks ([Pb] of 28.41 ppm). The high [Pb] in certain rock types such as the metatuff's ([Pb] of 147.86 ppm) or Argillite ([Pb] of 98.75 ppm) could be a result of high sulfide rock concentration in the Carolina terrane (Figure 1; Mobley et al., 2014). Further in-depth analysis of GIS data could result in a better understanding of the relationship between the Carolina terrane and [Pb] in certain rock types.

Given the above discussion of Pb in rocks and minerals, there are no viable major sources of traditional lead ores. Therefore, the most obvious source of lead in the geologic environment must be from granitic rocks, where it occurs in trace amounts comparable to crustal and soil data sets.

Erosion and Weathering

Physical and chemical weathering transport Pb from source rocks into the soil profile and the hydrologic system (Blackburn and Dennen, 1988; Bierman and Montgomery, 2014). Because of South Carolina has a humid subtropical climate and the major weathering process is chemical. Isotopically stable Pb is soluble in water that has pH levels of 6 – 8 (Jurgens et al. 2019; Spiro and Stigliani, 1996). Generally pH is unit less, and is represents the negative $\log_{10}$ value of a hydrogen ion (Neuendorf et al., 2011). Pb oxides do not easily dissolve in water under normal conditions (1 atm and 20°C). Pb carbonates are generally insoluble, whereas Pb sulfates are more soluble in water that is 25°C or warmer (Lenntech, 2019; Spiro and Stigliani, 1996). The presence of sulfuric acid acts as a catalyst and increases solubility of both Pb carbonates and Pb sulfates (Lenntech, 2019; Crockford and Brawley, 2002). Sulfuric acid also can be produced in the crust when sulfate-bearing rocks react with water and oxygen (Spiro and Stigliani, 1996). Anthropogenic Pb has a high solubility and will remain stable once transported and deposited in soils (Kong et al., 2018). Chemical and physical weathering can catalyze reactions in Pb sulfates and Pb carbonates, releasing the Pb, S, and CO_2 into the environment.

Pb in Soils

Weathering of bedrock and the accumulation of organic matter create soil (Bierman and Montgomery, 2014). Through weathering processes, Pb is transported from sialic igneous rocks, like those found in the Piedmont, to sediments, soils, and hydrologic systems (Huff, 1976; Lovering, 1976). Geogenic [Pb] in soil is strongly dependent on the compositions of the surrounding bedrock as a result of erosional processes (Lovering, 1976). Because South Carolina has a humid subtropical climate, physical and chemical processes play a major role in weathering of existing rocks. The Southeast's humid climate also keeps the [Pb] in soil low because the element is less mobile in humid environments than in arid ones (Cocker, 1998). Pb transport increases during periods of drought due to eolian process moving Pb eroded out of organic material absorbed in salts and clays (Cocker, 1998). This transport could result in exaggerated Pb levels in both soils and water systems if sampling was done during period of drought.

In 2010, the USEPA determined that the mean geogenic [Pb] in South Carolina soils was 14.4 ppm which is lower than the national average of 16 - 19 ppm (Battelle Memorial Institute 1998; Shacklette and Boerngen 1984; United State Environmental Protection Agency 2018). Georgia soils have a mean geogenic [Pb] of 13.2 ppm, while North Carolina's soils have a mean geogenic [Pb] of 21.3 ppm (United States Environmental Protection Agency 2018). The geogenic [Pb] in Georgia, North Carolina,

South Carolina Rock’s Lead Concentrations			
Rock Type	**Pb (ppm)**	**Rock Type**	**Pb (ppm)**
Amphibolite	14.9	Marble	11.1
Andesite	0	Metagraywacke	10
Aplite	64	Metatuff	147.9
Argillite	98.8	Phyllite	17.5
Calc-Silicate	10.4	Phyllite/Slate	41.5
Carbonate	48.8	Quartz	12.5
Dacite	175	Quartz Diorite	70
Diabase	5.5	Quartzite	30.5
Diorite	6.8	Rhyolite	21.5
Felsic	45	Sandstone	10
Gabbro	5.9	Schist	55.5
Gneiss	42.2	Ultramafic	8.9
Granite	28.2		
Granodiorite	39.8		
Greenstone	20.1		
Hornfels	72.5		
Intermediate	23.3		
Mafic	28.4		

Table 4. Information showing [Pb] of South Carolina rock groups in ppm. Data was taken from U.S. Geological Survey (2008). Data my be skewed due to the Carolina Terrane’s high sulfide rock concentrations (Mobley et al., 2014).

and South Carolina soils parallel the area of the sialic rocks (Table 5). Figure 2 shows sialic rock areas located in the Piedmont.

Soil data also show an increase of [Pb] with depth (Smith et al., 2014; Figures 4 – 9). The [Pb] is clearly lower in the top 5 cm of Georgia, North Carolina, and South Carolina soils that it is in the A and C Horizons (Smith et al. 2015). The relationship between Pb and the different soil horizons in the Southeastern United States is an area of potential future research.

Pb in the Hydrologic System

Soil Pb can be transported into the hydrologic system, particularly when the soil is deposited adjacent to a river and stream. Rates of stream erosion on bank material will determine how much sediment will be removed (Bierman and Montgomery, 2014). Once free Pb is in the water

system, it can be oxidized and solubilized:

$$2Pb + O_2 + 4H^+ = 2Pb^2 + 2H_2O$$

The solubilization rate associated with this reaction is strongly dependent on pH levels in the water (Spiro and Stigliani, 1996). For this reason, Pb will dissolve more efficiently in soft water, or water with low Ca^{2+} and Mg^{2+} concentrations ([Ca^{2+}] and [Mg^{2+}]) and lower pH (pH less than 7) (Spiro and Stigliani, 1996; DeSimone et al., 2009). Briggs et al. (1977) defined soft water as having a [Ca^{2+}] of 0 to 60 ppm, while hard water has a [Ca^{2+}] greater than 61 ppm. At a regional scale, the surface waters of Georgia, North Carolina, and South Carolina have relatively low [Ca^{2+}] and are generally considered “soft water” (Briggs and Ficke, 1977). Patterson and Padgett (1984) concluded that groundwater in the South Carolina Piedmont is mostly soft, with the exception being areas underlain by carbonate rock. Limestone aquifers have very hard water (Patterson and Padgett, 1984).

There is a strong relationship between the compositions of ground and surface water (Todd, 1960). Groundwater is pulled down by the force of gravity and will remain around the saturated zone until it is discharged into surface water bodies (oceans, lakes, streams, rivers, etc.) or independent springs (Todd, 1960). Pb in groundwater is often a combination of both anthropogenic and geogenic Pb (Millot and Negrel, 2015). These categories of Pb can be distinguished by comparing isotopic ratios (Reimann, et al., 2016; Millot and Negrel, 2015; Kong et al., 2018). It is important to note that groundwater isotopic [Pb] might diverge from the host rocks as result of the presence of secondary U- and Th- rich minerals also being dissolved in the groundwater (Millot and Negrel, 2015). According to Millot and Negrel (2015), this relationship would be detectable by an unusually high concentration of the radiogenic Pb isotopes (^{206}Pb, ^{207}Pb, and ^{208}Pb) which is typical of granitic aquifers.

ANALYSIS

Stream and River Sediments

In the 1970's the USGS sampled fluvial sediments across the nation as part of NURE. Geochemical analyses were done, and test results are available through a USGS data portal. These data were interpolated to depict the total (both geogenic and anthropogenic) Pb in river and stream sediments

Soil Lead Concentration Compared to Felsic Rock Area		
State	**Area (Km^2)**	**Soil [Pb] (ppm)**
North Carolina	24,206	21.3
South Carolina	17,854	14.4
Georgia	16,231	13.2

Table 5. Area of Felsic rocks was calculated from Hibbard et al., (2006) map (Figure 2). The states soil [Pb] were provided by USEPA (2018). It is clear from this table that the amount of Pb in the soil is related to the area of felsic rocks within the state.

in Georgia, North Carolina, and South Carolina (Figure 10 & 11). The gaps in data shown on Figures 10 and 11, reflect analytical results less than the detectable amount. For this reason, these areas have been left blank on the figure.

It is important to note that NURE samples may include both geogenic and anthropogenic Pb. In rural parts of South Carolina that have a limited history of industrial development, [Pb] likely reflects a high geogenic to anthropogenic [Pb] ratio. In contrast, urban centers with a history of industrial development may contain a significant component of anthropogenic Pb, and this development may be reflected in higher [Pb]. For example, samples collected from Sumter, Columbia, and Rock Hill have [Pb] highs of 1150 ppm, 903 ppm, 427 ppm respectively. The [Pb] highs are particularly visible when viewed in conjunction with a state land-use map (Figure 12; Homer et al., 2015).

The [Pb] highs found in south-central North Carolina could be attributed to high arsenic (As) levels being eroded from sulfide minerals from the Carolina Slate Belt (Figure 10; Pippin et al., 2003). Pb is commonly found in As minerals (Salmien, 2019; Bowell et al., 2014). Along with its association with As, Pb is often found in gold deposits (Feiss et al., 1991; National Academies of Sciences, Engineering, and Medicine, 2017; Svetlitskaya and Nevolko, 2017; Molnar et al. 2015; Hillman et al., 2017). On the river and stream map (Figure 13), it is possible to see a slight increase in [Pb] around historic gold mines in the South Carolina Piedmont, particularly the gold deposits located in Edgefield and McCormick Counties (Maybin, 1997). The reason why there is a correlation between these mines in the stream and river sediments and not in the soils (Figures 5, 7, & 9) is an area of potential future research.

The location of high [Pb] southeast of the Fall Line in the upper Coastal Plain could be related to the transport of Pb from the sialic Piedmont rocks by fluvial processes. The location of this “Pb Line” is slightly northwest of the Orangeburg Scarp, a geologic feature that divides the Upper and Middle Coastal Plain’s (Figure 1). The way in which Pb is transported in Coastal Plain sediments and its relation to the Orangeburg Scarp could be another area of future study.

Waters of Concern

As previously stated, the Pb in Georgia, North Carolina, and South Carolina is considered geogenic and related to granitic plutons and felsic metamorphic rocks. The waters of concern (WOC) defined by the South Carolina Department of Health and Environmental Control (DHEC) are scattered throughout the State (Figure 3). Pb anomalies in WOC's that are near granitic plutons most likely have a large component of geogenic lead. Samples collected in proximity to urban areas are more likely to contain a component of anthropogenic Pb (Figure 12). Pb anomalies in WOCs from the Lower Coastal Plain may not be related to geogenic Piedmont sources. The rate at which feldspar breaks down in the weathering environment will cause Pb to disperse. Pb isotope ratios can be used to determine anthropogenic or geogenic origin in the WOCs (Kong et al., 2018).

CONCLUSION

South Carolina has an average [Pb] of 14.4 ppm, which is reflected both in the river and stream sediments (NURE), and soil and rock geochemical datasets. The distribution of South Carolina’s [Pb] is

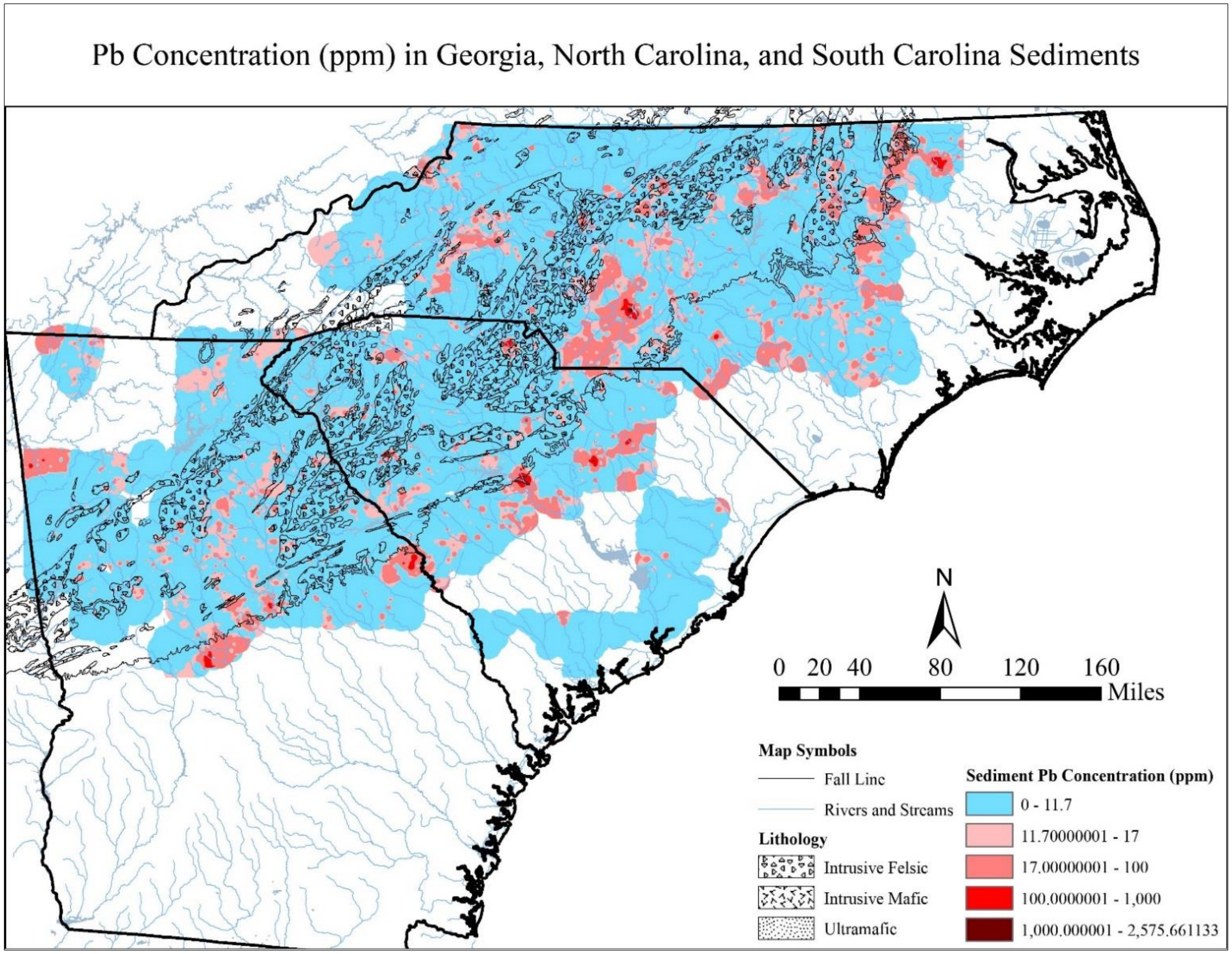

Figure 10. Depiction of Lead (Pb) concentrations (ppm) in Georgia, North Carolina, and South Carolina Sediments. Samples collected by the National Uranium Resource Evaluation (NURE) and compiled in U.S. Geological Survey (2016) along river and stream bodies and depicts both anthropogenic and geogenic Pb. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid. Rivers/streams are depicted by blue lines.

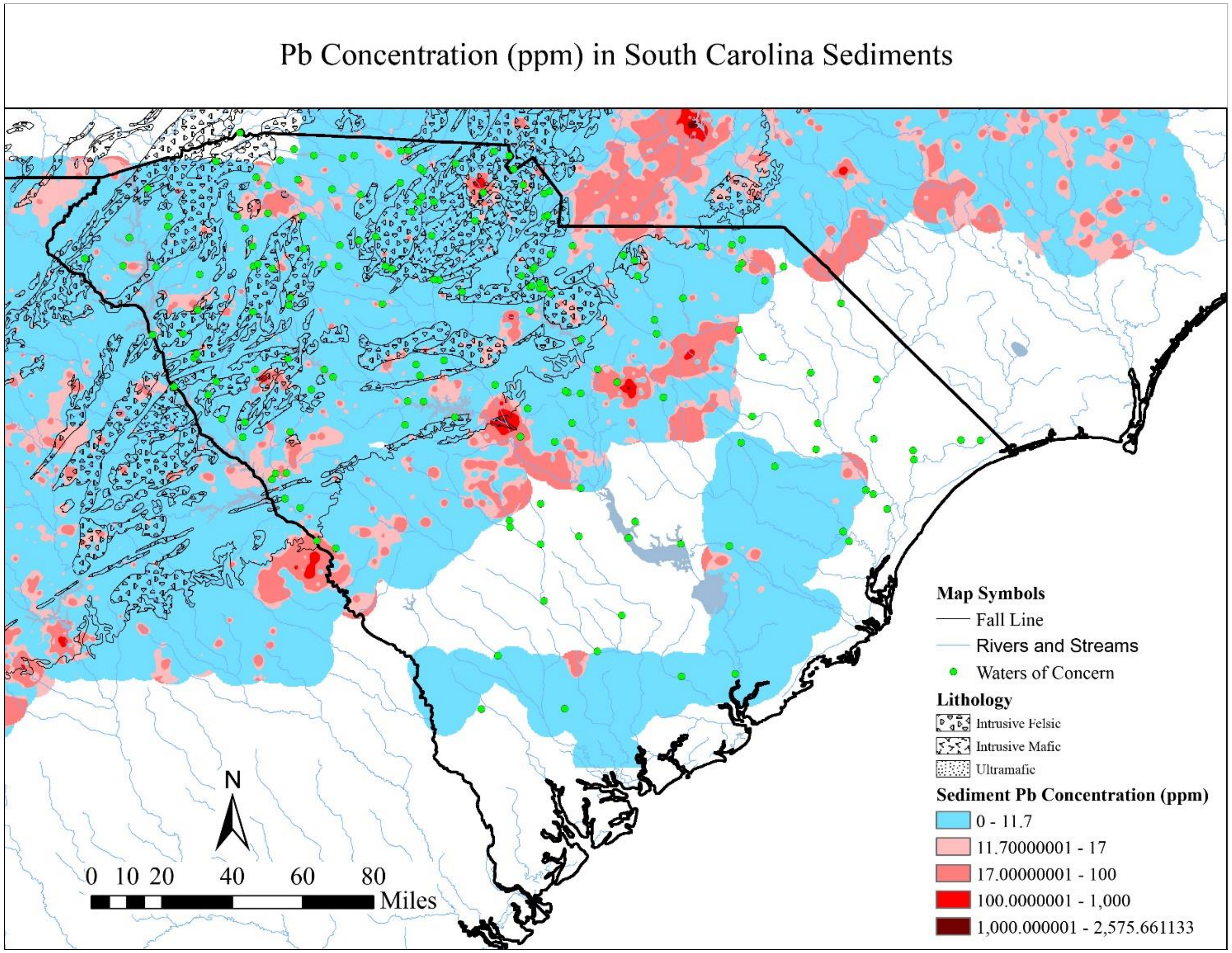

Figure 11. Depiction of Lead (Pb) concentrations (ppm) in South Carolina Sediments. Samples collected by the National Uranium Resource Evaluation (NURE) and compiled in U.S. Geological Survey (2016) along river and stream bodies and depicts both anthropogenic and geogenic Pb. A Geologic map taken from Hibbard et al. (2006) showing mafic and felsic rocks in the piedmont has been overlaid. Rivers/streams are depicted by blue lines. Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

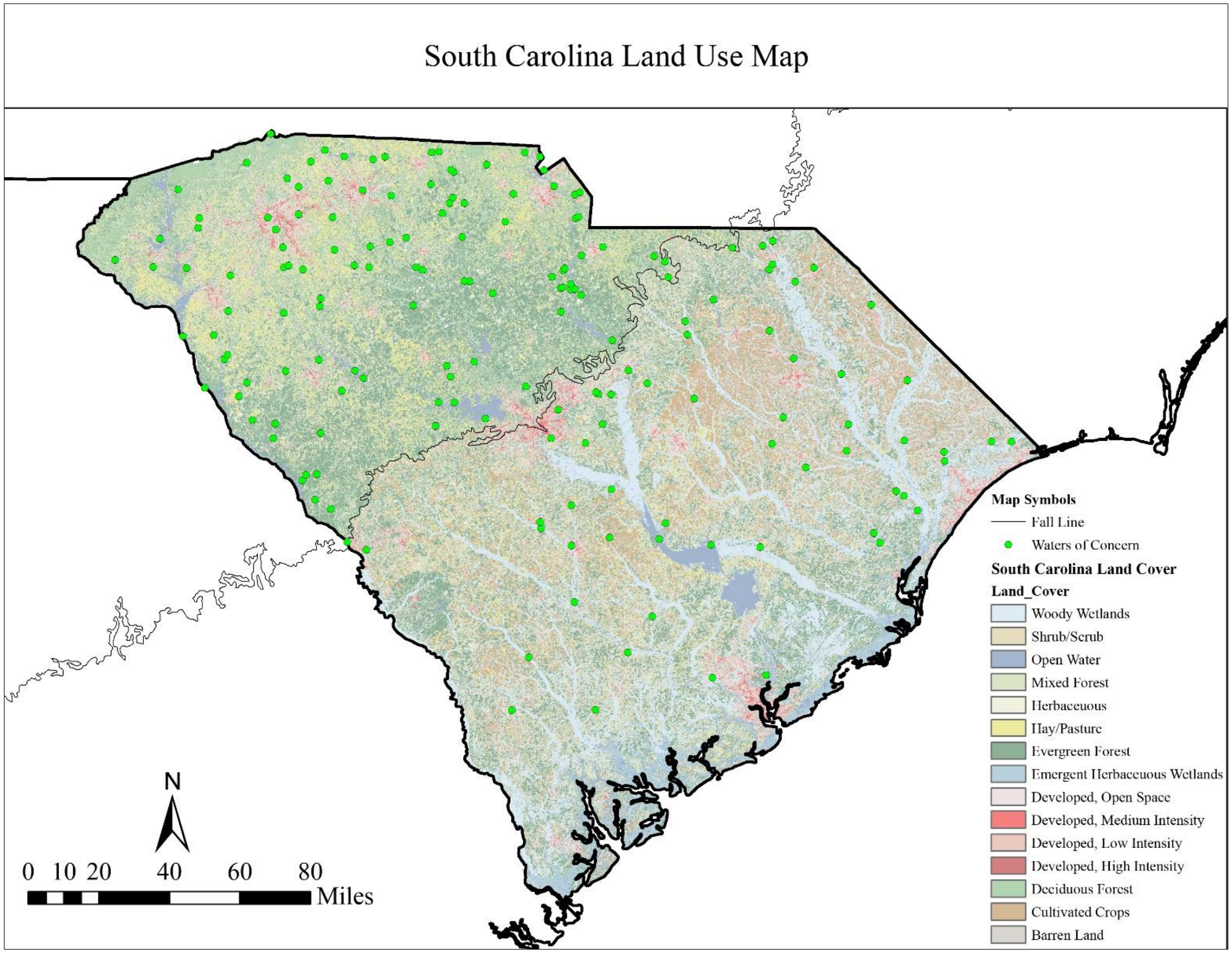

Figure 12. South Carolina Land Use map, information taken from Homer et al., 2015. Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

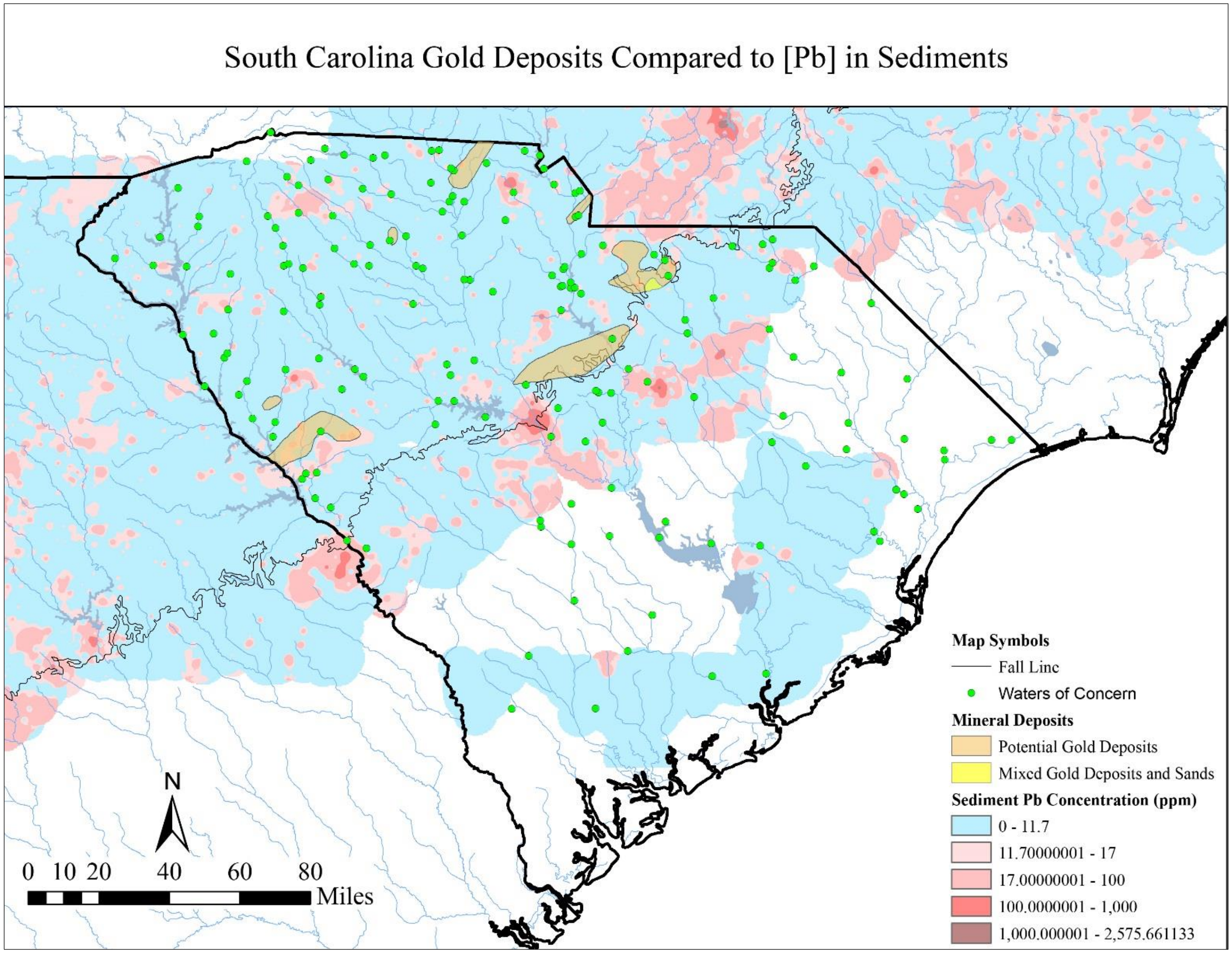

Figure 13. South Carolina river and stream sediments [Pb] (interpolated from U.S. Geological Survey, 2016) with a map of South Carolina Gold Deposits overlaid (Taken from Maybin, 1997). Green dots green dots indicate locations of waters of concern (WOC) provided by the South Carolina Department of Health and Environmental Control (DHEC).

similar to Georgia and North Carolina. The southeastern coastal states lack a prevalent history of Pb extraction, and there are no large deposits of galena, anglesite, or minerals in which Pb is a major component. In all three states, the majority of Pb appears to be concentrated in the Piedmont region. The cause of this areal concentration is suggested to be from proximity to numerous granitic plutons and felsic metamorphic rocks found in that region. The area of [Pb] soil anomalies parallels the granitic rocks of all three states. Pb moves from the granitic rocks into the soil through physical and chemical weathering. The subtropical climate in South Carolina limits the mobility of Pb in the sediment and soil profile. However, soft water similar to that found in the Piedmont can increase Pb mobilization in both surface and groundwater. Chemistry of soft water may be the ultimate factor in mobility. But more work needs to be done.

Even if some of the Pb in the WOCs originated from the sialic rocks in the Piedmont of South Carolina. However, certain samples collected around urban areas and in the Lower Coastal Plain may be related to anthropogenic sources. Further study on the WOC Pb isotope ratios is needed before a final assessment can be made related to the geochemical nature of South Carolina Pb.

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