ESOP

Environmental Surveillance and Oversight Program

2018 DATA REPORT

dhec
Healthy People. Healthy Communities.

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SRNS – Environmental Management Division

DOE-SR Environmental Quality Management Division

Purpose

PURPOSE OF THIS REPORT

WHAT: South Carolina's Department of Health and Environmental Control (SC DHEC) monitors the Department of Energy's Savannah River Site (SRS) for potential contaminants and produces a report of all its annual findings.

WHY: Due to nuclear material testing and lack of environmental regulations during the Cold War era, radioactive and non-radioactive constituents are present on SRS property. SRS has been sampling multiple media for many years. However, to verify the data being collected on and around SRS, SCDHEC conducts independent monitoring associated with the site to provide a second set of results for comparison.

HOW: In order to have a verification system for SRS's annual data, the Department of Energy-Savannah River (DOE-SR) partnered with SC DHEC as part of a 1995 Agreement in Principle (AIP) to create the Environmental Surveillance and Oversight Program (ESOP). ESOP is a division of SC DHEC specific to the Midlands Aiken Environmental Affairs Office. There are 10 team members with varying expertise working in ESOP that collect and analyze samples of air, water, soil, sediment, vegetation, milk, fish, and game for radiological and non-radiological constituents.

WHERE: Samples are collected on site property, around its perimeter, and in background locations. Depending upon the media, some DHEC sample locations coincide with those of DOE-SR. These locations are compared in our report.

WHEN: Samples are collected weekly, quarterly, biannually, and annually and are dependent upon the type of media and can be affected by availability of resource, accessibility, and weather.

Team Photo (left to right): Richard Burnett, Tim Mettlen, Katherine Kane, Gregg O'Quinn, Grace Anne Martin, Krista McCuen, Beth Cameron, Greg Mason, Thomas Rolka, Jeffrey Joyner

RADIATION – Occurs when an unstable atom tries to become stable by releasing some of its energy in the form of an alpha or beta particle or gamma wave.

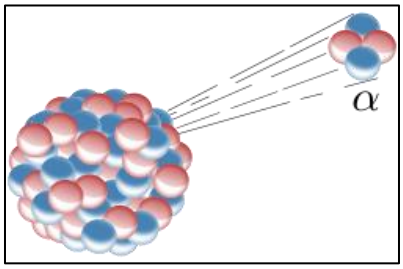
TYPES OF RADIATION

ALPHA – results when the nucleus of an atom releases two protons and two neutrons. Due to this particle being heavier in mass, it can be stopped by the air, skin, or paper. External exposure is not dangerous, but if swallowed, breathed in, or enters a person through a cut, it can harm the human body.

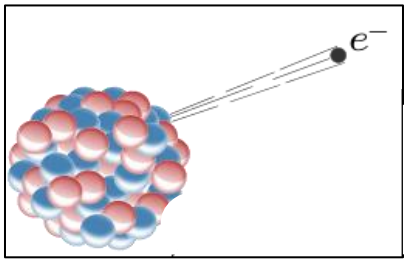
BETA – occurs when an atom releases an electron (negative charge). Since it is lighter in mass and faster moving, it can travel greater distances and can be stopped by a layer of wood or metal but can penetrate the outer layer of skin. It can cause skin burns.

GAMMA – is the release of pure energy that is fast moving and able to travel longer distances until it hits either concrete or lead. It will pass through the human body resulting in internal and external bodily damage.

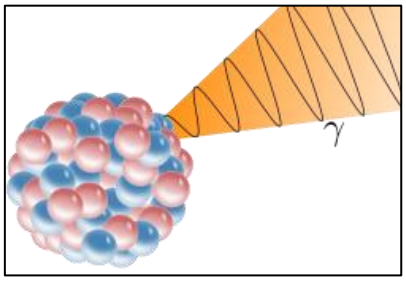
ALPHA RADIATION:



BETA RADIATION:



GAMMA RADIATION:



RADIATION:

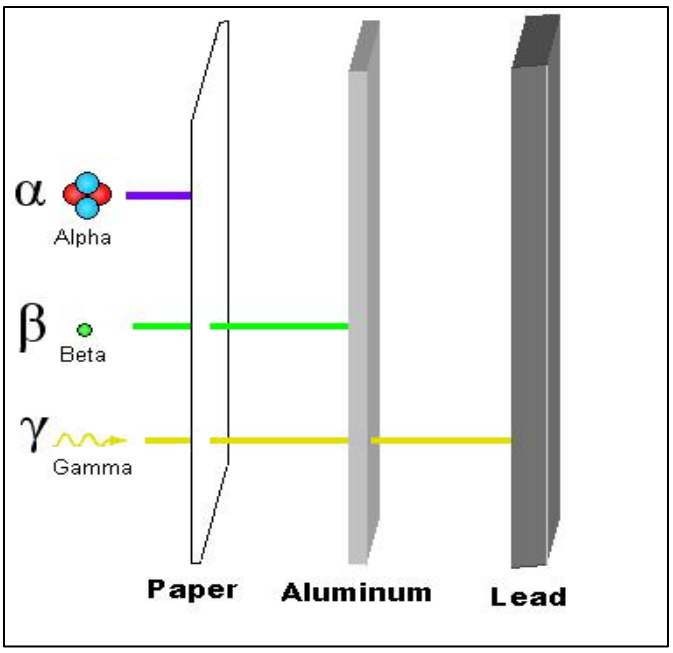


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Table 1. Gamma Analytes

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-7	Be-7
Cerium-144	Ce-144
Cobalt-58	Co-58
Cobalt-60	Co-60
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Potassium-40	K-40
Plutonium-238	Pu-238
Plutonium-239/240	Pu-239/240
Manganese-54	Mn-54
Sodium-22	Na-22
Lead-212	Pb-212
Lead-214	Pb-214
Radium-226	Ra-226
Ruthenium-103	Ru-103
Antimony-125	Sb-125
Thorium-234	Th-234
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Table 2. Metal Analytes

Analyte	Abbreviation
Barium	Ba
Beryllium	Be
Cadmium	Cd
Chromium	Cr
Copper	Cu
Lead	Pb
Manganese	Mn
Mercury	Hg
Nickel	Ni
Zinc	Zn

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Acronyms and Units of Measure

LIST OF ACRONYMS

ABR	Allendale Barricade
AEI	Average Exposed Individual
AIK	Aiken
AKN	Sample locations in Aiken County
ALD	Sample locations in Allendale County
ALN	Allendale
B/J	Beaufort-Jasper
BGN	Burial Grounds North
BOD	Biochemical Oxygen Demand
BWL	Sample locations in Barnwell County
CDC	Centers for Disease Control and Prevention
DIL	Derived Intervention Level
DKH	Dark Horse at the Williston Barricade
DHEC	South Carolina Department of Health and Environmental Control
DNR	South Carolina Department of Natural Resources
DO	Dissolved Oxygen
DOE	Department of Energy
DOE-SR	Department of Energy-Savannah River
ESOP	Environmental Surveillance and Oversight Program
EPA	United States Environmental Protection Agency
ESV	Ecological Screening Value
FDA	United States Food and Drug Administration
GW	Groundwater
HLW	High Level Waste
Hwy. 17	United States Highway 17
Hwy. 301	United States Highway 301
IAEA	International Atomic Energy Agency
JAK	Jackson
LLD	Lower Limit of Detection
LLW	Low Level Waste
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDL	Minimum Detection Level
MEI	Maximum Exposed Individual
NA	Not Applicable
ND	Not Detected
NEL	New Ellenton
NORM	Naturally Occurring Radioactive Material
NS	No Sample
NSBLD	New Savannah Bluff Lock & Dam
PCB	Polychlorinated Biphenyls
PRG	Preliminary Remediation Goals
RM	River Mile
RSL	Regional Screening Level
RSW	Radiological Surface Water
SCAT	South Carolina Advanced Technology

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SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
SSL	Soil Screening Level
SW	Surface Water
TKN	Total Kjeldahl Nitrogen
TLD	Thermoluminescent Dosimeter
TSP	Total Suspended Particulates
TSS	Total Suspended Solid
USFS	United States Forestry Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound

LIST OF ISOTOPES AND ABBREVIATIONS

I-129	Iodine-129
Sr-89/90	Strontium-89/90
Sr-90	Strontium-90

UNITS OF MEASURE

<	Less than
±	Plus or minus. Refers to one standard deviation unless otherwise stated
±2	Plus or minus 2 standard deviations.
°C	temperature in Celsius
Ci	Curie
cnt	counts
g/mL	grams per milliliter
hrs/yr	hours per year
kg/yr	kilograms per year
L/yr	liters per year
m^3/yr	cubic meters per year
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	Milligrams Per Liter
mL	milliliter
mL/L	milliliter per liter
MPN	Most Probable Number
mrem	millirem or milliroentgen equivalent man
NTU	Nephelometric Turbidity Unit
pCi/g	picocuries per gram
pCi/L	Picocuries per liter
pCi/m^3	picoCuries per cubic meter
pCi/mL	picocuries per milliliter
SU	standard units

Introduction

In 1950, the U.S. Atomic Energy Commission established the Savannah River Site (SRS) (1954-1992) with the mission of producing nuclear materials, primarily tritium and plutonium. SRS is a Department of Energy (DOE) facility located approximately 20 miles from Aiken, South Carolina. SRS boundaries lie within Aiken, Allendale, and Barnwell counties and span approximately 310 square miles. During legacy operations, radionuclides were released into the surface water, groundwater, soils, and atmosphere. Although the reactors are no longer operating, work continues at SRS with the primary focus being on cleaning up legacy wastes and remediating areas associated with former operations.

Due to the large number of contaminants that could potentially be released from SRS, the Centers for Disease Control and Prevention (CDC) performed a site assessment to determine the potential health effects of any discharged radionuclides to the off-site public. Most of the radiological releases originated from processes associated with the reactor areas (R, K, P, L, and C) and the separations areas, but there are other areas of releases as a result of the varied processes at SRS.

K Reactor at SRS – No longer in operation

Tritium was one of the principle nuclear materials produced at SRS to multiply the firepower of plutonium in nuclear weapons (Till et al., 2001). Tritium releases originated from processes associated with the reactors, separations areas, D-Area, and tritium facilities. The two main types of tritium releases came from direct site facility releases and migration from seepage basins in the separations areas, the burial ground, and the K-Area containment basin. In the early operational years, nearly 100 percent of the discharges to streams were related to direct releases. Tritiated water's ability to react chemically like nonradioactive water in living cells lends itself to be more hazardous biologically than tritium gas (CDC SRSHES, 1997).

Alpha-emitting and beta-emitting radionuclides were also released to liquid effluent. Alpha-emitting radionuclide releases from M-Area primarily affected Tims Branch, which ultimately flows into Upper Three Runs Creek. Fourmile Branch is the stream most affected by alpha- and beta-emitting releases coming from the separations areas, and releases from the reactor areas affected all streams except for Upper Three Runs Creek (Till et al., 2001). Steel Creek, Pen Branch, and Lower Three Runs Creek were mainly affected by beta-emitting releases from the reactors. Strontium-90 (Sr-90) is a main contributor of beta activity and came primarily from the reactors (Till et al., 2001).

Plutonium was manufactured at SRS in H-Area from fuel rods and in F-Area from targets (Till et al., 2001). Releases at SRS occurred primarily through the discharge of liquid effluent. Iodine-129 (I-129) is a fission product of reactor fuel that has a very long half-life. Most occurred during fuel processing (Till et al., 2001). Technetium-99 (Tc-99) was produced in SRS production reactors as a fission byproduct of uranium and plutonium. This radionuclide was released to the environment from the separations areas ventilation systems, the aqueous

environment from liquid waste in waste tanks, and the Solid Waste Disposal Facility (Westinghouse Savannah River Company [WSRC], 1993).

Strontium was a fission product in SRS reactors, subsequently released from F-area and H-area (WSRC, 1998). SRS operations have also released strontium into the environment through normal site operations and equipment failure.

H Canyon at SRS – Still in operation at the site

Routine operations at SRS have released cesium-137 (Cs-137) to the regional environment surrounding SRS. The most significant releases occurred during the early years of site operation when Cs-137 was released to seepage basins and site streams. The SRS facilities that have documented Cs-137 releases are the production reactors, separations areas, liquid waste facilities, the solid waste disposal facility, central shops, heavy water rework facility, Saltstone Facility, and the Savannah River National Laboratory (SRNL).

The Department of Energy is self-regulating. Until 1995, the public had to rely solely on DOE to ensure their health and the environment was protected. DOE formed an Agreement in Principal (AIP) with the South Carolina Department of Health and Environmental Control (SC DHEC) to perform independent environmental monitoring and oversight of SRS. This partnership provides an extra source of information to the public regarding the effectiveness of the DOE monitoring activities. From this agreement, the Environmental Surveillance and Oversight Program (ESOP) of DHEC was initiated to supplement and compliment monitoring functions of this unique facility. DHEC monitoring provides an added protection due to the potential for catastrophic environmental releases that pose a threat to the state.

Program development at SRS is stable and evolves based on changing missions. The foremost focus is on legacy waste and materials that are stored or have been disposed of on-site and pose a current release to the environment. Some of DOE-SR's primary activities are concerned with identifying concentrations and migration of radionuclides in the aquatic environment, detecting and verifying accidental releases, characterizing concentration trends, and determining associated impacts on human health and the environment. This report provides results of samples collected by DHEC related to SRS, trending data to document how contaminants are changing, and information on how these changes may impact the surrounding communities. The data reported by DHEC is based on detections only. DHEC's ESOP will continue its mission of monitoring and oversight around SRS to ensure the site's on-going activities continue to be safe for the public and the environment.

Chapter 1 Radiological Atmospheric Monitoring on and Adjacent to SRS

1.1.0 PROJECT SUMMARY

Example of an Air Monitoring Station with Rain Collection Pans and Glass Fiber Filters (on top) and Silica Gel Columns (inside)

Atmospheric transport has the potential to impact the citizens of South Carolina from releases associated with activities at SRS. The Atmospheric Monitoring project independently conducts routine, quantitative monitoring of atmospheric radionuclide releases associated with SRS, which it uses to identify concentration trends that could require further investigation. In 2017, nine air monitoring stations were used; however, two locations were discontinued in 2018 due to redundancy in location and logistics issues. Air monitoring capabilities in 2018 included 19 thermoluminescent dosimeter (TLD) monitoring locations and seven air monitoring stations that collected samples using glass fiber filters, rain collection pans, and silica gel columns. Glass fiber filters are used to collect total suspended particulates (TSP) in the air. Particulates are screened weekly for gross alpha and beta-emitting activity. Precipitation, when present, is sampled and analyzed monthly for tritium. Silica gel distillates of atmospheric moisture are analyzed monthly for tritium. TLDs are collected and analyzed every quarter for ambient beta/gamma levels. Radiological atmospheric monitoring sites were established to provide spatial coverage of the project area (Sections 1.4.0 Map and 1.5.0, Table 1). One air monitoring station is located at the center of the site, three of the air monitoring stations are at SRS perimeter, and three are found outside of the site boundary within public areas. Thirteen of the TLDs are on or near the site perimeter, one is in the center of the site, and five are within 25 miles of the site in surrounding population centers. DHEC emphasizes monitoring SRS perimeter locations for radionuclides in atmospheric media for potential public exposure.

1.2.0 RESULTS AND DISCUSSION

Air Monitoring Summary Statistics can be found in Section 1.6.0 and all Air Monitoring Data can be found in the 2018 DHEC Data File.

1.2.1 Total Suspended Particulates

DHEC and the Department of Energy-Savannah River (DOE-SR) had gross alpha detections in 2018. Section 1.5.0, Figure 1 shows average gross alpha activity for SRS perimeter locations and illustrates trends for the last five years of gross alpha values for DHEC and DOE-SR.

DHEC and DOE-SR had gross beta detections in 2018. Small seasonal variations at each monitoring location have been consistent with historically reported DHEC values (DHEC, 2017). Section 1.5.0, Figure 2 shows average gross beta activity for the SRS perimeter locations and illustrates trending of gross beta values for DHEC and DOE-SR from the last five years.

1.2.2 Ambient Beta/Gamma

DHEC conducts ambient beta/gamma monitoring through the deployment of TLDs around the perimeter of SRS. In 2018, ambient beta/gamma average quarterly totals ranged from 22.78 (TLD-07) to 34.68 (TLD-06) mrem. Section 1.5.0, Figure 3 shows data trends at the SRS Perimeter for average ambient beta/gamma values in TLDs for DHEC and DOE-SR.

1.2.3 Tritium

Tritium continues to be the predominant radionuclide detected in the perimeter samples. Most of the tritium detected in DHEC perimeter samples may be attributed to the release of tritium from tritium facilities, separation areas, and from wide spread and fleeting sources (SRNS, 2018).

Example of TLDs present at 19 locations

Tritium in Air

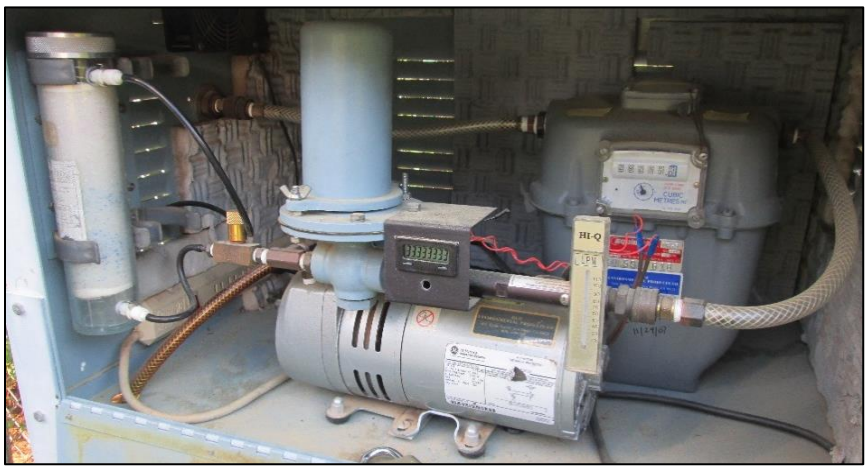
Tritium in air values reported by DHEC are the result of using the historical method of calculating an air concentration of tritium based on the upper limit value of absolute humidity (11.5 grams of atmospheric moisture per cubic meter) in the geographic region (National Council on Radiation Protection and Measures [NCRP], 1984). In 2018, the DHEC and DOE-SR average tritium activity was well below the 32,000 pCi/m^3 level that was derived by DHEC from the Nuclear Regulatory Commission (NRC) Annual Limit on Intake for tritium (NRC, 2018). This number is a dose equivalent concentration that would yield approximately 10 mrem to a member of the public at the site boundary.

The perimeter average for DHEC tritium in air activity (12.06 pCi/m^3) was lower than the DOE-SR perimeter average activity (78.92 pCi/m^3). These variations could be caused by different sampling locations, number of locations, sample frequency and method of calculating air concentration.

Average tritium in air activity at the SRS perimeter reported by DHEC for 2018 was higher than reported in 2017 and has fluctuated over the last six years. DOE-SR also reported an increase from 2017 to 2018 with fluctuations over the past six years. Section 1.5.0, Figure 4. illustrates data trends of atmospheric tritium activity for DHEC and DOE-SR as measured and calculated at the SRS perimeter.

Tritium in Precipitation

In 2018, DHEC and DOE-SR averages for tritium activity in precipitation were well below the Environmental Protection Agency standard of 20,000 pCi/L for drinking water (EPA, 2002d).



Inside View of Air Monitoring Station

Silica Gel Column

Section 1.5.0, Figure 5 shows average tritium in precipitation activity for SRS perimeter locations and illustrates trending tritium in precipitation values for DHEC and DOE-SR from the last five years.

During the 2018 sampling period, tritium detected in precipitation ranged from 244 pCi/L to 30112.3 pCi/L (found on-site at Burial Ground North (BGN) in June). The maximum reported value for DHEC perimeter locations was collected at the JAK air station with 6847.4 pCi/L in June. The DHEC average measured activity for perimeter locations above the lower limit of detection for tritium in precipitation was 2796 (± 2935.7) pCi/L. The DOE-SR average measured value for tritium activity in precipitation at the SRS perimeter was 1989.6 for all samples (± 2396.5 pCi/L) (SRNS, 2019).

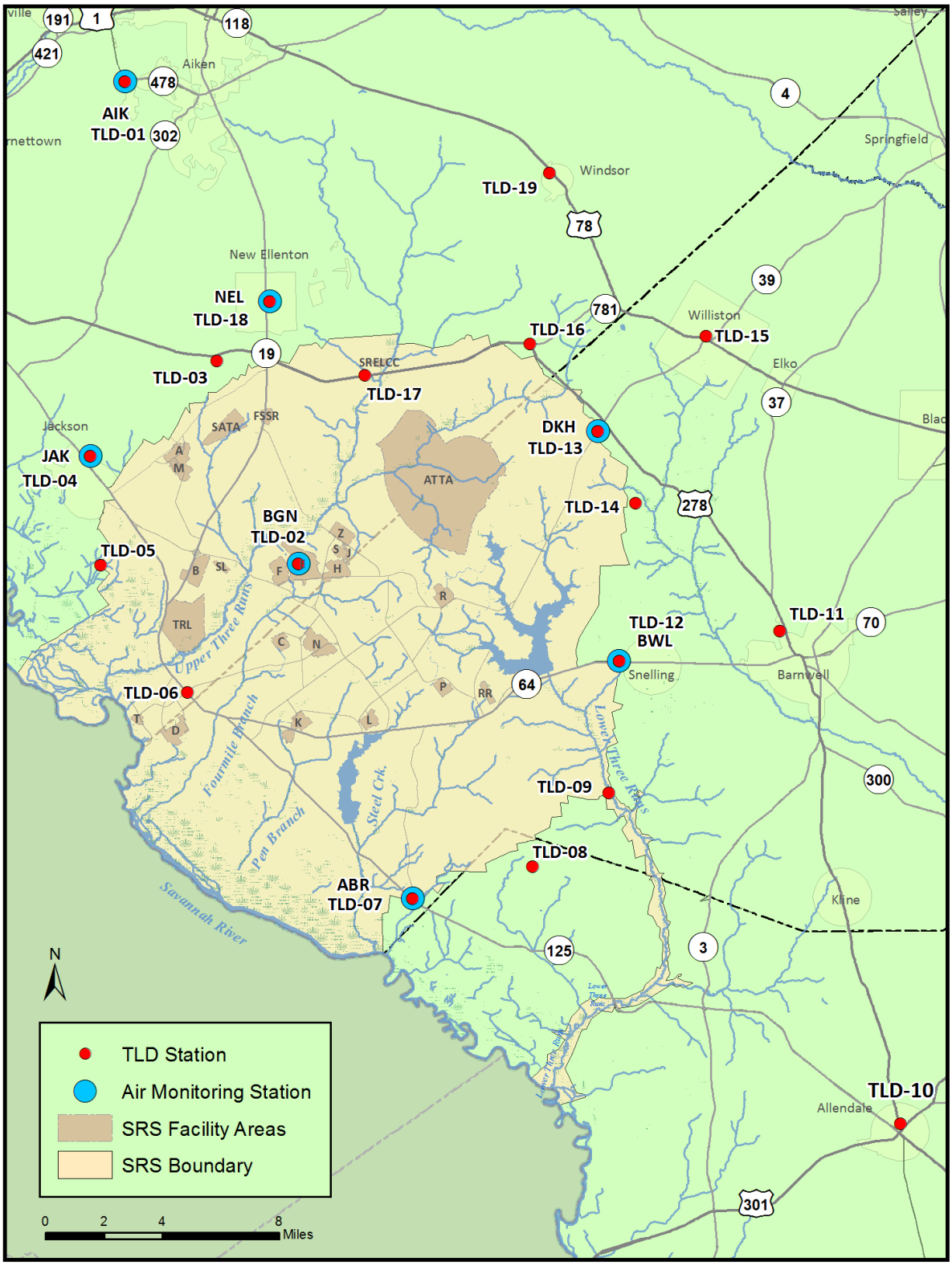
1.3.0 CONCLUSIONS AND RECOMMENDATIONS

All DHEC data collected in 2018 confirmed reported DOE-SR values for gross alpha/beta, ambient beta/gamma, and tritium in the environment at the SRS boundary with no anomalous data noted for any monitored parameters with the exception of the tritium increase during the late May/early June timeframe. The elevated tritium detections for that period were a result of the increase in monitored releases which was due to short-term maintenance activities in the Tritium Facility (SRNS, 2019).

Due to continued potential releases from site facilities (tritium facilities, separations areas, etc.), DHEC will continue to collect weekly TSP for gross alpha/beta, monthly atmospheric and precipitation tritium samples, and quarterly ambient beta/gamma samples.

1.4.0 MAP

Radiological Atmospheric Monitoring Sample Locations



2018 ESOP Radiological Air Monitoring Map www.scdhec.gov

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1.5.0 TABLES AND FIGURES

Table 1. Radiological Atmospheric Monitoring Locations

TLD Sample Locations

Sample ID	Location	Proximity to SRS
TLD-01	Collocated with AIK Air Station	Within 25 miles of SRS
TLD-02	Collocated with BGN Air Station	Center of SRS
TLD-03	Savannah River Research Park	SRS Perimeter
TLD-04	Collocated with JAK Air Station	SRS Perimeter
TLD-05	Crackerneck Gate	SRS Perimeter
TLD-06	TNX gate at Hwy 125	SRS Perimeter
TLD-07	Collocated with ABR Air Station	SRS Perimeter
TLD-08	Junction of Millet Road and Round Tree Road	SRS Perimeter
TLD-09	Patterson Mill Road at Lower Three Runs Creek	SRS Perimeter
TLD-10	Collocated with ALN Air Station	Within 25 miles of SRS
TLD-11	Barnwell Health Department	Within 25 miles of SRS
TLD-12	Collocated with BWL Air Station	SRS Perimeter
TLD-13	Collocated with DKH Air Station	SRS Perimeter
TLD-14	Seven Pines Road Collocated with SRS Air Station	SRS Perimeter
TLD-15	Williston Police Department	Within 25 miles of SRS
TLD-16	Junction of US-278 and SC-781	SRS Perimeter
TLD-17	US-278 SREL Conference Center and Hwy 125	SRS Perimeter
TLD-18	Collocated with NEL Air Station	SRS Perimeter
TLD-19	Windsor Post Office	Within 25 miles of SRS

Air Monitoring Stations

Sample ID	Location	Proximity to SRS
BGN	Burial Grounds North, SRS	Center of SRS
BWL	Barnwell Barricade	SRS Perimeter
ABR	Allendale Barricade	SRS Perimeter
DKH	Dark Horse	SRS Perimeter
NEL	New Ellenton, S.C.	SRS Perimeter/ Population Area
JAK	Jackson, S.C.	SRS Perimeter/ Population Area
AIK	Aiken Elementary Water Tower	Within 25 miles of SRS/ Population Area

TABLES AND FIGURES

Figure 1. DOE-SR and DHEC Comparison of Average Gross Alpha for Total Suspended Particulates at the SRS Perimeter (SRNS, 2015-2019; DHEC, 2015-2018)

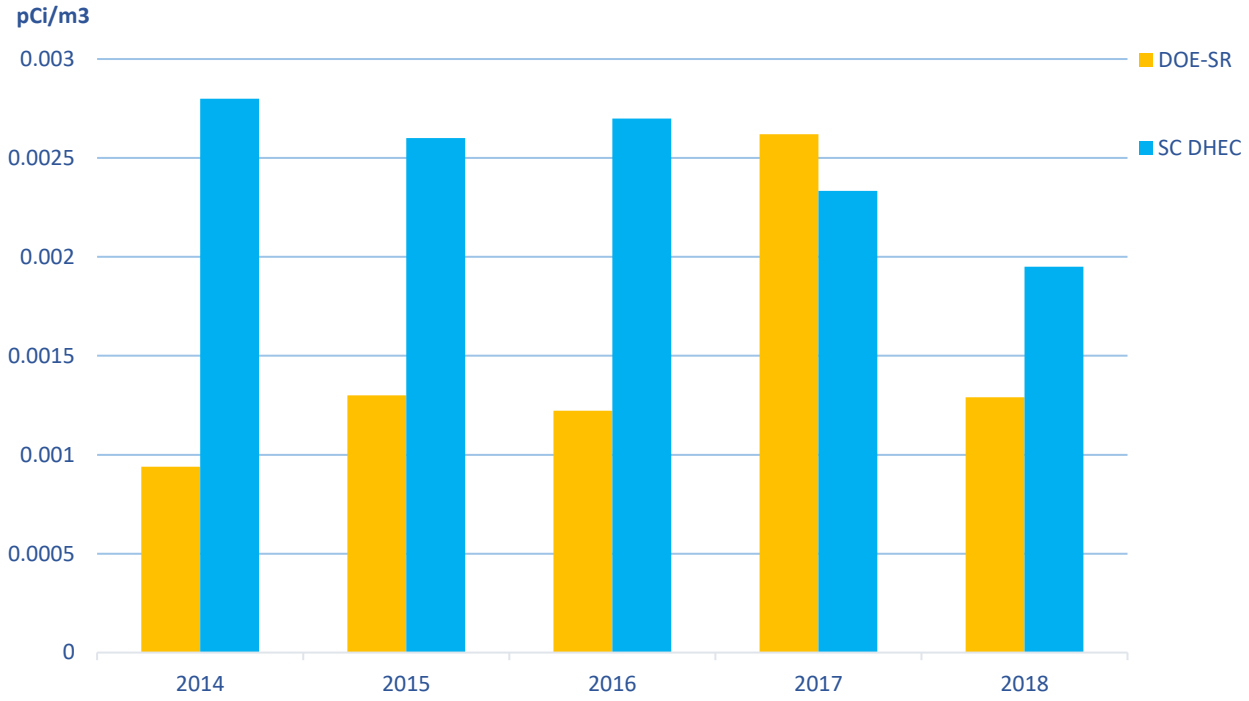

Figure 2. DOE-SR and DHEC Comparison of Average Gross Beta for Total Suspended Particulates at the SRS Perimeter (SRNS, 2015-2019; DHEC, 2015-2018)

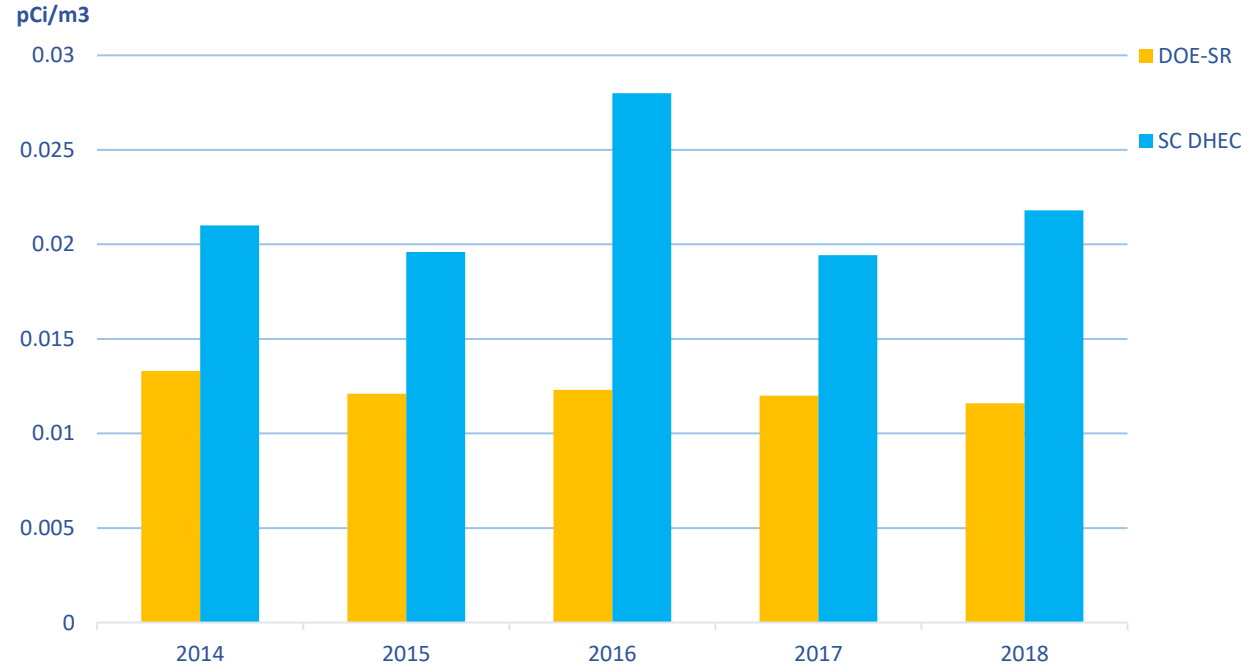

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Figure 3. DOE-SR and DHEC Comparison of Yearly Average Ambient Beta/Gamma in TLDs at the SRS Perimeter (SRNS, 2015-2019; DHEC, 2015-2018)

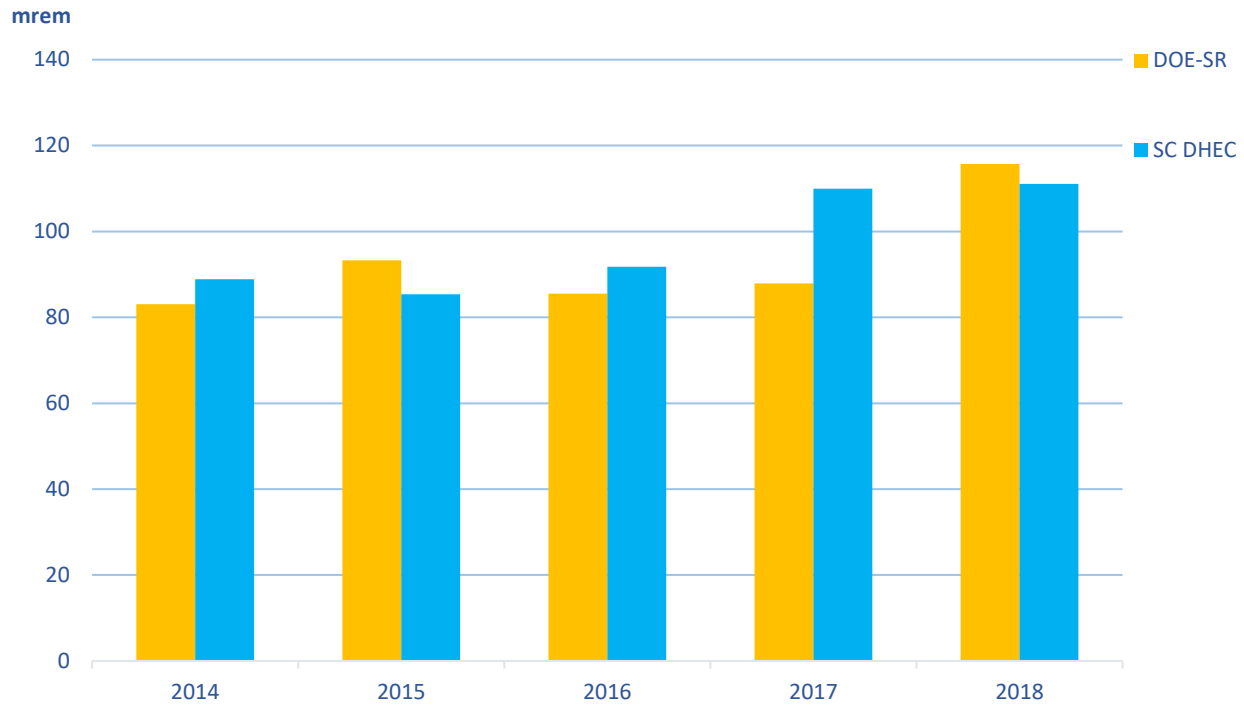

Figure 4. DOE-SR and DHEC Comparison of Average Tritium in Air at the SRS Perimeter (SRNS, 2015-2019; DHEC, 2015-2018)

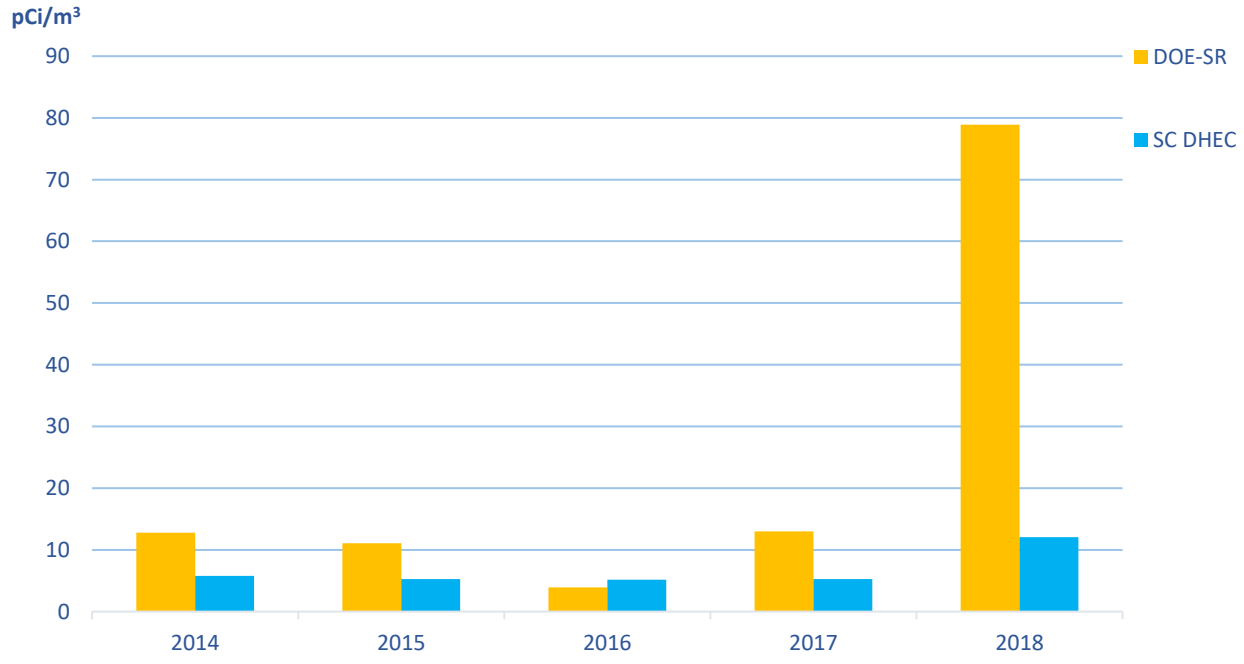

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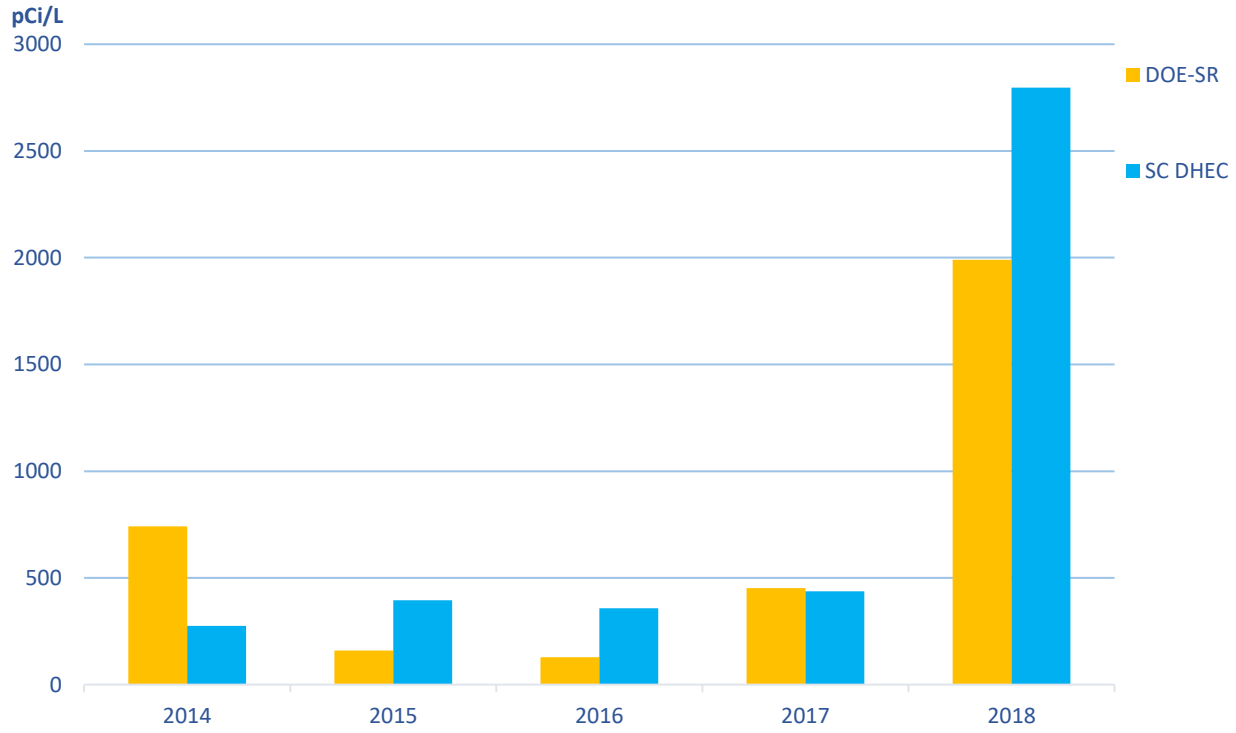
Figure 5. DOE-SR and DHEC Comparison of Average Tritium in Precipitation at the SRS Perimeter (SRNS, 2015-2019; DHEC, 2015-2018)



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1.6.0 SUMMARY STATISTICS

2018 Quarterly Averages of Ambient TLD Beta/Gamma Data

Sample ID	Average (mrem)	Standard Deviation (mrem)	Median (mrem)	Minimum (mrem)	Maximum (mrem)
TLD-01	22.30	1.49	20.20	23.70	22.65
TLD-02	36.47	1.20	35.30	37.70	36.40
TLD-03*	25.95	1.98	24.10	28.40	25.65
TLD-04*	23.58	1.76	21.90	26.00	23.20
TLD-05*	30.00	0.94	28.80	31.10	30.05
TLD-06*	34.68	1.79	32.00	35.70	35.50
TLD-07*	22.78	0.43	22.50	23.40	22.60
TLD-08*	30.00	1.16	28.60	31.00	30.20
TLD-09*	29.83	1.01	28.80	31.00	29.75
TLD-10	25.65	1.76	23.80	27.30	25.75
TLD-11	30.28	1.64	28.00	31.90	30.60
TLD-12*	28.23	1.41	26.70	29.90	28.15
TLD-13*	23.70	1.61	22.50	26.00	23.15
TLD-14*	31.45	1.50	29.90	33.50	31.20
TLD-15	30.55	0.86	29.30	31.20	30.85
TLD-16*	24.03	1.34	22.70	25.50	23.95
TLD-17*	29.65	2.05	28.40	32.70	28.75
TLD-18*	27.10	1.44	25.80	28.90	26.85
TLD-19	29.30	2.61	26.10	32.50	29.30

NOTE: * IS A PERIMETER LOCATION

SUMMARY STATISTICS

2018 DHEC Air Station Gross Alpha Data in pCi/m^3

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	0.0019	0.0009	0.0016	0.0007	0.0046	50	51
Dark Horse (DKH)	0.0022	0.0021	0.0016	0.0004	0.0145	50	51
Aiken Elementary Water Tower (AIK)	0.0018	0.0009	0.0017	1.06E-06	0.0050	51	52
New Ellenton, S.C. (NEL)	0.0020	0.0010	0.0018	0.0007	0.0054	49	52
Jackson, S.C. (JAK)	0.0020	0.0010	0.0019	0.0004	0.0046	51	52
Burial Ground North (BGN)	0.0018	0.0008	0.0017	0.0004	0.0049	50	51
Barnwell Barricade (BWL)	0.0018	0.0009	0.0015	1.07E-06	0.0044	51	52

2018 DHEC Air Station Gross Beta Data in pCi/m^3

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	0.0208	0.0064	0.0208	0.0082	0.040	51	51
Dark Horse (DKH)	0.0239	0.0177	0.0211	0.0087	0.137	51	51
Aiken Elementary Water Tower (AIK)	0.0188	0.0058	0.0182	0.0062	0.033	52	52
New Ellenton, S.C. (NEL)	0.0217	0.0066	0.0215	0.0085	0.038	52	52
Jackson, S.C. (JAK)	0.0221	0.0067	0.0217	0.0089	0.040	52	52
Burial Ground North (BGN)	0.0220	0.0069	0.0219	0.0091	0.040	51	51
Barnwell Barricade (BWL)	0.0207	0.0062	0.0202	0.0092	0.034	52	52

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SUMMARY STATISTICS

2018 DHEC Air Station Tritium Data in pCi/m^3

Location	Average *	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	3.82	1.37	3.60	2.69	6.8	7	12
Dark Horse (DKH)	12.08	18.70	6.07	3.40	54.4	7	12
Aiken Elementary Water Tower (AIK)	12.42	25.59	3.35	2.89	75.7	8	12
New Ellenton, S.C. (NEL)	23.62	53.31	6.25	2.80	165.7	9	12
Jackson, S.C. (JAK)	14.11	26.17	4.97	3.68	88.2	10	12
Burial Ground North (BGN)	177.82	108.07	166.10	8.00	371.4	12	12
Barnwell Barricade (BWL)	5.35	2.25	4.92	3.26	10.2	10	12

*Average of detections

2018 DHEC Tritium in Precipitation Data in pCi/L

Location	Average *	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	ND	NA	NA	<LLD	<LLD	0	12
Dark Horse (DKH)	459	NA	459	<LLD	459	1	11
Aiken Elementary Water Tower (AIK)	1012.2	1086.3	1012.2	244	1780	2	11
New Ellenton, S.C. (NEL)	2575.9	3298.9	2575.9	243	4909	2	12
Jackson, S.C. (JAK)	4185.7	3764.2	4185.7	1524	6847.4	2	11
Burial Ground North (BGN)	4789.3	8137.4	2117.9	691.8	30112.3	12	12
Barnwell Barricade (BWL)	ND	NA	NA	<LLD	<LLD	0	9

*Average of detections

Chapter 2 Ambient Groundwater Monitoring Adjacent to SRS

2.1.0 PROJECT SUMMARY

DHEC currently utilizes a regional groundwater monitoring well system consisting of cluster wells (C-wells) and network wells (private wells and public water systems). This groundwater well network consists of approximately 75 wells that are cyclically sampled every five years by DHEC. The C-wells are owned and maintained by the South Carolina Department of Natural Resources (DNR). These cluster wells are screened from shallow surficial aquifers to deeper aquifers up to depths exceeding 1,400 feet below ground surface. The C-well clusters are situated around the perimeter of SRS.

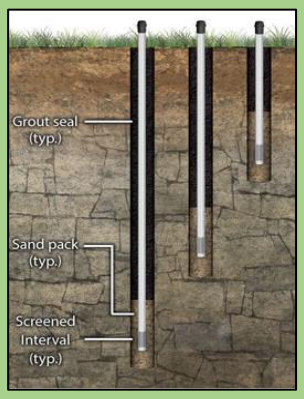
Monitoring these wells allows DHEC to evaluate groundwater quality adjacent to SRS, compare results with historical data, determine any potential SRS contaminant migration offsite, expand current ambient water quality databases, and provide the public with independently generated, region specific, groundwater quality information.

Groundwater samples are collected from wells within a 10-mile site boundary and background samples are collected from available municipal and private groundwater wells located between 30 and 100 miles from the SRS center point. A 10-mile sampling perimeter was selected based on regional well availability, and comparative review of known or suspected sources of groundwater contamination and local groundwater flow patterns. The project map in Section 2.4.0 depicts the network groundwater well locations, the extent of the study area, and the wells sampled in 2018. DHEC evaluates five aquifer zones (Upper Three Runs, Gordon, Crouch Branch, McQueen Branch, and the Piedmont Hydrogeologic Province).

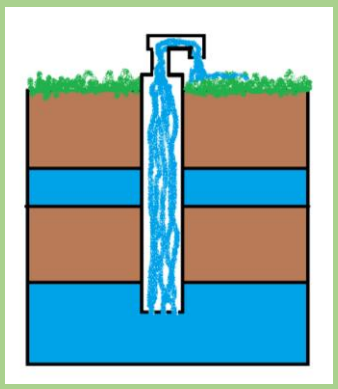
An **AQUIFER** is soil and/or rock containing water below the ground surface.

CLUSTER WELLS vs. NETWORK WELLS

CLUSTER WELLS are multiple wells that are at the same location but are drilled to varying depths to screen different aquifers.



NETWORK WELLS are single wells at a specific location screened in a specific aquifer.



2.2.0 RESULTS AND DISCUSSION

Groundwater Monitoring Summary Statistics can be found in Section 2**.7.**0 and all Groundwater Monitoring Data can be found in the 2018 DHEC Data File.

DHEC collected groundwater from 15 C-Well Cluster wells (C-01, C-02, and C-03) and privately owned Greene Wells. Based on a review of the wet chemistry, metals, tritium, gross alpha, non-volatile beta, and gamma-emitting radioisotope analytical data provided by the DHEC

Above: Cluster well being pumped and field tested for field parameters. Right: Water parameter measurement system

analytical and radiological laboratories, only naturally occurring or NORM contaminants were detected in the groundwater wells sampled. See Section 2.5.0, Table 1 for a list of the network of sampling wells with their assigned aquifer.

Groundwater investigations performed by state and federal agencies such as DHEC, DNR, and the United States Geological Survey (USGS) have confirmed the presence of naturally occurring radionuclides in groundwater across South Carolina (Agency for Toxic Substances and Disease Registry [ATSDR], 2007). However, contaminants commonly found in SRS groundwater include: volatile organic compounds (VOCs), metals, and tritium. If known contaminants are found in wells located within the DHEC sampling network, the affected wells would be investigated further to help determine the source.

The United States Environmental Protection Agency (EPA) has a drinking water Maximum Contaminant Level (MCL) of 20,000 pCi/L for tritium, 15 pCi/L for gross alpha, and 50 pCi/L for non-volatile beta (EPA, 2002d). In 2018, DHEC did detect tritium, gross alpha, or non-volatile beta in 11 of its 15 groundwater wells but all were well below action levels. Those results can be found in Section 2.7.0.

Collecting water from pump to test for non-radiological material

The presence of metals and other non-radiological contaminants in the environment can be attributed to man-made processes (industrial manufacturing), agricultural activities, and the natural breakdown of mineral deposits. A review of metal and non-radiological detections indicates that their limited presence and concentration are most likely due to the parameters that are naturally occurring. In 2018, 15 groundwater samples were collected to test for VOCs, nitrate/nitrite, metals, mercury, and turbidity. All detected non-radiological parameters were below their respective MCLs and/or action levels, with the exception of Iron at an average of 0.401 mg/L which is above the Secondary Maximum Containment Level of 0.3 mg/L (EPA, 2018).

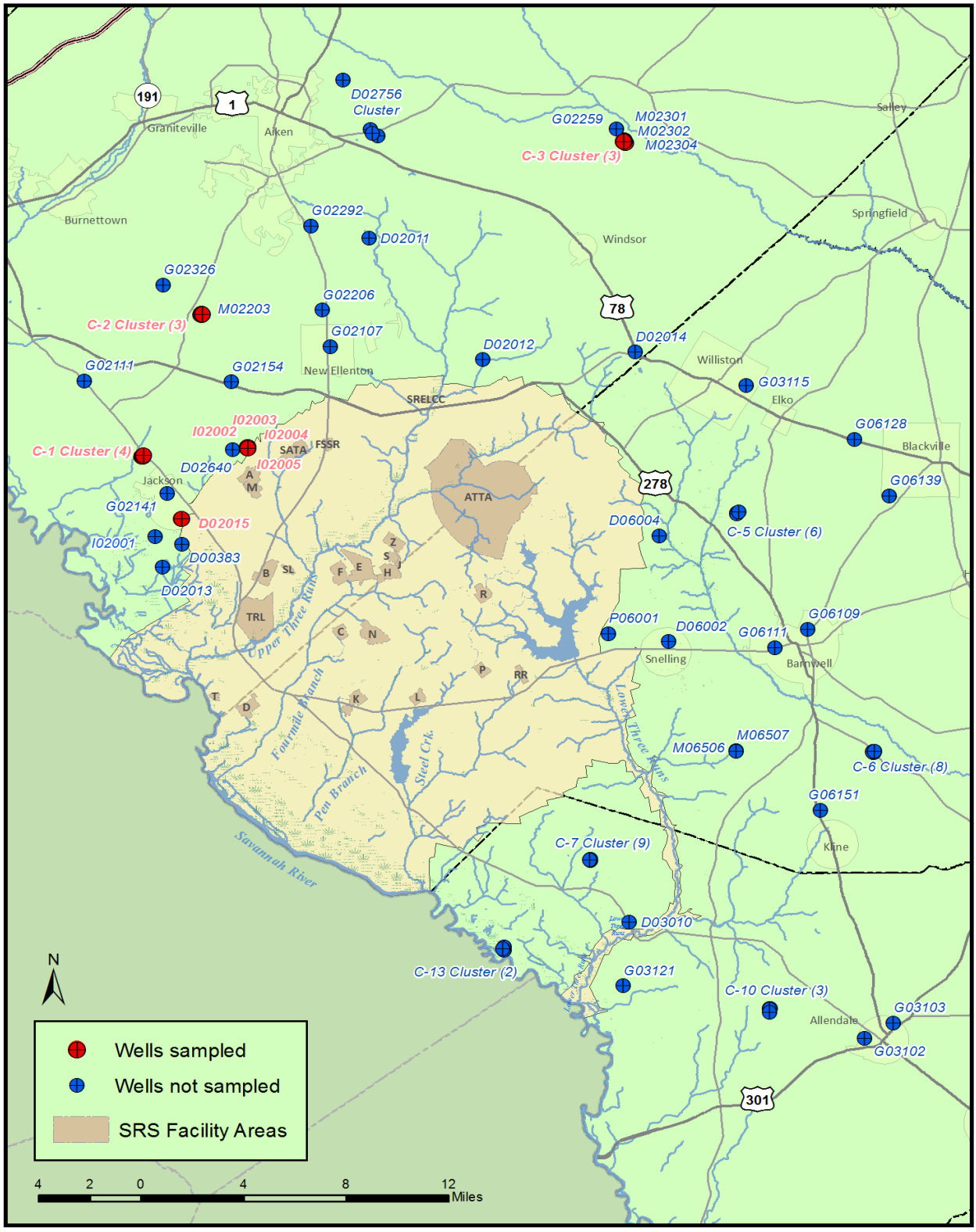
2.3.0 CONCLUSIONS AND RECOMMENDATIONS

DOE-SR collects groundwater samples from a separate onsite monitoring well network, therefore, direct DHEC offsite groundwater comparisons could not be made. However, the 2018 SRS report identifies numerous areas of groundwater contamination throughout the SRS property (SRNS, 2019). Various contaminants such as VOCs, tritium, gross alpha/beta radionuclides, and strontium-90 have been found in these areas (SRNS, 2017). Naturally occurring parameters detected in the 2018 DHEC groundwater sampling event include aluminum, cadmium, calcium, copper, iron, lead, magnesium, manganese, sulfate, thallium, and zinc, as well as nitrate/nitrates.

Due to identified areas of groundwater contamination on SRS, DHEC will continue to monitor groundwater quality to identify any future SRS offsite contaminant migration.

2.4.0 MAP

2018 Groundwater Sampling Locations



2018 ESOP Groundwater Monitoring Map www.scdhec.gov

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2.5.0 TABLES AND FIGURES

Table 1. DHEC Groundwater Monitoring Wells Sampled in 2018

Well Number	Well Name	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
M02101	SCDNR Cluster C-01, AIK-2378	220.3	185	CB
M02102	SCDNR Cluster C-01, AIK-2379	224.2	266	CB
M02103	SCDNR Cluster C-01, AIK-2380	228.9	385	MB
M02104	SCDNR Cluster C-01, AIK-902	231.9	511	MB
M02202	SCDNR Cluster C-02, AIK-825	418.8	231	CB
M02204	SCDNR Cluster C-02, AIK-818	418.3	425	MB
M02205	SCDNR Cluster C-02, AIK-817	418.9	535	MB
M02303	SCDNR Cluster C-03, AIK-847	299	193	CB
M02305	SCDNR Cluster C-03, AIK-845	296.9	356	MB
M02306	SCDNR Cluster C-03, AIK-826	294.9	500	MB
I02002	Greene Well #1	380	278	CB
I02003	Greene Well #2	380	280	CB
I02004	Greene Well #3	372	276	CB
I02005	Greene Well #4	372	276	CB
D02015	Greene Residence Well	192	100	SP

Notes:
1). ft amsl is feet above mean sea level
2). ft bgs is feet below ground surface
3). CB is Crouch Branch
4). MB is McQueen Branch
5). SP is Steeds Pond

2.6.0 Regional Geology

The study area, including SRS, is in west-central South Carolina. The regional geology is characterized as the Aiken Plateau of the Coastal Plain physiographic province. SRS is located approximately 20 miles southeast of the fall line of the Piedmont physiographic province. A thickening wedge of Cenozoic and Cretaceous sediment, which overlies Paleozoic crystalline basement rock and Triassic sedimentary rocks, underlies the area south of the fall line (Aadland et al., 1995). The sediment, consisting of alternating sands and clays with Tertiary carbonates, thickens toward the southeast from zero at the fall line to more than 1,800 feet at the Allendale-Hampton County line. The sediment is about 1,100 feet thick beneath the central portion of SRS and dips toward the southeast at about 35 feet per mile. A more detailed review of regional geology and hydrogeology is given in the 2020 DHEC Groundwater Project Plan.

2.7.0 SUMMARY STATISTICS

2018 Radiological Groundwater Data in pCi/L

Analyte	Average Concentration	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Tritium	217.5	246.2	85.7	65	502	3	15
Gross Alpha	5.2	6.6	2.1	1.5	19.5	8	15
Gross Beta	11.6	1.3	11.6	10.7	12.5	2	15

2018 Non-radiological Groundwater Data in mg/L

mg/L	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples	MCL
Aluminum	0.142	0.122	0.096	0.057	0.32	4	10	0.05-0.2*
Cadmium	0.00027	0.00023	0.00017	0.00014	0.00061	4	15	0.005
Calcium	1.253	2.163	0.4	0.2	8.7	15	15	NA
Chloride	1.54	0.151	1.6	1.2	1.7	10	10	250*
Copper	0.1	NA	0.1	0.1	0.1	1	15	1.3
Lead	0.0148	0.018	0.0085	0.0021	0.055	7	15	0.015
Nitrate/ Nitrite	0.412	0.329	0.45	0.022	0.75	9	15	1
Iron	0.401	0.510	0.19	0.083	1.3	5	15	0.3*
Magnesium	0.204	0.056	0.2	0.084	0.31	15	15	NA
Manganese	0.0156	0.002	0.016	0.014	0.017	2	15	0.05*
Sulfate	7.7	NA	7.7	<LLD	7.7	1	15	250*
Thallium	0.0003	0.0002	0.0003	0.0002	0.0006	6	15	0.002
Zinc	1.444	0.898	1.25	0.022	2.8	10	15	5*

Notes:
1). Values are based upon detections only.
2). * is representative of a Secondary Maximum Contaminant Level (MCL)

Chapter 3 Radiological Monitoring of Drinking Water Adjacent to SRS

3.1.0 PROJECT SUMMARY

DHEC evaluates drinking water quality to provide information on the radiological impact of SRS to community drinking water systems adjacent to and downstream of the site. DHEC samples 23 drinking water systems. Monthly composite samples are taken from four Savannah River-fed systems: one upstream location (North Augusta) and three downstream of SRS (Purrysburg Beaufort/Jasper (B/J), Chelsea B/J, and Savannah, Georgia). Additionally, semi-annual grab samples are collected from 19 selected public drinking water systems that are not primarily served by the Savannah River. These systems are located outside of the SRS perimeter and are up to 30 miles from the center point of the site (Map, Section 3.4.0).

SURFACE WATER – water that collects on the surface of the ground in the form of streams, ponds, lakes, rivers, or the ocean.

GROUNDWATER – water stored underground in sediment pores or crevices in rock. It may eventually be used by plants, taken up through wells by humans, or discharge into another body of water.

DRINKING WATER – Surface water or groundwater that has been treated through a cleaning process to be available for healthy consumption by humans.

In 2018, DOE-SR collected drinking water from two surface water fed systems (North Augusta and Purrysburg B/J) that are collocated with the DHEC Savannah River fed systems. Currently, DOE-SR does not conduct drinking water sampling from other public systems off SRS property. DHEC and DOE-SR analyze for and compare all samples for gross alpha, non-volatile beta, gamma-emitting radionuclides, and tritium.

3.2.0 RESULTS AND DISCUSSION

Drinking Water Monitoring Summary Statistics can be found in Section 3.6.0 and all Drinking Water Monitoring Data can be found in the 2018 DHEC Data File.

In 2018, DHEC and DOE-SR detected tritium above the lower limit of detection (LLD) in all the Savannah River-fed systems both upstream and downstream of SRS. Average tritium levels at the upstream system in North Augusta were 257 pCi/L for DHEC and 183.6 pCi/L for DOE-SR. The DHEC tritium detectable average for all systems downstream of SRS (Purrysburg B/J, Chelsea B/J and Savannah, Georgia) was 460 pCi/L, and the DOE-SR average for Purrysburg B/J was 391.4 pCi/L. These activities are well below the EPA established 20,000 pCi/L drinking water limit (EPA, 2002d). Section 3.5.0, Figure 1 illustrates the DHEC trending data and Figure 2 illustrates a DHEC and DOE-SR comparison for Savannah River-fed systems over the past five years.

Gamma-emitting radionuclides of concern List of Tables, Table 1, page ix, were not detected above the LLD and have not been detected for any of the drinking water samples collected by DHEC or DOE-SR since 2002.

DHEC detected gross alpha in seven of the 19 samples from the drinking water systems not supplied by the Savannah River (Aiken, Langley Water District, College Acres Public Water District, Beech Island, Valley Public Service Authority, Williston, and SCAT Park) at an average of 3.11 pCi/L. DHEC did not find gross alpha in the four Savannah River-fed systems. DOE-SR

had no gross alpha detections in the upstream (North Augusta) or downstream (Purrysburg) river locations.

DHEC detected non-volatile beta at one sample location (Williston) from the drinking water systems not supplied by the Savannah River at 5.57 pCi/L. DHEC and DOE-SR both had detections of gross beta in the upstream and downstream Savannah River-fed systems (Section 3.5.0, Table 2). Speciation is not conducted for gross alpha or non-volatile beta unless there is a detection above their respective EPA MCLs of 15 pCi/L and 50 pCi/L (EPA, 2002d).

Section 3.5.0, Figures 3 and 4 illustrate the trends in gross alpha and non-volatile beta activities over the past five years. Although there were several detections above the LLD during the 2018 reporting period, none of the analytes exceeded their respective EPA established MCLs. Gross alpha and non-volatile beta, at their observed concentrations, are not considered to be known human health risks.

3.3.0 CONCLUSIONS AND RECOMMENDATIONS

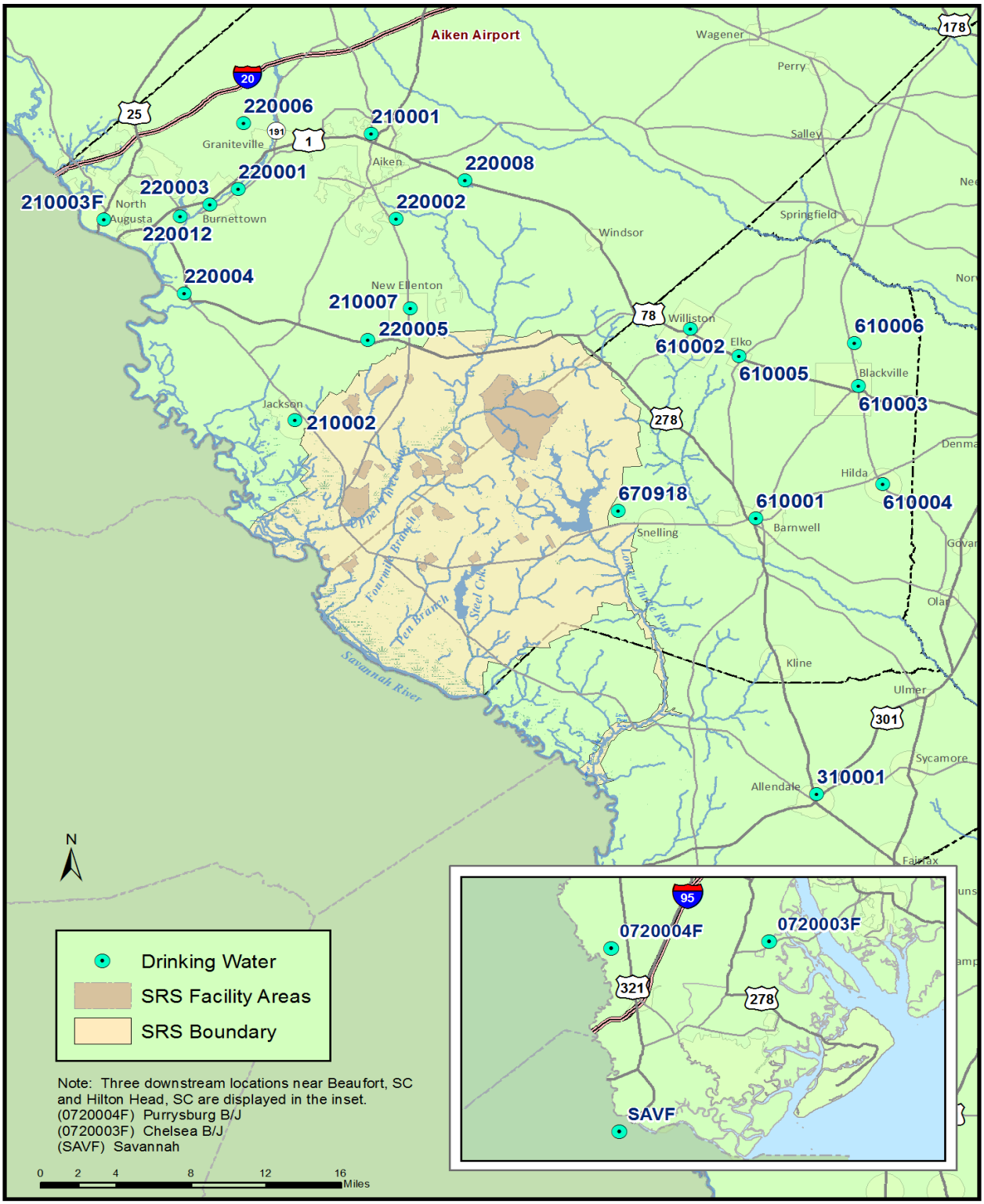
Tritium continues to be the most abundant radionuclide detected in public drinking water supplies potentially impacted by SRS. Tritium was detected in both groundwater and surface water systems during 2018, while tritium was detected only in surface water in 2017. Observed tritium activities were low when compared to the EPA MCL for tritium in drinking water, which is 20,000 pCi/L. Detections of gross alpha and non-volatile beta were all below their respective MCLs. DOE-SR does not sample systems not served by the Savannah River; therefore, DHEC will continue to monitor these off-site public water systems in the event these wells are impacted by contaminated groundwater from SRS.

The DHEC Drinking Water Monitoring Project continues to be an important source of essential data for assessing human health exposure pathways. DHEC will continue to monitor surface water quality due to the extent of the surface water contamination on SRS, and its potential to migrate, and potentially impact, drinking water systems downstream from SRS. Continued sampling will also provide the public with an independent source of radiological data for drinking water systems within the SRS study area.

DHEC continues to reevaluate the drinking water systems monitored by the drinking water project. Primary and background drinking water systems will be added and removed from the list of sampled drinking water systems as deemed necessary to maintain monitoring coverage. Sampling of background water systems will be done in the future, as they provide a more complete understanding of the distribution and nature of naturally occurring radionuclides in South Carolina drinking water systems.

3.4.0 MAP

Drinking Water Sampling Locations



2018 ESOP Drinking Water Monitoring www.scdhec.gov

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3.5.0 TABLES AND FIGURES

Table 1. Drinking Water Systems Sampled by DHEC

System Number	System Name	Number of Taps	Population
0210001	Aiken	19,444	42,286
0210002	Jackson	1,312	3,602
0210007	New Ellenton	2,417	5,763
0220001	Langley Water District	324	754
0220002	College Acres Public Water District	539	1,330
0220003	Bath Water District	315	755
0220004	Beech Island	3,320	7,916
0220005	Talatha Water District	727	1,698
0220006	Breezy Hill Water District	5,808	13,692
0220008	Montmorenci Water District	1,457	3,442
0220012	Valley Public Service Authority	2,959	6,828
0310001	Allendale	1,530	3,882
0610001	Barnwell	2,097	4,557
0610002	Williston	1,629	2,953
0610003	Blackville	1,208	2,973
0610004	Hilda	124	311
0610005	Elko	150	371
0670075	Healing Springs	1	6*
0670918	SCAT Park	11	125
0210003F	North Augusta	11,854	21,072
0720003F	Chelsea B/J	53,860	114,515
0720004F	Purrysburg B/J		
SAVF	Savannah	Unknown	168,958
	Total		
	Savannah River-fed systems downstream from SRS	53,860+Savannah	283,473
	Systems not fed from the Savannah River downstream of SRS	57,226	124,316

Notes:
1. Data was obtained from DHEC Environmental Facility Information System database
2. ***** This number is much higher due to public access to the natural spring

TABLES AND FIGURES

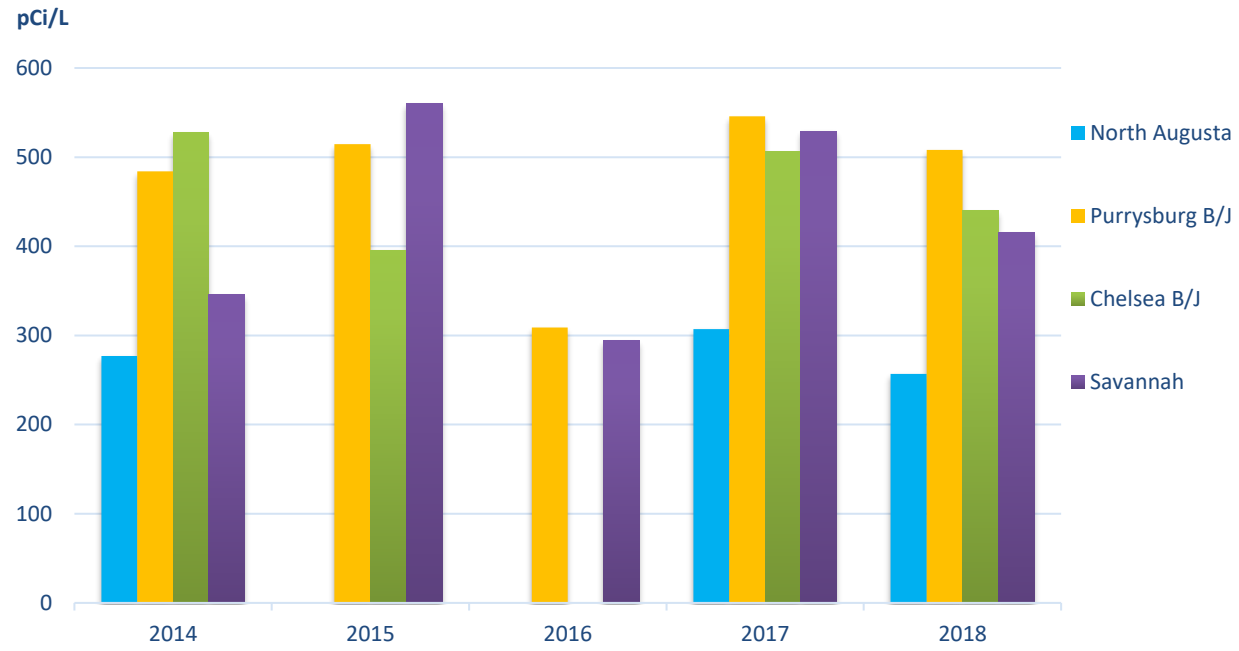
Table 2. DOE-SR and DHEC Data Comparisons for 2018 in pCi/L

Location	DHEC Tritium	DOE-SR Tritium	DHEC Gross Alpha	DOE-SR Gross Alpha	DHEC Gross Non-volatile Beta	DOE-SR Gross Non-volatile Beta
Upstream Location						
North Augusta	257	183.6	ND	ND	5.18	1.80
Downstream Locations						
Chelsea B/J	440	NS	ND	ND	4.09	NS
Purrysburg B/J	508	391.4	ND	ND	ND	1.87
Savannah	415	NS	ND	ND	4.4	NS
Downstream Average	460	391.4	NA	NA	4.32	1.87

Notes:
1. NS is Not Sampled
2. ND is Not Detected

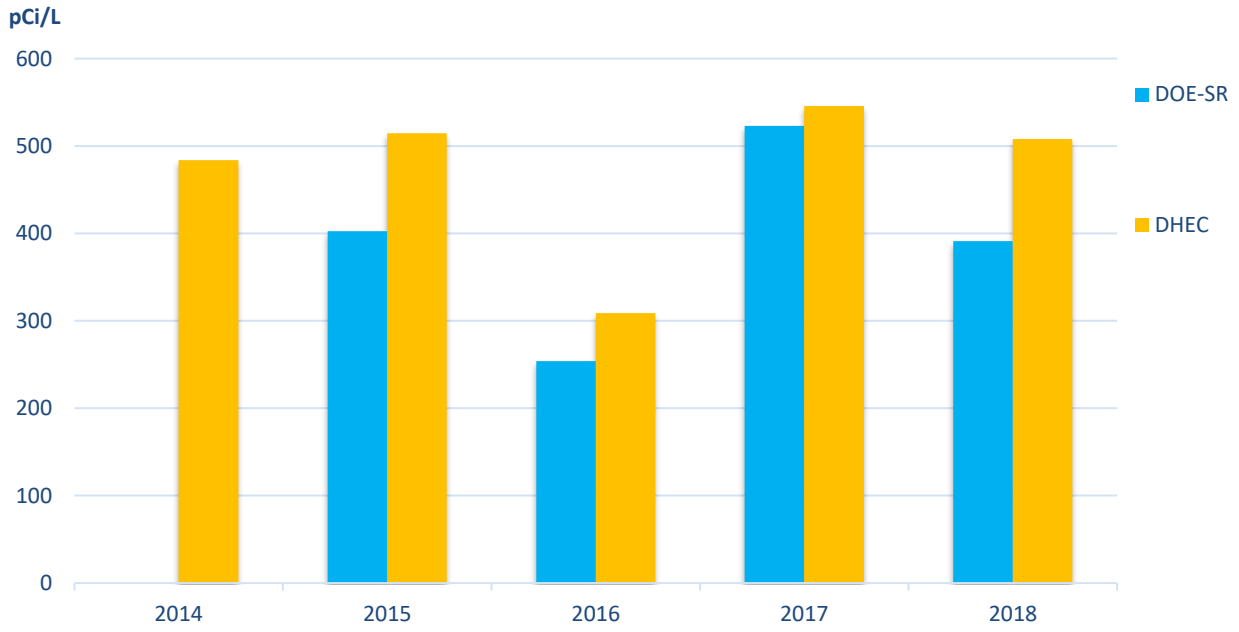
TABLES AND FIGURES

Figure 1. DHEC Yearly Tritium Averages in Savannah River-Fed Systems (DHEC, 2015--2018)



Note: Tritium was not detected at North Augusta in 2015 and 2016, or Chelsea B/J in 2016.

Figure 2. DHEC and DOE-SR Tritium Detection Averages Purrysburg B/J (SRNS, 2015-2019; DHEC, 2015-2018)



Note: DOE-SR did not sample Purrysburg B/J in 2014.

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TABLES AND FIGURES

Figure 3. DHEC Yearly Gross Alpha Averages in Drinking Water Systems (DHEC, 2015-2018)

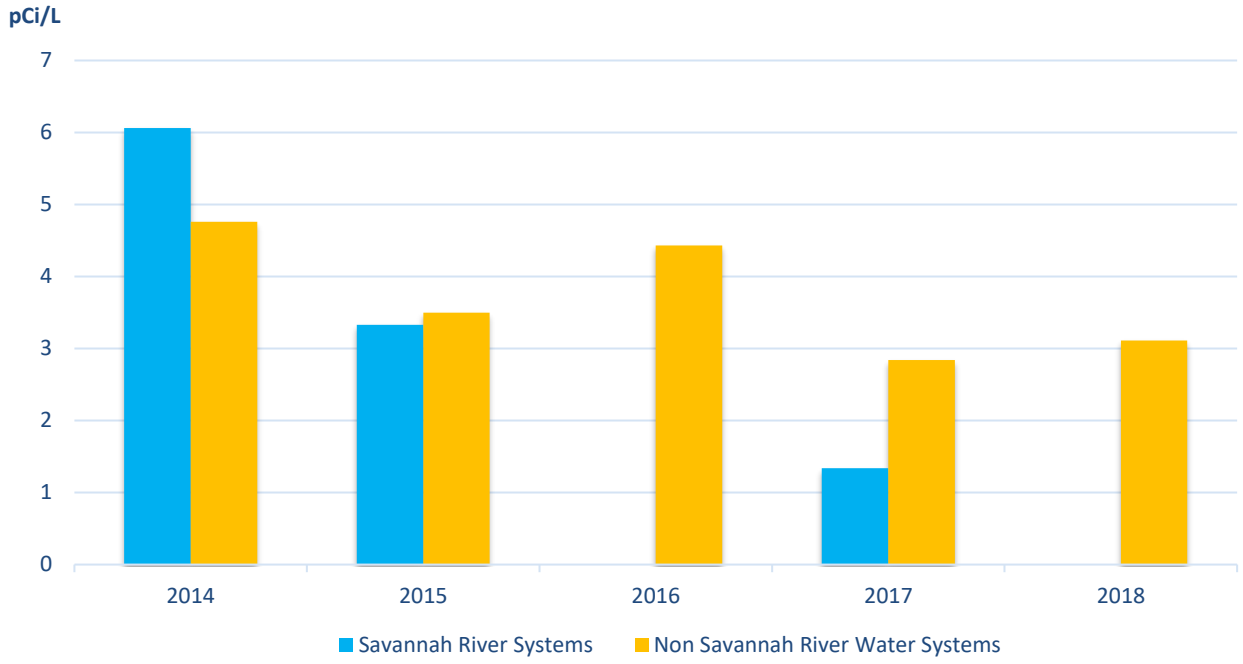
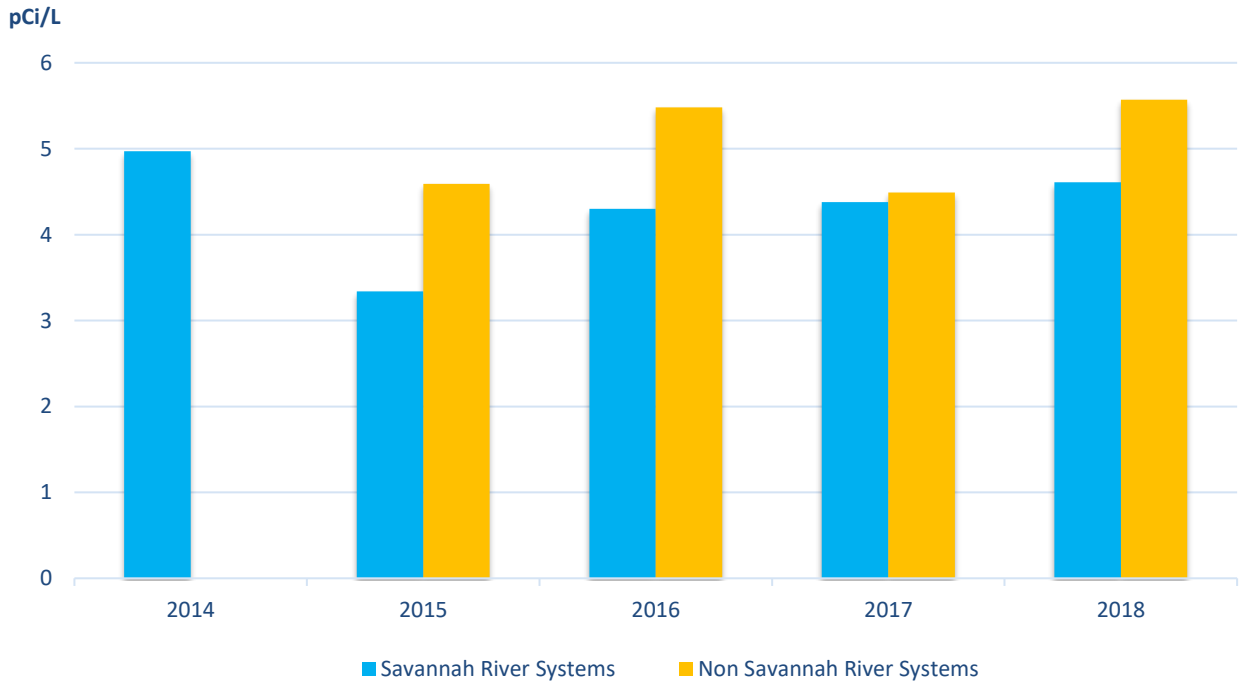


Figure 4. DHEC Yearly Non-Volatile Beta Averages in Drinking Water Systems (DHEC, 2015-2018)



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3.6.0 SUMMARY STATISTICS

2018 DHEC Savannah River-Fed Water System Data

Gross Non-volatile Beta (pCi/L)							
System Name	**Average**	**Standard Deviation**	**Median**	**Minimum Detect**	**Maximum Detect**	**Number of Detects**	**Number of Samples**
North Augusta	5.18	1.13	5.18	4.38	5.98	2	12
Chelsea B/J	4.09	NA	4.09	4.09	4.09	1	12
Purrysburg B/J	ND	NA	NA	ND	ND	0	12
City of Savannah	4.40	1.08	3.87	3.69	5.64	3	10
Yearly Average of Detectable Gross Beta			4.61				
Standard Deviation			0.965				

Tritium (pCi/L)							
System Name	**Average**	**Standard Deviation**	**Median**	**Minimum Detect**	**Maximum Detect**	**Number of Detects**	**Number of Samples**
North Augusta	257	18.2	257	233	278	6	12
Chelsea B/J	440	170.7	396	269	763	9	12
Purrysburg B/J	508	247.0	402	305	1114	11	12
City of Savannah	415	204.4	327	225	754	8	10
Yearly Average of Detectable Tritium			424				
Standard Deviation			204.8				

Notes:
1. ND is Not Detected
2. NA is Not Applicable
3. Yearly Average and Standard Deviation were calculated from the from the raw data found in Data File 2018 and does not use the averages in the table.

Chapter 4 Radiological Monitoring of Surface Water on and Adjacent to SRS

4.1.0 PROJECT SUMMARY

The focus of the Radiological Monitoring of Surface Water (RSW) project is to test and survey the streams and creeks on SRS as well as the Savannah River. Since the Savannah River is the primary drinking water source for some downstream communities, it is important to monitor radionuclide concentrations in the river. Surface water samples are collected and analyzed for radionuclides, and the results are compared to DOE-SR data. DHEC supports DOE-SR's objectives to ensure the primary goal of drinking water safety is established and met.

Collecting samples to be tested for tritium using the early detection system at SV-118

DHEC collects surface water samples from 13 specific locations within and outside of the SRS boundary as part of an ambient sampling network (Section 4.4.0, Map). Section 4.5.0, Table 1, identifies sample ID, location, rationale, and frequency. Some locations were chosen because they are considered public access locations. All but one of the public access locations are downstream of SRS, which provides a potential means for exposure to radionuclides. Jackson Boat Landing (SV-2010), is upstream from SRS activities and is a public access location.

Quarterly samples are collected for tritium analysis from the four creek mouths that flow from SRS directly into the Savannah River (Upper Three Runs Creek, Fourmile Branch, Steel Creek, and Lower Three Runs Creek). Pen Branch is not sampled because the Savannah River Swamp interrupts the flow of this creek and there is no creek mouth access.

An enhanced surface water monitoring program was implemented to provide downstream drinking water systems with advance notice of the potential for increased tritium levels in the Savannah River. This early detection facet is possible because of the continuous monitoring of the five SRS streams that flow to the Savannah River. Samples for tritium analysis are collected from seven locations with automatic water samplers. Additionally, a grab sample is collected from Johnson's Boat Landing (SV-2080) and U.S. Highway 301 at the Savannah River (SV-118).

An additional component of the RSW Project is the Supplemental Surface Water Monitoring Program implemented in 2005. The purpose of this sampling program is to monitor any potential releases of radionuclides. Sample locations are located along Upper Three Runs, Fourmile Branch, and Steel Creek. This monitoring was established for early detection of unplanned releases from SRS source term areas. An additional sample location was added in 2015 at

Example of a Composite Sample

McQueen Branch. This location was added to monitor the Saltstone low level waste operations. The McQueen Branch sample is a monthly composite that is collected by DOE and split with DHEC. These samples are collected as unofficial results for notification purposes only.

In August of 2007, DHEC began collecting ambient grab samples from a location on Lower Three Runs. This sampling was conducted in response to elevated tritium levels detected in groundwater samples near the Energy Solutions (formerly Chem-Nuclear) facility in Snelling, South Carolina. The purpose of adding this location was to differentiate any potential tritium contributions to Lower Three Runs from Energy Solutions and SRS activities.

Quarterly sampling for I-129 and Tc-99 is conducted at the supplemental location on Fourmile Branch due to concerns that these are possible constituents related to effluent from the burial grounds, which could enter the surface water.

4.2.0 RESULTS AND DISCUSSION

Radiological Monitoring of Surface Water Summary Statistics can be found in Section 4.6.0 and all Radiological Monitoring of Surface Water Data can be found in the 2018 DHEC Data File.

The data presented in this section concerns DHEC's monitoring of SRS's ambient and on-site streams. Enhanced and supplemental data are not displayed in the annual report and data file due to their sole purpose of serving as an early detection system for downstream drinking water users.

DHEC data from 2018 was compared to DOE-SR reported results (Section 4.5.0, Tables 2, 3, and 4). The DHEC and DOE-SR collocated sampling sites were Tims Branch at Road C, Upper Three Runs Creek at Road A, Fourmile Branch at Road A-12.2, Pen Branch at Road A-13.2, Steel Creek at Road A, the Savannah River at U.S. Highway 301 Bridge, and Lower Three Runs Creek at Road B. DOE-SR sampled at several other locations along these streams. However, the data comparisons are only for the collocated sample sites.

Example of a Grab Sample

Tritium

In 2018, DHEC and DOE-SR had detections for tritium at all collocated sample locations (Section 4.5.0, Table 2). DHEC Average tritium activities at Jackson Boat Landing (SV-2010) and Upper Three Runs Creek at United States Forestry Service (USFS) Road 2-1 (SV-2027)

were not directly impacted by SRS operations. These locations are upstream from SRS impacts and are considered background locations. DHEC and DOE-SR samples indicate that Fourmile Branch and Pen Branch have the highest average tritium activity of all SRS streams. The 2018 DHEC and DOE-SR tritium results appear to be consistent with historically reported data values (Section 4.5.0, Figures 2-7). Section 4.5.0, Figure 1 shows trending data for DHEC tritium averages for the past five years.

Tritium activity in the Savannah River at the creek mouths of the four SRS streams are typically monitored on a quarterly basis; however, due to excessive rainfall contributing to dangerous river conditions in the last quarter in 2018, samples were only collected three times during the year. Samples collected at the creek mouth of Fourmile Branch (SV-2015) had the highest average tritium activity of 3,960 pCi/L of all creek mouth locations.

Gamma

As part of a gamma spectroscopy analysis, samples were analyzed monthly for gamma-emitting radionuclides (List of Tables, Table 1, page x). DHEC had two locations with averages above the MDA for Cs-137: Fourmile Branch at Road C (5.3 pCi/L) and Upper Three Runs Creek at SC 125 (4.62 pCi/L). All other gamma results were below the Minimum Detection Limit.

Pouring a sample to be tested for tritium

Iodine-129 and Technetium-99

I-129 and Tc-99 samplings of the supplemental location on Fourmile Branch were monitored on a quarterly basis by DHEC. One of the four quarterly I-129 samples had a detection above the MDA with a reading of 0.96 pCi/L. All of the quarterly samples had Tc-99 detected with an average of 2.11 pCi/L. DHEC and DOE-SR do not have a collocated sampling site for I-129 and Tc-99. Therefore, these analytes were not compared.

I-129 and Tc-99 would be included under the EPA established MCL of 4 millirem per year. The average concentration of I-129, which is assumed to yield 4 millirem per year, is 1 pCi/L. If other radionuclides emitting beta particles and photon radioactivity are present in addition to I-129 and Tc-99, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year (EPA, 2002c).

Alpha

In 2018, alpha-emitting radionuclides were detected at five of the nine DHEC locations where monthly composite samples were collected. DHEC detected gross alpha activity at four of the seven collocated sampling locations while DOE-SR detected activity at all of the collocated locations. DHEC and DOE-SR samples indicate that Tims Branch exhibited the highest alpha

activity of the collocated locations with 3.36 pCi/L (DHEC) and 4.12 pCi/L (DOE-SR) (Section 4.5.0, Table 3, SRNS, 2019).

Historically, Upper Three Runs Creek at SC 125 (SV-325) yields detections for alpha activity (DHEC, 2015-2018). Isotopic analysis performed by DOE-SR revealed the source to be natural uranium (SRNS, 2011). This may contribute to the common occurrence of alpha detections at this location. The 2018 average alpha activity of 3.03 pCi/L at DHEC's SV-325 was below the EPA MCL for drinking water of 15 pCi/L (EPA, 2002c). Beginning in 2009, samples collected at this location exhibited particles of sediment and detritus. This increase in turbidity seems to be related to storm events. Samples with high turbidity can have potential interferences during alpha/beta analysis. Alpha particles, and to a lesser extent, beta particles, are attenuated by salts and solids dried onto a planchette (EPA, 2010). Pump tubing is evaluated during each sample collection at all locations to ensure no blockage of sediment has occurred.

Pouring a composite sample to be tested for tritium and gamma and gross alpha/beta radionuclides

Beta

Beta-emitting radionuclide activity was detected in four of nine locations where monthly composite samples were collected. DHEC detected gross beta activity at three of the seven collocated sampling locations while DOE-SR detected activity at all of the collocated locations (Section 4.5.0, Table 4). For both DHEC and DOE-SR, the sample exhibiting the highest average gross beta activity was Fourmile Branch at Road 12.2 (SV-2039) at an average of 5.03 pCi/L (DHEC) and of 4.02 pCi/L (DOE-SR) (SRNS, 2019).

EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The EPA screening MCL for gross beta-emitting particles for drinking water systems is 50 pCi/L minus natural potassium-40 (K-40) (EPA, 2002c). All averages were below this limit.

DOE-SR reported a single detection of Sr-89/90 at 0.786 pCi/L at the collocated sample site at Fourmile Branch. DOE-SR reported four single detections of Am-241 at DHEC collocated sites: Upper Three Runs at Road A, Fourmile Branch at Road A, and Lower Three Runs at Road B, and at Steel Creek Mouth (River Mile 141.5). All detections yielded an average value of 0.0132 pCi/L (SRNS, 2019).

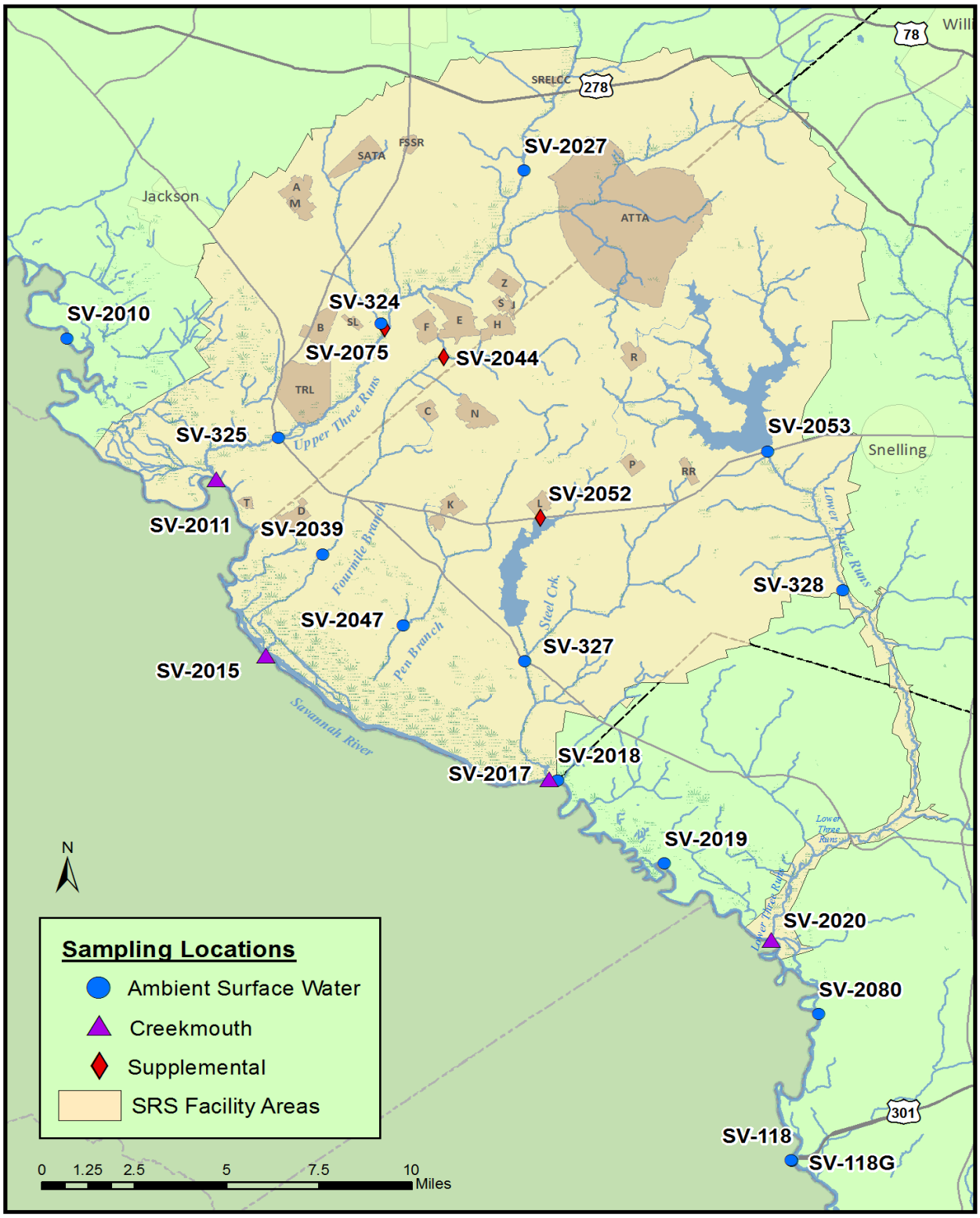
4.3.0 CONCLUSIONS AND RECOMMENDATIONS

Differences in average values between DHEC and DOE-SR could be attributed, in part, to the nature of the medium and the specific point and time of when the sample was collected. DHEC will continue independent collection and analysis of surface water on and adjacent to SRS. This

monitoring effort will provide an improved understanding of radionuclide levels in SRS surface waters. Beginning in 2019, DHEC plans to change the supplemental radiological surface water route to be sampled on a monthly basis. DHEC will periodically evaluate modifying the monitoring activities to better accomplish the project's goals and objectives. Further refinement of the RSW project may result in additional sampling locations being incorporated into the ambient or enhanced monitoring regimes. Monitoring will continue as long as there are activities at SRS that create the potential for contamination to enter the environment, as well as past radioactive contamination that still exists due to unexpired half-lives.

4.4.0 MAP

Radiological Surface Water Monitoring Locations



2018 ESOP Radiological Surface Water Monitoring www.scdhec.gov

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4.5.0 TABLES AND FIGURES

Table 1. 2018 Surface Water Sampling Locations and Frequency

Ambient Monitoring Locations

ID	Location	Rationale	Frequency
SV-2010	Savannah River at RM 170.5 (Jackson Boat Landing)	Accessible to public; upstream all SRS operations; Near Jackson population center; Up river control; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-324	Tims Branch at SRS Road C	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-325	Upper Three Runs Creek at S.C. 125 (SRS Road A)	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2039	Fourmile Branch at Road A-12.2	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2047	Pen Branch at Road A-13.2	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-327	Steel Creek at S.C. 125 (SRS Road A)	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2018	Savannah River at RM 141 (Steel Creek Boat Landing)	Accessible to the public; Adjacent to SRS perimeter Downstream of SRS operations; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2019	Savannah River at RM 134.5 (Little Hell Boat Landing)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Weekly tritium grab
SV-2080	Savannah River at RM 125 (Johnson's Boat Landing)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Tri-weekly tritium grab
SV-118	Savannah River at RM 118.8 (Hwy 301 Bridge)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-328	Lower Three Runs Creek at Patterson Mill Road	Within SRS perimeter; Downstream of SRS operations and Par Pond; Tributary monitoring	Weekly tritium grab
SV-2053	Lower Three Runs Creek at Road B	Within SRS perimeter; Downstream of SRS operations and Par Pond; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2027	Upper Three Runs Creek at SRS Road 2-1	Within SRS perimeter; Upstream from SRS operations; Upstream control; Tributary monitoring	Weekly tritium grab

TABLES AND FIGURES

Table 1. (Cont.)

Creek Mouth Locations

ID	Location	Rationale	Frequency
SV-2011	Upper Three Runs Creek Mouth at RM 157.4	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2015	Fourmile Branch at RM 150.6	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2017	Steel Creek Mouth at RM 141.5	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2020	Lower Three Runs Creek at RM 129.1	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium

Supplemental Locations

ID	Location	Rationale	Frequency
SV-2070	McQueen Branch	Downstream from Saltstone LLW Operations	Monthly gamma composite
SV-2075	Upper Three Runs Creek at Road C	Downstream from F-and H-Areas HLW Tanks	Weekly gamma composite
SV-2044	Fourmile Branch at Road C	Downstream from F-and H-Areas HLW Tanks	Weekly gamma composite
SV-2052	Steel Creek at the top of L-Lake	Downstream from P- and L- Areas	Weekly gamma composite

Notes:
1. ID is Sampling Location Identification Code Number
2. RM is River Mile
3. HLW is High Level Waste
4. LLW is Low Level Waste
5. Tri-Weekly Enhanced sample data is used for detection purposes only

TABLES AND FIGURES

Table 2. 2018 Tritium Data Comparison for DHEC and DOE-SR Collocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detects	Number of Samples
Tims Branch at Road C	SV-324	441	321	371	260	2408	49	52
	TB-5	561	196	462	446	905	5	12
Upper Three Runs Creek at Road A	SV-325	865	672	704	265	4767	52	52
	U3R-4	1679	1835	778	384	5220	13	15
Fourmile Branch at Road 12.2	SV-2039	30047	5642	32347	17683	37461	52	52
	FM-6	27258	4412	28350	17500	32200	12	12
Pen Branch at Road 13.2	SV-2047	12763	3502	13444	5512	19791	52	52
	PB-3	10868	3364	119504	40504	15100	12	12
Steel Creek at Road A	SV-327	1827	344	1806	1245	2926	52	52
	SC-4	1486	317	1425	1070	2090	12	12
Highway 301 Bridge at RM 118.8	SV-118	549	375	410	274	2169	43	52
	RM 118	421	310	315	136	1600	52	52
Lower Three Runs Creek at Road B	SV-2053	281	72	261	220	529	16	52
	L3R-1A	346	16	346	335	357	2	12

Notes:
1. Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2018 (SRNS, 2019)
3. ND is Not Detected
4. NA is Not Applicable

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TABLES AND FIGURES

Table 3. 2018 Alpha Data Comparison for DHEC and DOE-SR Collocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detects	Number of Samples
Tims Branch at Road C	SV-324	3.36	2.00	2.65	1.37	7.42	10	12
	TB-5	4.12	3.47	2.64	1.68	13.20	12	12
Upper Three Runs Creek at Road A	SV-325	3.03	0.79	3.13	1.81	4.24	9	12
	U3R-4	0.41	0.16	0.37	0.21	0.94	21	52
Fourmile Branch at Road 12.2	SV-2039	ND	NA	NA	ND	ND	0	12
	FM-6	1.01	1.06	0.69	0.42	3.95	10	12
Pen Branch at Road 13.2	SV-2047	1.36	NA	1.36	1.36	1.36	1	12
	PB-3	0.67	0.38	0.56	0.29	1.24	8	12
Steel Creek at Road A	SV-327	4.1	3.72	4.1	1.47	6.73	2	12
	SC-4	0.47	0.18	0.45	0.23	0.68	6	12
Highway 301 Bridge at RM 118.8	SV-118	ND	NA	NA	ND	ND	0	12
	RM 118	0.33	0.14	0.29	0.21	0.65	8	51
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	ND	ND	0	12
	L3R-1A	0.34	0.11	0.29	0.25	0.47	3	12

Notes:
1). Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2). DOE-SR data is from the SRS Environmental Data Report for 2018 (SRNS, 2019)
3). ND is Not Detected
4). NA is Not Applicable

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TABLES AND FIGURES

Table 4. 2018 Beta Data Comparison for DHEC and DOE-SR Collocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detects	Number of Samples
Tims Branch at Road C	SV-324	3.67	NA	3.67	3.67	3.67	1	12
	TB-5	2.07	1.00	1.71	0.96	4.22	12	12
Upper Three Runs Creek at Road A	SV-325	ND	NA	NA	ND	ND	0	12
	U3R-4	2.77	1.94	1.80	1.06	6.92	14	14
Fourmile Branch at Road 12.2	SV-2039	5.03	1.33	4.39	4.32	7.03	4	12
	FM-6	4.02	1.55	3.61	2.66	8.70	12	12
Pen Branch at Road 13.2	SV-2047	ND	NA	NA	ND	ND	0	12
	PB-3	1.01	0.49	0.86	0.49	2.17	12	12
Steel Creek at Road A	SV-327	ND	NA	NA	ND	ND	0	12
	SC-4	1.13	0.13	1.12	0.90	1.38	12	12
Highway 301 Bridge at RM 118.8	SV-118	3.78	NA	3.78	3.78	3.78	1	12
	RM 118	1.97	0.27	1.96	1.20	2.48	51	51
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	ND	ND	0	12
	L3R-1A	1.02	0.17	0.99	0.68	1.31	12	12

Notes:
1). Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2). DOE-SR data is from the SRS Environmental Data Report for 2018 (SRNS, 2019)
3). ND is Not Detected
4). NA is Not Applicable

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TABLES AND FIGURES

Figure 1. DHEC Average Tritium Data Trends for 2014-2018 (DHEC, 2015-2018)

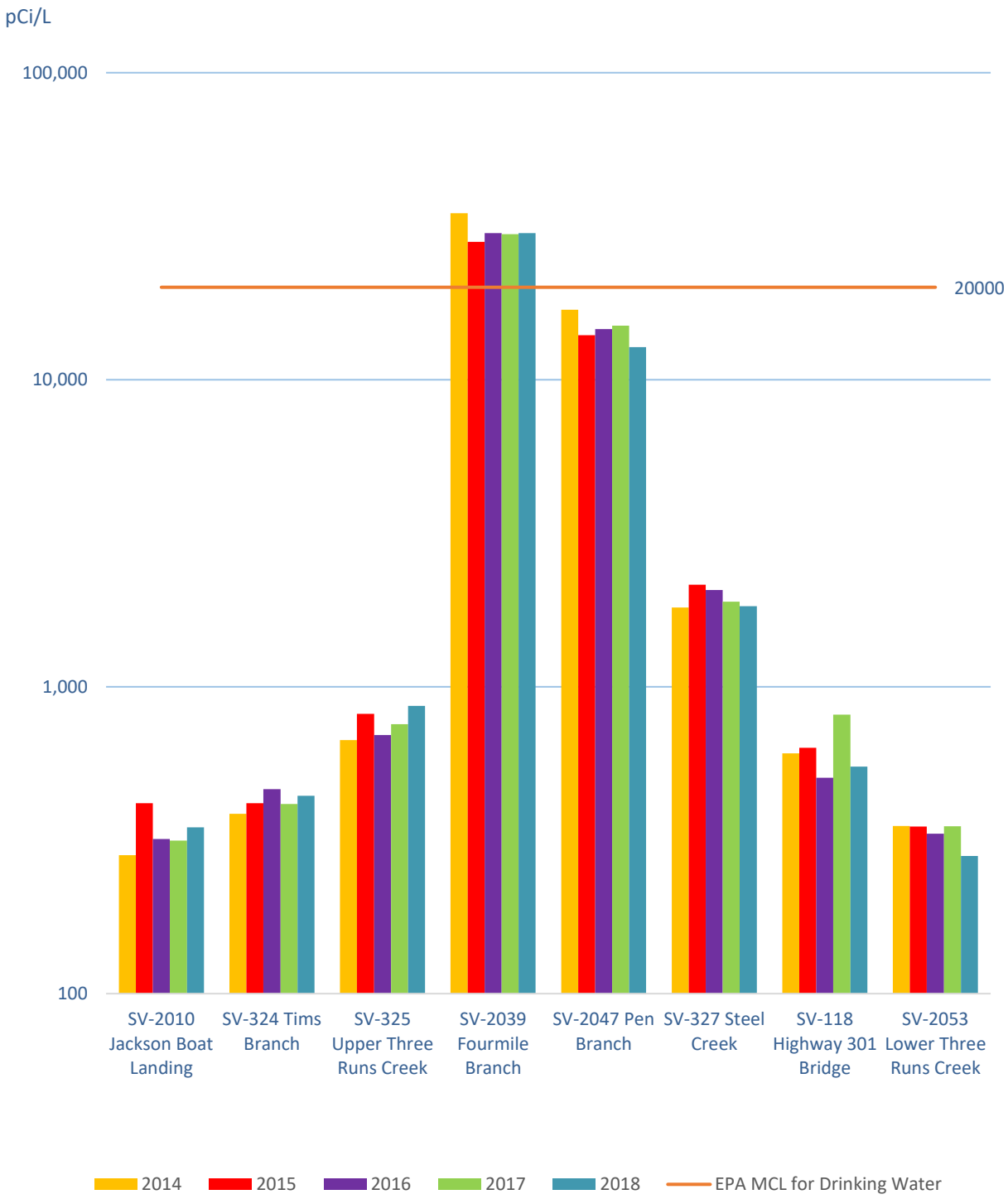

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Figure 2. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for Upper Three Runs Creek at S.C. Highway 125 (SRNS, 2015-2019; DHEC, 2015-2018)

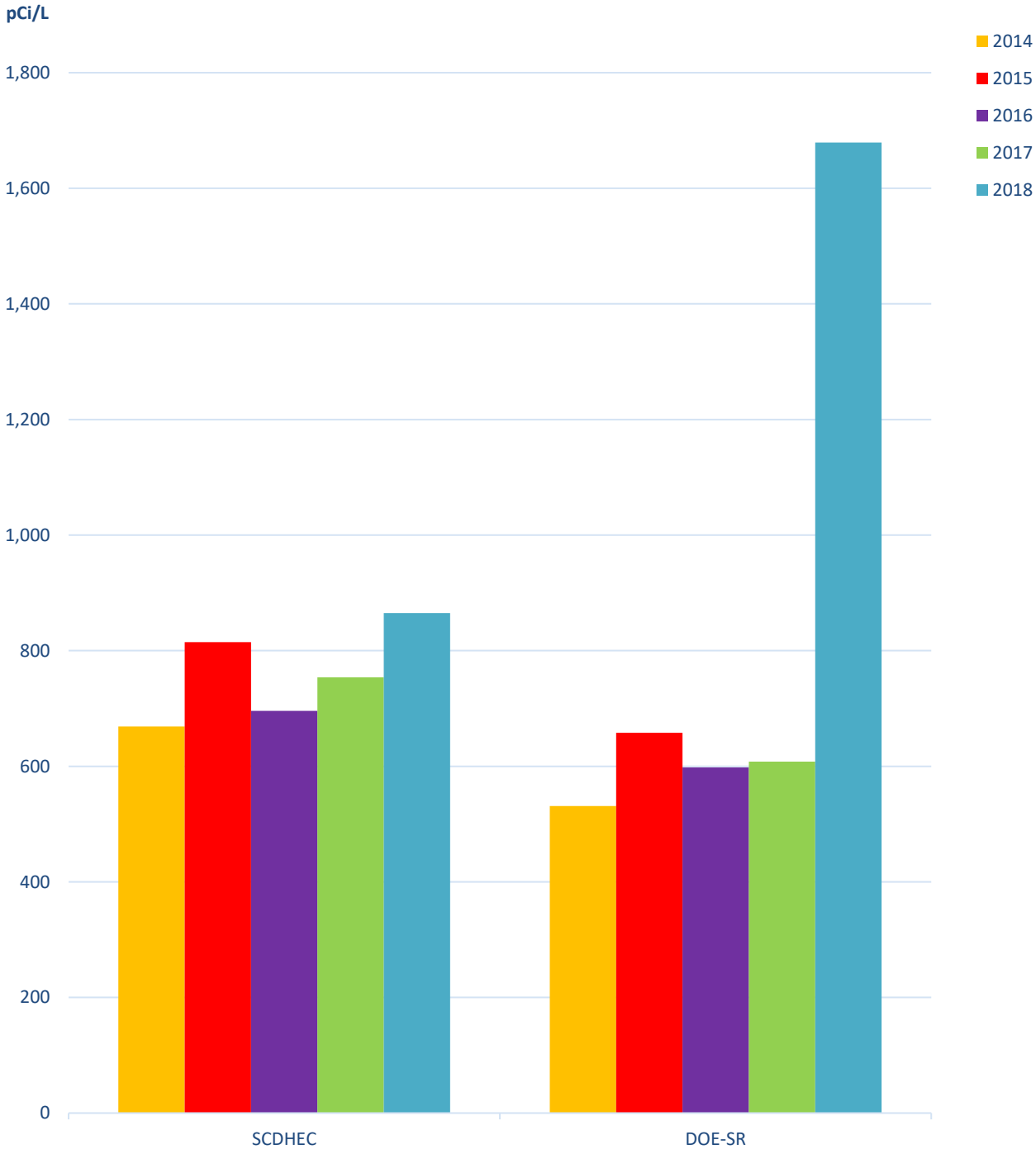

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Figure 3. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for Fourmile Branch at USFS Road 12. (SRNS, 2015-2019; DHEC, 2015-2018)

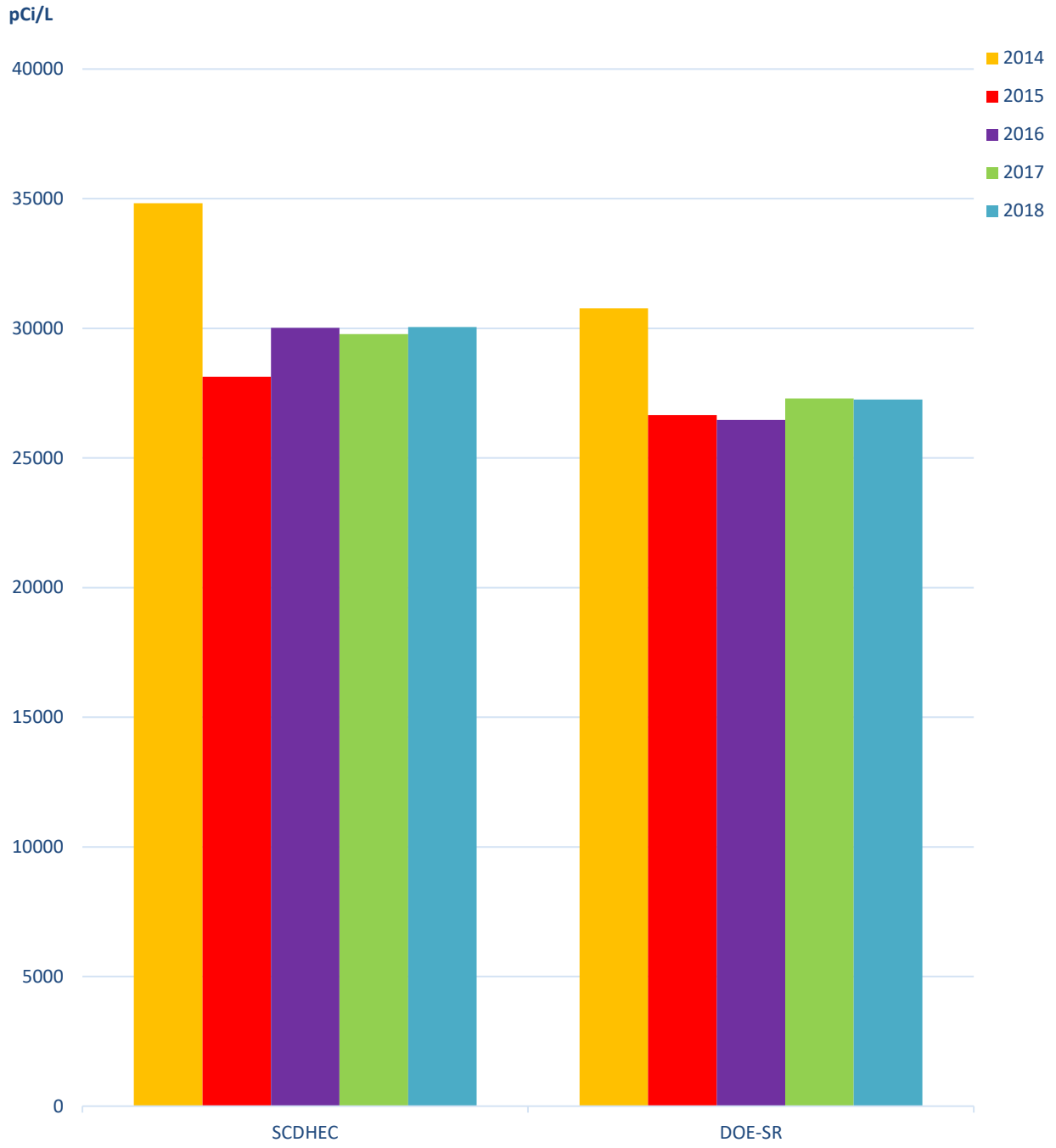

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Figure 4. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for Pen Branch at USFS Road 13.2 (SRNS, 2015-2019; DHEC, 2015-2018)

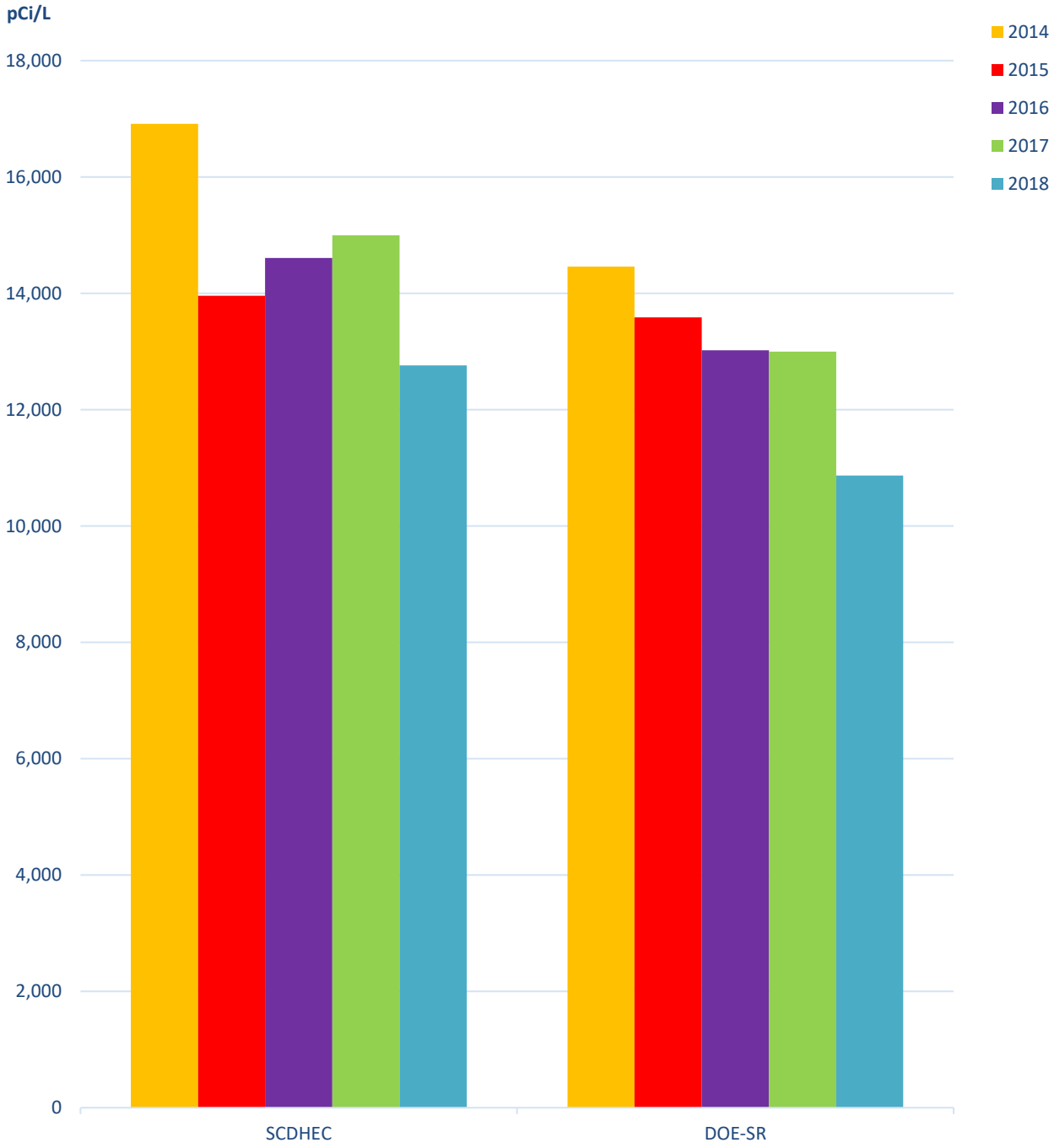

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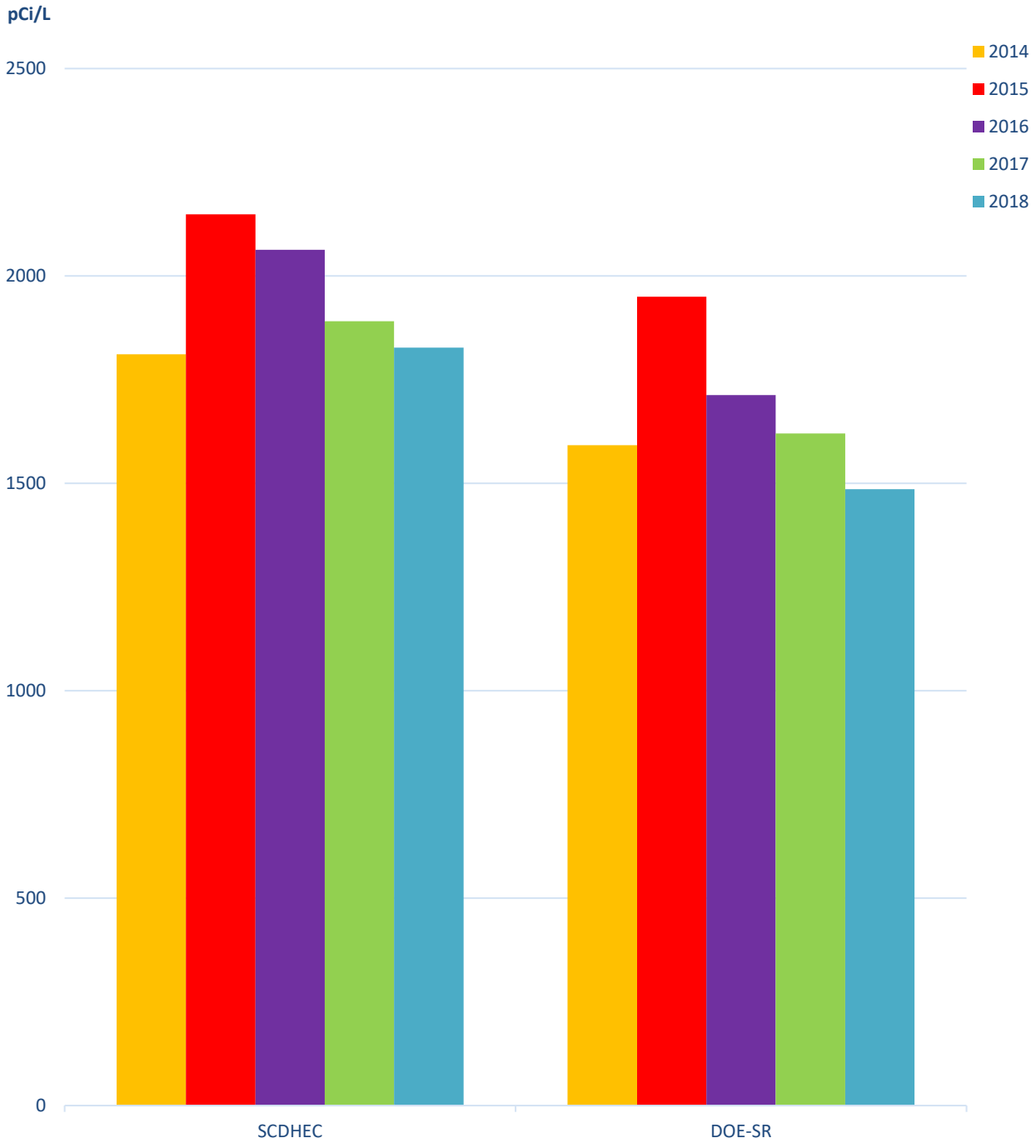
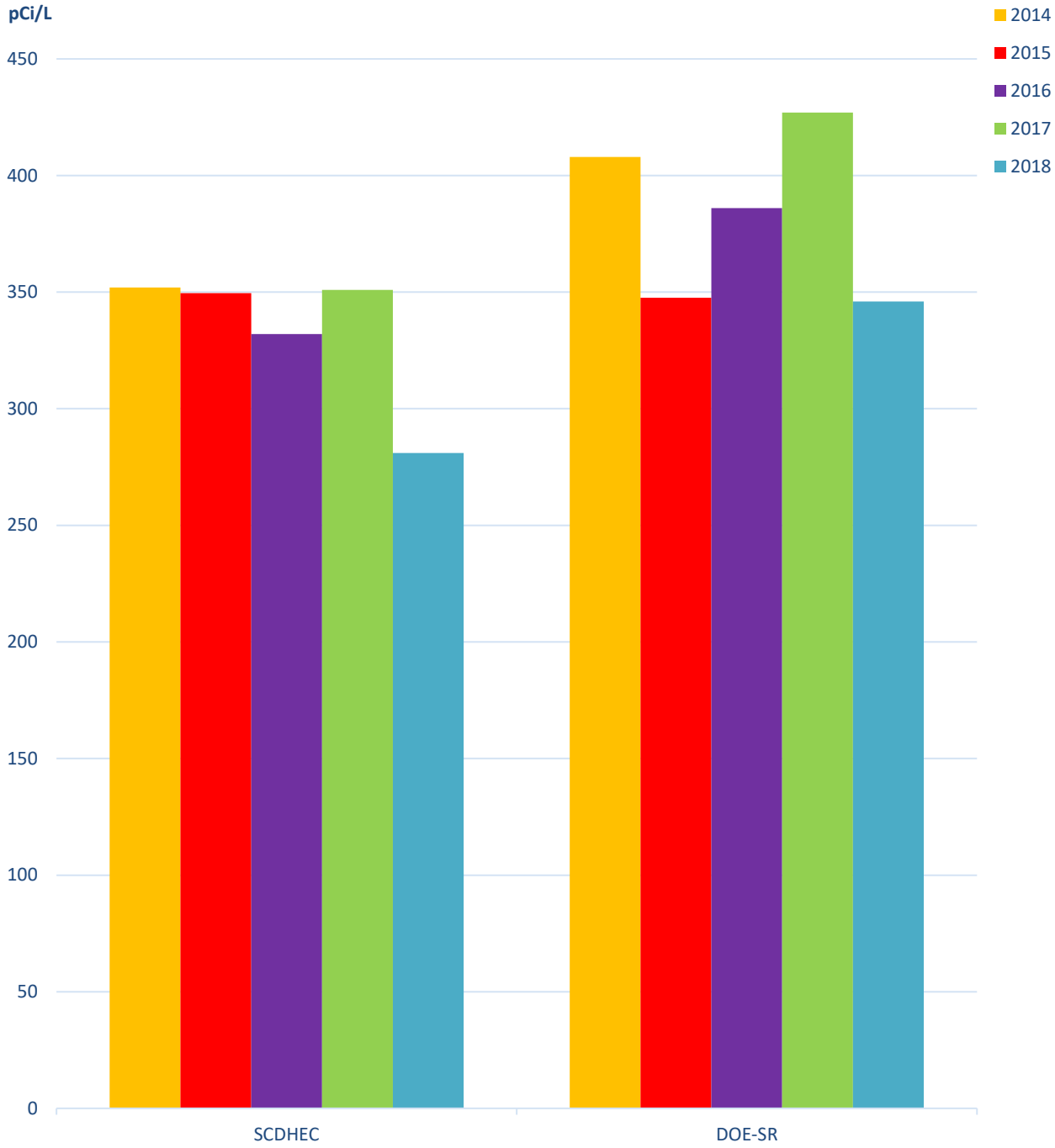
Figure 5. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for Steel Creek at S.C. Highway 125 (SRNS, 2015-2019; DHEC, 2015-2018)



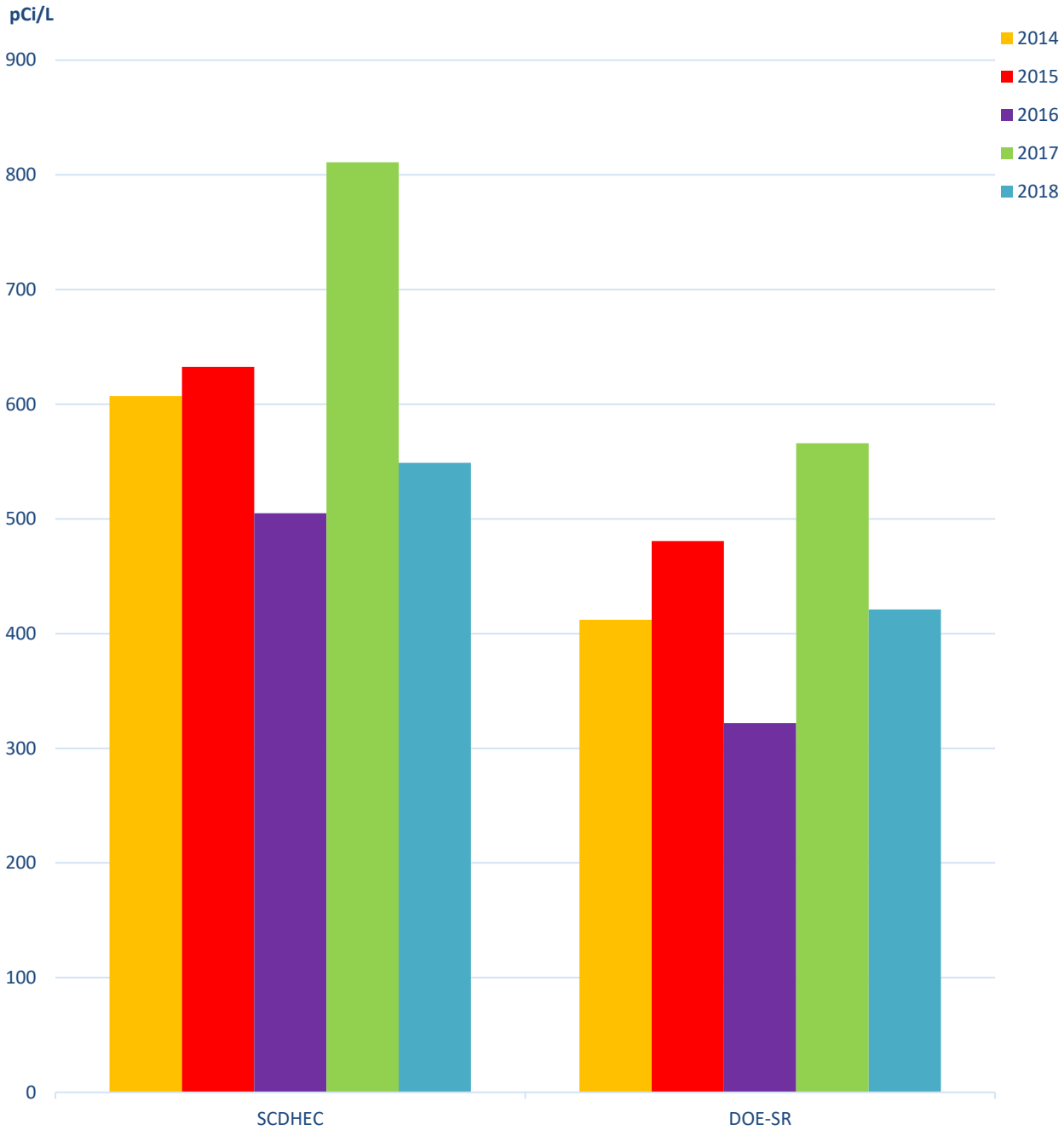
TABLES AND FIGURES

Figure 6. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for Lower Three Runs Creek at SRS Road B (SRNS, 2015-2019; DHEC, 2015-2018)



TABLES AND FIGURES

Figure 7. 2014-2018 Average Tritium Data Trends for DHEC and DOE-SR for the Savannah River at US Highway 301 Bridge (SRNS, 2015-2019; DHEC, 2015-2018)



4.6.0 SUMMARY STATISTICS

2018 DHEC Ambient Monitoring Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
Jackson Boat Landing (SV-2010)	348	219	291	219	1319	25	50
Tims Branch (SV-324)	441	321	371	260	2408	49	52
Upper Three Runs Creek at S.C. 125 (SV-325)	865	672	704	265	4767	52	52
Fourmile Branch (SV-2039)	30047	5642	32347	17683	37461	52	52
Pen Branch (SV-2047)	12763	3502	13444	5512	19791	52	52
Steel Creek (SV-327)	1827	344	1806	1245	2926	52	52
Steel Creek Boat Landing (SV-2018)	1109	1446	555	244	7322	48	51
Little Hell Boat Landing (SV-2019)	682	635	409	238	2654	38	51
Highway 301 Bridge (SV-118)	549	375	410	274	2169	43	52
Lower Three Runs Creek at Patterson Mill Rd. (SV-328)	1293	353	1213	570	2100	51	52
Lower Three Runs Creek at Road B (SV-2053)	281	72	261	220	529	16	52
Upper Three Runs Creek at SRS Road 2-1 (SV-2027)	571	622	295	227	2136	12	52

2018 DHEC Creek Mouth Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
Upper Three Runs Mouth @ RM 157.4 (SV-2011)	516	238	401	358	790	3	3
Fourmile Branch Mouth @ RM 150.6 (SV-2015)	3960	6356	338	242	11298	3	3
Steel Creek Mouth @ RM 141.5 (SV-2017)	897	763	524	358	1755	3	3
Lower Three Runs Mouth @ RM 129.1 (SV-2020)	459	123	457	337	583	3	3

Note: In 2018, due to flooded rivers and safety concerns a fourth sample was not able to be taken for creek mouths

SUMMARY STATISTICS

2018 DHEC Ambient Monitoring Data-Alpha

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
Jackson Boat Landing (SV-2010)	0.998	NA	0.998	0.998	0.998	1	12
Tims Branch (SV-324)	3.36	2.00	2.65	1.37	7.42	10	12
Upper Three Runs Creek at S.C. 125 (SV-325)	3.03	0.793	3.13	1.81	4.24	9	12
Fourmile Branch (SV-2039)	ND	NA	NA	ND	ND	0	12
Pen Branch (SV-2047)	1.36	NA	1.36	1.36	1.36	1	12
Steel Creek (SV-327)	4.1	3.72	4.1	1.47	6.73	2	12
Steel Creek Boat Landing (SV-2018)	ND	NA	NA	ND	ND	0	12
Highway 301 Bridge (SV-118)	ND	NA	NA	ND	ND	0	12
Lower Three Runs Creek at Road B (SV-2053)	ND	NA	NA	ND	ND	0	12

2018 DHEC Ambient Monitoring Data-Beta

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
Jackson Boat Landing (SV-2010)	ND	NA	NA	ND	ND	0	12
Tims Branch (SV-324)	3.67	NA	3.67	3.67	3.67	1	12
Upper Three Runs Creek at S.C. 125 (SV-325)	ND	NA	NA	ND	ND	0	12
Fourmile Branch (SV-2039)	5.03	1.33	4.39	4.32	7.03	4	12
Pen Branch (SV-2047)	ND	NA	NA	ND	ND	0	12
Steel Creek (SV-327)	ND	NA	NA	ND	ND	0	12
Steel Creek Boat Landing (SV-2018)	4.09	0.658	4.09	3.62	4.55	2	12
Highway 301 Bridge (SV-118)	3.78	NA	3.78	3.78	3.78	1	12
Lower Three Runs Creek at Road B (SV-2053)	ND	NA	NA	ND	ND	0	12

Chapter 5 Non-radiological Monitoring of Surface Water on SRS

5.1.0 PROJECT SUMMARY

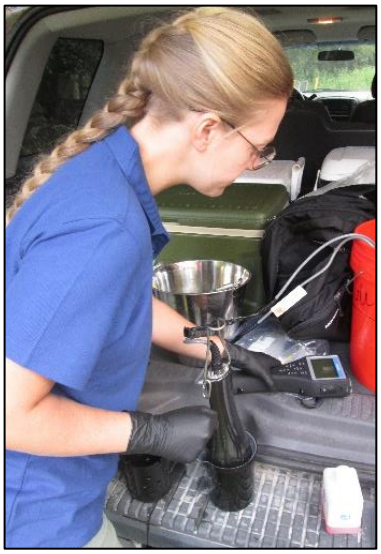
The streams located on SRS receive a wide variety of permitted point source discharges and non-point source run-off from on-site facilities and operations. These discharges specifically include, but are not limited to, industrial storm water, utility water, treated industrial and sanitary wastewater, and run-off from land-disturbing activities. Data from SRS Environmental Reports and DHEC ESOP are used to monitor the ambient water quality of streams on SRS.

POINT SOURCE POLLUTION:
"Pollution that comes from a specific, identifiable source, such as a pipe or channel"

NONPOINT SOURCE POLLUTION:
"Sources that are diffuse, without a single identifiable point of origin, including runoff from agriculture, forestry, and construction sites"

Source: EPA

DHEC assessed the surface water quality for non-radiological parameters in 2018 at SRS by sampling the on-site streams for inorganic and organic constituents. The streams on SRS are tributaries that feed into the Savannah River and are classified as freshwater by DHEC's Bureau of Water (DHEC, 2012b). As an indication of possible water quality issues, DHEC data is compared to the freshwater standard guidelines in DHEC's Water Classifications and Standards, Regulation 61-68 (DHEC, 2014b). These guidelines give numeric criteria for specific parameters and narrative criteria that indicate conditions of biological integrity and water quality for aquatic life and human health. The fact that a stream does not meet the specified numeric standards for a particular parameter does not mean the stream is polluted or of poor quality. Natural conditions can cause streams to exceed the standards.



Standardizing the Horiba Water Testing System

Nine DHEC sample locations were strategically chosen to monitor ambient surface water conditions and detect the non-radiological impact from DOE-SR operations. A map of DHEC sample locations can be found in Section 5.4.0. Six of the DHEC sample locations are collocated with DOE-SR sample locations to provide data comparisons (Section 5.5.0, Table 1). The stream sample locations were selected based on accessibility and their proximity upstream and downstream of DOE-SR operations before flowing into the publicly accessible Savannah River. A list of water quality parameter analyses and sample frequency can be found in Section 5.5.0, Table 2.

5.2.0 RESULTS AND DISCUSSION

Non-radiological Monitoring of Surface Water Summary Statistics can be found in Section 5.6.0 and all Non-radiological Monitoring of Surface Water Data can be found in the 2018 DHEC Data File.

Many chemical and biological processes in surface waters can be affected by pH, a measurement that indicates the alkalinity or acidity of a substance (EPA, 1997). The streams encountered at

SRS are typical of southeastern streams characterized as black-water. A black-water stream is one that has a deep, slow-moving channel that flows through forested swamps and wetlands. Decaying vegetation in the water results in the leaching of tannins from the vegetation which results in transparent, acidic water that is darkly stained, resembling tea or coffee. Low pH is typical for black-water streams such as those sampled at SRS (Hughes et al., 2000).

The pH standard for all South Carolina freshwater streams is between 6.0 and 8.5 standard units (SU) (DHEC, 2014b). All DHEC locations had yearly averages within the standard except for Tims Branch at Road C (NWSV-324) with an average pH of 5.35, Upper Three Runs at Road A (NWSV-325) with a pH average of 5.67, and Upper Three Runs at Road 2-1 (NWSV-2027) with an average pH of 5.81. All of these streams are black-water streams, which could contribute to them having a pH lower than 6. See Section 5.5.0, Figure 1 for a comparison of DHEC and DOE-SR data for collocated samples (SRNS, 2019).

Oxygen is cycled through the environment and is both produced and consumed in streams. The amount of oxygen in its dissolved form in water is the Dissolved Oxygen (DO). The Biochemical Oxygen Demand (BOD) is the amount of oxygen consumed by microorganisms in stream water. Water quality is diminished when the BOD is high, which depletes the oxygen in the water. Low DO means less oxygen to support higher forms of aquatic life (EPA, 1997). The South Carolina freshwater standard for DO is a daily average of no less than 5.0 milligrams per liter (mg/L) with no individual sample to be below 4.0 mg/L (DHEC, 2014b). All individual samples and yearly averages met the DO standard in 2018. A DO comparison of DHEC and DOE-SR data for collocated samples can be found in Section 5.5.0, Figure 2 (SRNS, 2018). There are no numeric criteria in the South Carolina freshwater standards for a maximum BOD level; however, all 2018 DHEC samples were near or below the LLD of 2.0 mg/L. DOE-SR did not collect BOD samples in 2018, therefore, no comparison can be made for BOD.

Temperature can affect biological and chemical processes in a stream. All aquatic organisms can be negatively impacted by temperatures that vary from the naturally occurring range (EPA, 1997). The South Carolina freshwater standards state that the temperature of free-flowing freshwater shall not be increased more than 2.8°C above natural temperature conditions and shall not exceed a maximum of 32.2°C (DHEC, 2014b). DHEC data showed that the stream temperatures during each sampling event were comparable to each other, including samples representative of natural conditions that were upstream of most SRS operations.

Alkalinity is important for aquatic life in freshwater systems because it buffers pH changes that occur naturally or as a result of anthropogenic sources. Components of alkalinity, such as carbonate and bicarbonate, will incorporate some toxic heavy metals and reduce their toxicity (EPA, 1997). There are no numeric criteria in the South Carolina freshwater standards for alkalinity. However, the National Technical Advisory Committee recommends a minimum alkalinity of 20 mg/L and that natural alkalinity not be reduced by more than 25 mg/L. Waters having insufficient alkalinity due to natural conditions do not have to be supplemented with artificially added materials to increase the alkalinity. Alkalinity resulting from naturally occurring materials, such as carbonate and bicarbonate, is not considered a health hazard in drinking water supplies (National Academy of Sciences [NAS], 1974).

In 2018, all the locations sampled had yearly averages below the recommended minimum level for alkalinity. The low alkalinity, as related to pH, in SRS streams may be due to the source of surface water, geology of the site, and its variances in the levels of deposits of calcium carbonate. DOE-SR did not sample for alkalinity in 2018, therefore, no comparison can be made.

Drawing up creek water for testing

Turbidity is a measure of water clarity caused by suspended or dissolved particles that can scatter light to make the water appear cloudy. The freshwater quality standard for turbidity in South Carolina streams is not to exceed 50 nephelometric turbidity units (NTU) provided existing uses are maintained (DHEC, 2014b). All DHEC monitored streams were below the standard for turbidity in 2018. DOE-SR did not sample for turbidity in 2018, therefore, no comparison can be made. Turbidity is directly affected by the water's Total Suspended Solids (TSS), which refers to the amount of material suspended in the water (EPA, 1997). There is no freshwater quality standard for TSS. A TSS comparison of DHEC and DOE-SR data for collocated samples can be found in Section 5.5.0, Figure 3 (SRNS, 2019).

The South Carolina freshwater *E. coli* standard is a daily maximum of 349 Most Probable Number per 100mL (MPN/100mL). All nine streams sampled had individual samples that exceeded 349 MPN/100mL. Three locations (SV-325, SV-2047, SV-2055) had a yearly average above the standard. DOE-SR did not collect samples for *E. coli* in 2018, therefore, no comparison can be made.

Phosphorous and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. However, in excess they can cause significant water quality problems. Phosphorous and nitrogen cycle through the environment in a variety of forms and can indirectly impact DO and other water quality indicators (EPA, 1997). In 2018, DHEC sampled for total phosphorous and various forms of nitrogen, including nitrate/nitrite, total Kjeldahl nitrogen (TKN), and ammonia. There are no numeric criteria in the South Carolina freshwater standard for any of these parameters.

DHEC uses the most conservative of the federally established drinking water standards for nitrate/nitrite levels to indicate ambient water quality in freshwater streams for nutrients. The EPA drinking water standards for nitrate/nitrite levels are 10 mg/L and 1 mg/L, respectively, and are designed to protect the public from consumption of high levels of these nutrients (EPA, 2009). As a conservative measure, DHEC uses a maximum of 1 mg/L as an indication of possible water quality issues.

Overall the nutrient levels on SRS are similar to the levels found throughout the Savannah River Basin. DOE-SR did not sample for TKN or ammonia in 2018, therefore, no comparison can be made. A comparison of DHEC and DOE-SR data from collocated samples for total phosphorous and nitrate/nitrite, respectively, can be found in Section 5.5.0, Figures 4 and 5.

Most metals are considered to be pollutants, including some that are toxic or known carcinogens. In 2018, DHEC personnel collected samples for the following metals: cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Due to the potential health effects of some metals, a yearly average, even if based on a single detection that exceeds the freshwater standards, may indicate a water quality issue. These metals, with the exception of iron and manganese, have numeric criteria for the protection of human health and aquatic life in the South Carolina freshwater quality standards.

Iron has a recommended EPA limit in freshwater streams of 1 mg/L (EPA, 2008). One of the DHEC and DOE-SR sample locations indicated levels above the EPA recommended level. The yearly average at Tims Branch was 2.51 mg/L (DHEC) and 3.03 mg/L (DOE-SR), respectively (SRNS, 2019). Tims Branch has several ground water seeps that contribute to its relatively low flow. It is likely that the elevated iron measured at this location is influenced by naturally occurring processes. Pen Branch at Road A-13.2 was slightly over the EPA freshwater stream limit with a yearly average of 1.05 mg/L. A couple of locations had individual samples with detections higher than the EPA limit for iron, with the highest being 2 mg/L. A comparison of DHEC and DOE-SR iron data for collocated samples can be found in Section 5.5.0, Figure 6.

All DHEC manganese sample results were within the levels seen in the Savannah River Basin (DHEC, 2013b). However, there is no standard for this parameter. DHEC and DOE-SR detected manganese in all the collocated sample locations. See Section 5.5.0, Figure 7 for a manganese comparison of DHEC and DOE-SR data for collocated samples (SRNS, 2019).

The freshwater quality standard for cadmium in South Carolina streams is not to exceed 0.0001 mg/L (DHEC, 2014b). DHEC samples had no cadmium levels above the standard. Beginning in August 2018, DOE-SR changed their laboratory analysis for cadmium to achieve a lower detection limit. The new detection limit being used is 0.00005 mg/L versus the 0.0005 mg/L which was used from January to July 2018. DOE-SR detected cadmium above the standard at four of the collocated sample locations in 2018 (SRNS, 2019).

The freshwater quality standards for chromium, copper, and nickel in South Carolina streams are not to exceed 0.011 mg/L, 0.0029 mg/L and 0.016 mg/L, respectively (DHEC, 2014b). There were no DHEC or DOE-SR detections above the standard for chromium in 2018. DHEC detected copper above the standard in one sample: SV-324 at 0.02 mg/L. DOE-SR detected copper above the standard at SV-327 at 0.0038 mg/L (SRNS, 2019). DHEC did not detect nickel in 2018. DOE-SR detected nickel in one of the collocated sample locations, but the average did not exceed the standard (SRNS, 2019).

The freshwater quality standard for lead in South Carolina streams is not to exceed 0.00054 mg/L (DHEC, 2014b). Due to laboratory limitations, DHEC has a lower limit of detection (LLD) higher than the standard. Therefore, any detection of lead would be over the standard. There were no detections of lead for DHEC. Beginning in August 2018, DOE-SR changed their laboratory analysis for lead to achieve a lower detection limit. DOE-SR had no lead detections above the standard in 2018 in the collocated samples (SRNS, 2019).

The freshwater quality standard for mercury in South Carolina streams is not to exceed 0.00091 mg/L (DHEC, 2014b). Mercury was not detected in any of the DHEC samples in 2018. DOE-SR detected mercury at one of the collocated sampling locations, but not in exceedance of the standard (SRNS, 2019).

The freshwater quality standard for zinc in South Carolina streams is not to exceed 0.037 mg/L (DHEC, 2014b). DHEC had no samples over the standard in 2018, while DOE-SR had an individual sample at SV-2039 with 0.053 mg/L and at SV-328 with 0.073 mg/L both in the month of February. A zinc comparison of DHEC and DOE-SR yearly averages for collocated samples can be found in Section 5.5.0, Figure 8.

Most VOCs, PCBs, and pesticides are pollutants, some of which are toxic. Most have numeric criteria for the protection of human health and aquatic life in the South Carolina freshwater quality standards. There were no detections of VOC, PCB, or pesticide contaminants in 2018 in the DHEC or DOE-SR samples (SRNS, 2019).

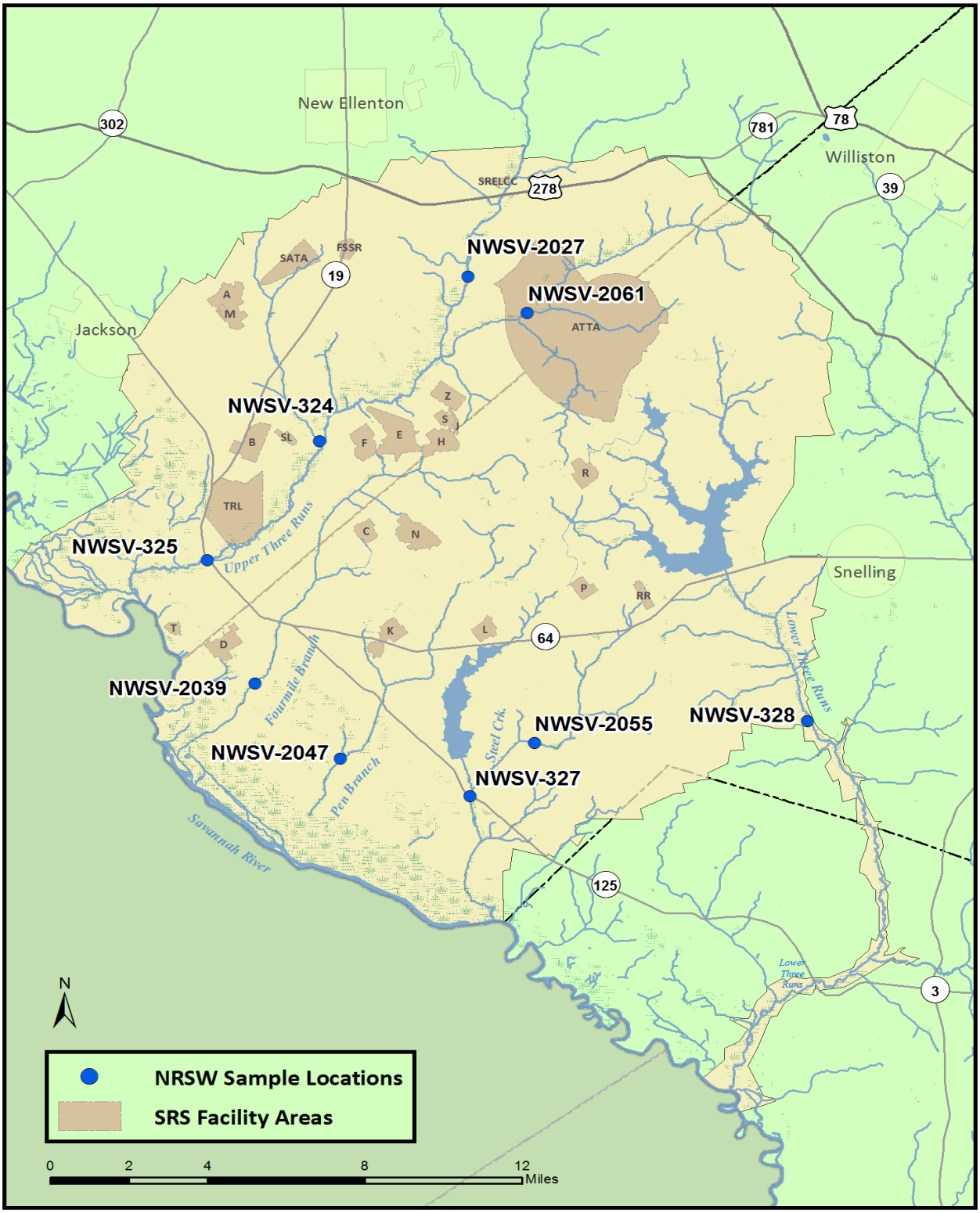
Small discrepancies in data between DOE-SR and DHEC may be attributed to differences in sample collection date and time, sample preservation, and lab analysis. Variances in statistical calculations, such as the yearly averages, may also attribute to dissimilarities. All data less than the LLD were left out of DHEC summary statistics due to lack of numeric information.

5.3.0 CONCLUSIONS AND RECOMMENDATIONS

The current parameters will continue to be monitored to establish trends that may warrant further investigation based on EPA or DHEC standards or recommended levels. Overall, the non-radiological water quality on SRS in 2018 compared favorably with the South Carolina Freshwaters Standard or other recommendations for the parameters and monitored locations. The 2018 DHEC results for most parameters were similar to the DHEC's Bureau of Water data for the Savannah River watershed (DHEC, 2013b). DHEC will continue to evaluate water quality based on the independent, non-radiological testing and surveillance of SRS surface water. Monitoring is required due to continued land disturbance from clean-up activities, new facility construction, logging, and new missions. The locations, number and frequencies of samples, and monitoring parameters are reviewed annually and modified as needed to maximize available resources and address SRS mission changes.

5.4.0 MAP

Non-radiological Surface Water Sampling Locations



2018 ESOP Non-Radiological Surface Water Monitoring

www.scdhec.gov

5.5.0 TABLES AND FIGURES

Table 1. 2018 DHEC Surface Water Sample Locations

Sample Location	Location Description	Location Rationale
NWSV-2027	Upper Three Runs at Road 2-1	Upstream of most SRS Operations
NWSV-2061	Tinker Creek at Road 2-1	Downstream of ATTA
NWSV-324*	Tims Branch at Road C	Downstream from M- & A-Areas
NWSV-325*	Upper Three Runs at Road A	Downstream from F-Area
NWSV-2055	Meyers Branch at Road 9	Downstream from P-Area
NWSV-2039*	Fourmile Branch at Road A-13.2	Downstream from F- and H-Areas
NWSV-2047*	Pen Branch at Road A-13.2	Downstream from K-Area
NWSV-327*	Steel Creek at Road A	Downstream from L-Lake
NWSV-328*	Lower Three Runs at Patterson Mill Road	Downstream from Par Pond

*Collocated with DOE-SR sample locations.

Table 2. 2018 DHEC Water Quality Parameter Analyses

Laboratory	Frequency	Parameter
Field	Monthly	Temperature, pH, Specific Conductivity, Dissolved Oxygen, and Total Dissolved Solids
DHEC Lab Aiken, S.C.	Monthly	Turbidity, BOD, E. Coli, and TSS
DHEC Lab Columbia, S.C.	Monthly	Alkalinity, Ammonia, Nutrients, Mercury, and Metals
DHEC Lab Columbia, S.C.	Semi-annually	VOCs, Pesticides, and PCBs

TABLES AND FIGURES

Figure 1. pH 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)

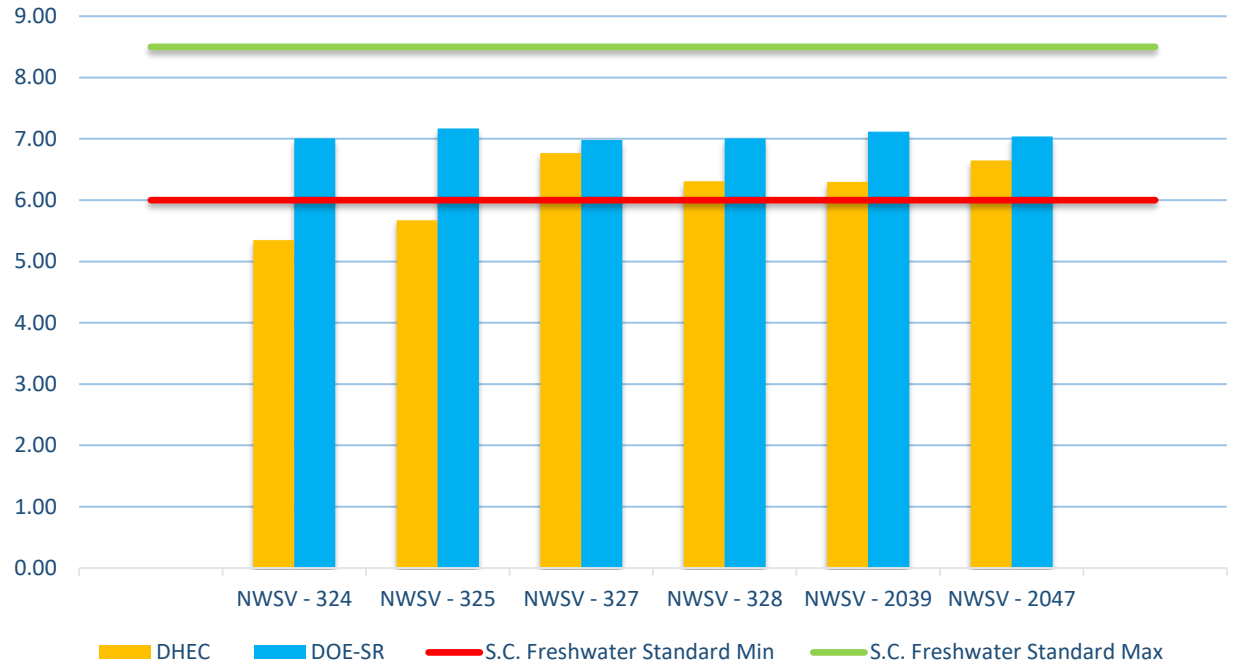
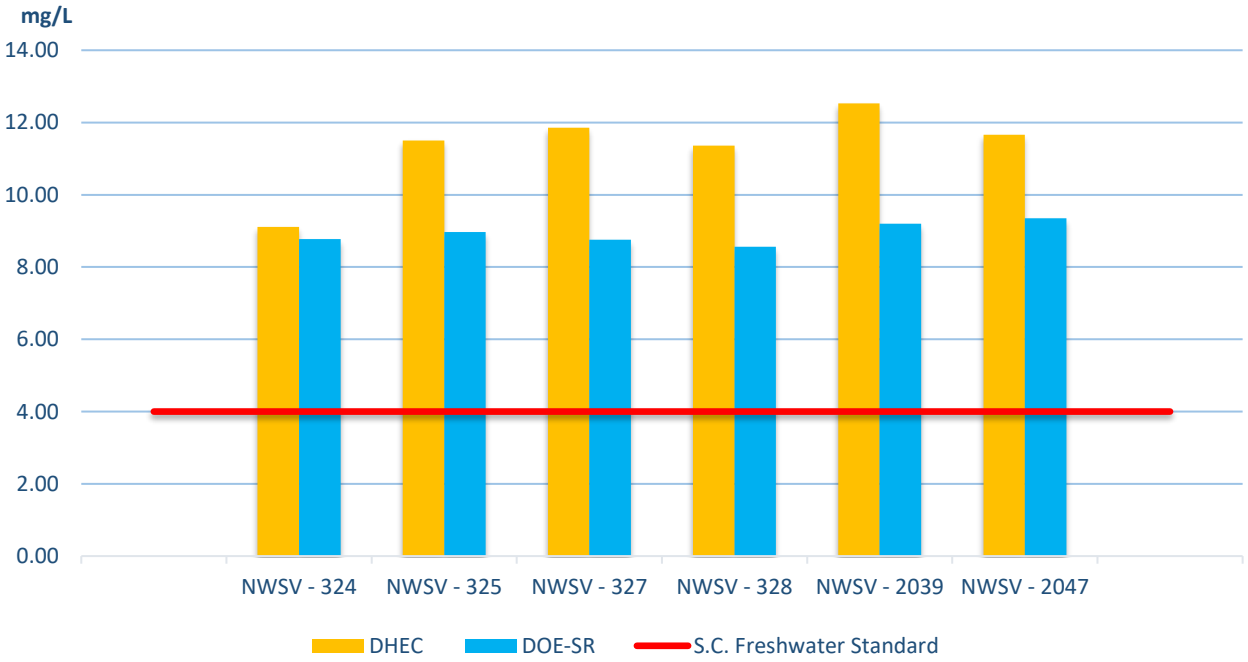


Figure 2. DO 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)



TABLES AND FIGURES

Figure 3. TSS 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)

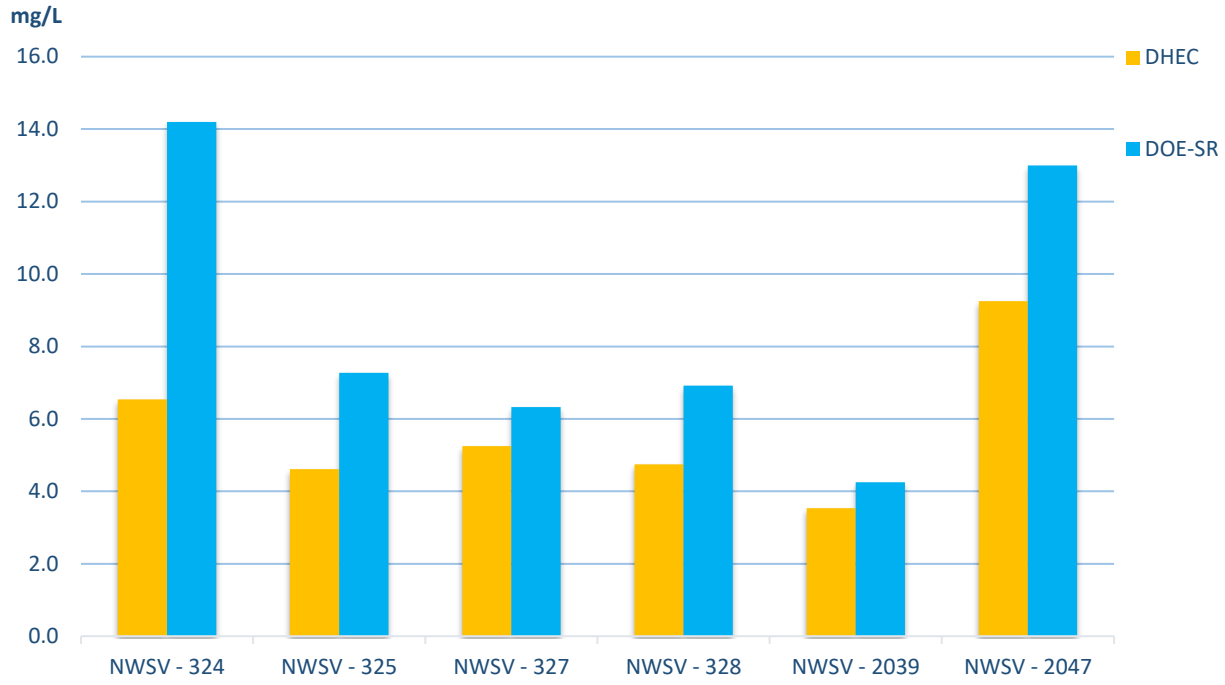


Figure 4. Total Phosphorous 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)

TABLES AND FIGURES

Figure 5. Nitrate/Nitrite 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)

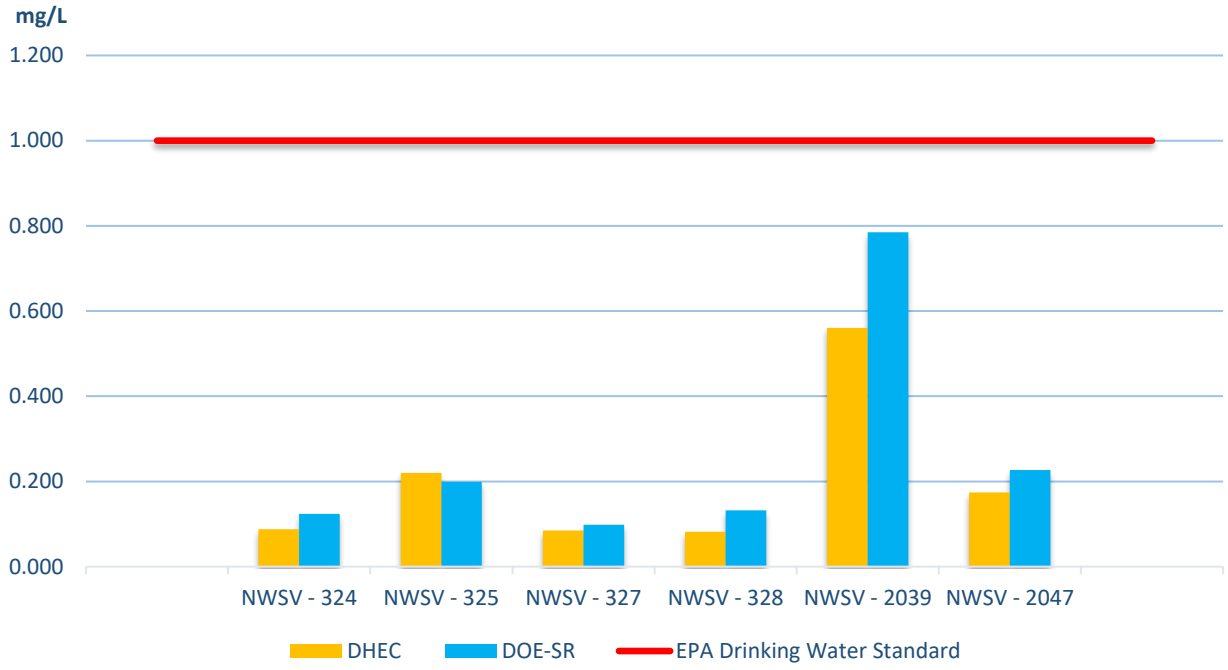
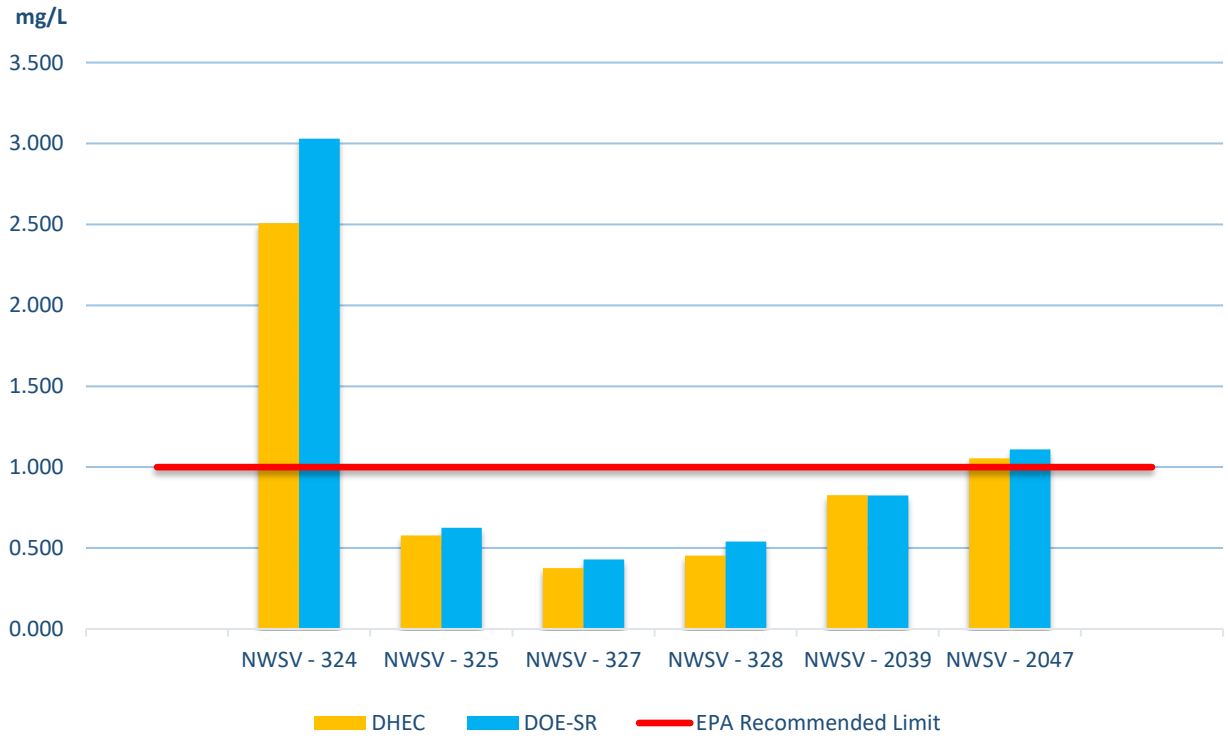


Figure 6. Iron 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)



TABLES AND FIGURES

Figure 7. Manganese 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)

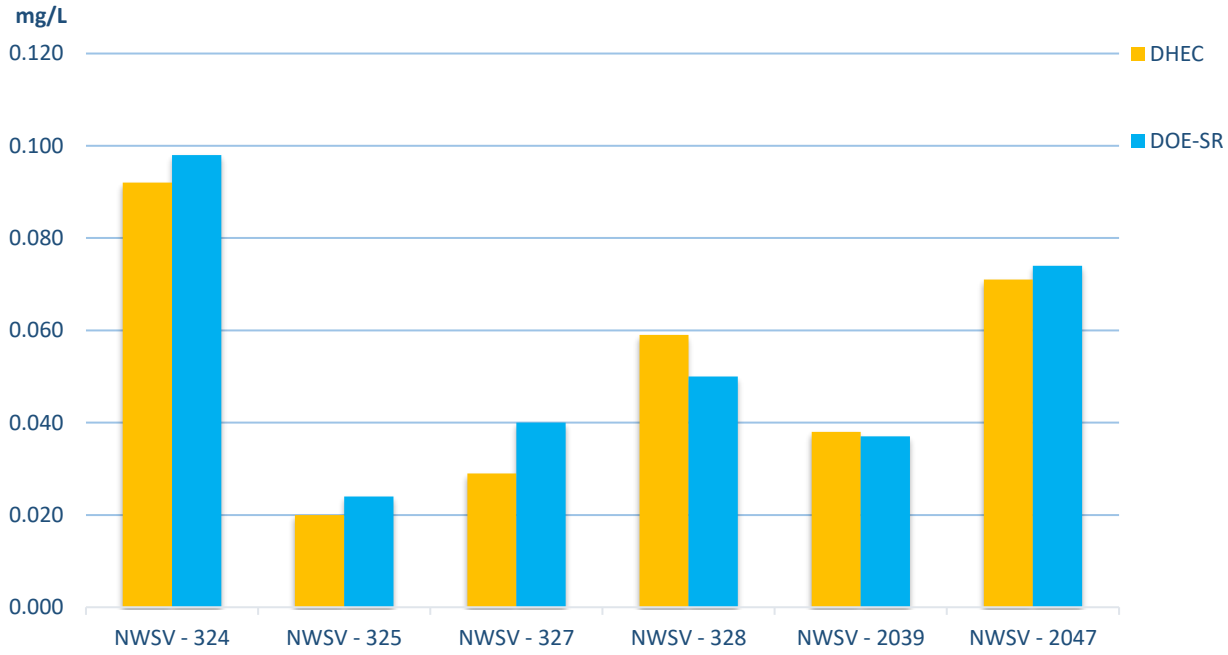
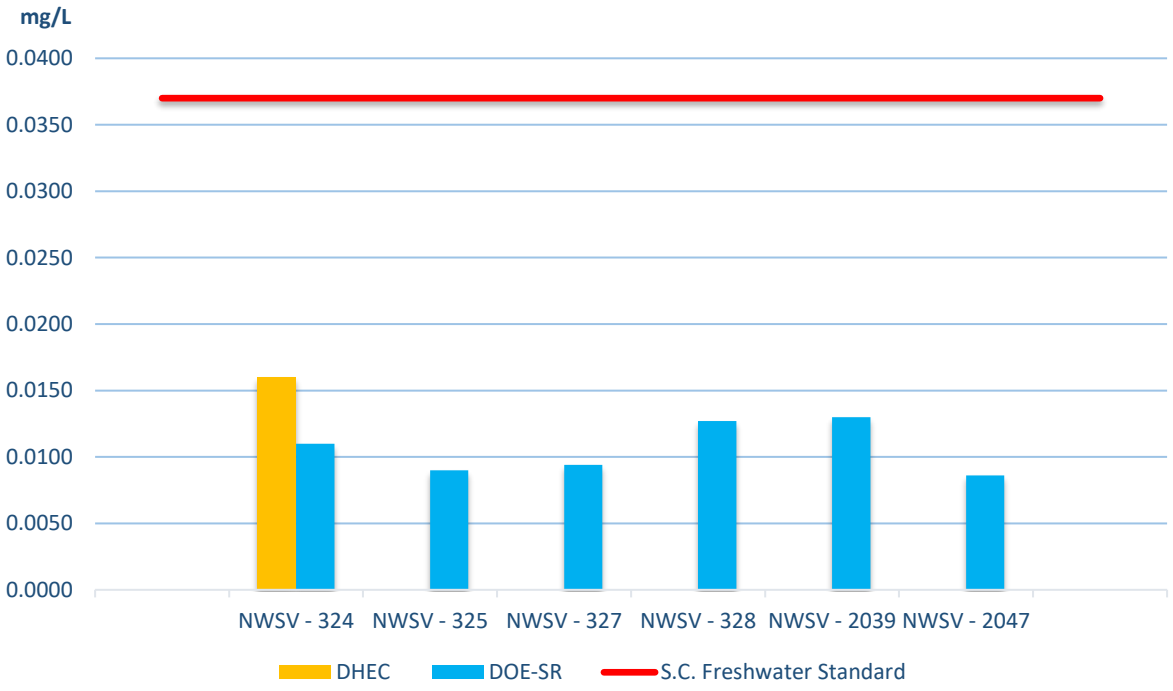


Figure 8. Zinc 2018 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2019)



Note: No bar indicates the sample average is <LLD and therefore is a non-detect

5.6.0 2018 SUMMARY STATISTICS

NWSV–324 Tims Branch at Road C

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	5.35	1.20	5.68	2.54	6.82	12
	DO (mg/L)	9.11	1.99	8.61	6.14	13.19	12
	Water Temp (°C)	16.61	6.64	15.95	4.70	24.08	12
	Conductivity (mS/cm)	0.02	0.01	0.02	0.01	0.02	8
Laboratory	Alkalinity (mg/L)	4.45	1.36	4.60	2.00	7.50	11
	Turbidity (NTU)	5.64	2.99	4.60	2.40	12.00	12
	BOD (mg/L)	2.50	NA	2.50	2.50	2.50	1
	TSS (mg/L)	6.54	4.11	5.95	1.70	17.00	12
	E. Coli (MPN/100mL)	306.28	276.73	233.65	18.50	866.40	12
	TKN (mg/L)	0.31	0.17	0.27	0.10	0.69	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.09	0.11	0.04	0.03	0.35	8
	Total Phosphorus (mg/L)	0.05	0.03	0.04	0.02	0.11	12
	Calcium (mg/L)	0.80	0.20	0.75	0.54	1.10	12
	Copper (mg/L)	0.02	NA	0.02	0.02	0.02	1
	Iron (mg/L)	2.51	1.04	2.45	1.10	4.50	12
	Magnesium (mg/L)	0.42	0.06	0.42	0.31	0.53	12
	Manganese (mg/L)	0.09	0.05	0.08	0.05	0.22	12
	Zinc (mg/L)	0.02	NA	0.02	0.02	0.02	1
	Hardness (mg/L)	3.70	0.73	3.65	2.60	4.90	12
	Aluminum (mg/L)	0.16	0.10	0.14	0.07	0.44	12

Notes for the 5.6.0 Summary Statistic Tables on pages 64-68:

1). ND is Not Detected

2). NA is Not Applicable

3). Beryllium, Cadmium, Chromium, Lead, Mercury, Nickel, and Thallium were not included in the charts as all locations had averages that were non-detects

NWSV-325 Upper Three Runs at Road A

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	5.67	0.81	5.81	3.64	6.65	12
	DO (mg/L)	11.50	3.11	10.67	8.13	17.76	12
	Water Temp (°C)	17.00	5.86	15.52	6.50	23.81	12
	Conductivity (mS/cm)	0.03	0.01	0.02	0.02	0.05	8
Laboratory	Alkalinity (mg/L)	3.93	1.97	3.85	1.40	9.60	12
	Turbidity (NTU)	4.25	1.17	4.50	2.10	6.20	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	4.61	2.43	3.85	1.60	8.70	12
	E. Coli (MPN/100mL)	410.20	459.57	238.20	96.00	>2419.6	12
	TKN (mg/L)	0.23	0.06	0.22	0.13	0.34	11
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.22	0.24	0.14	0.07	0.92	12
	Total Phosphorus (mg/L)	0.04	0.01	0.04	0.02	0.05	12
	Calcium (mg/L)	1.98	0.30	1.95	1.70	2.80	12
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.58	0.15	0.58	0.30	0.81	12
	Magnesium (mg/L)	0.43	0.05	0.41	0.38	0.55	12
	Manganese (mg/L)	0.02	0.01	0.02	0.01	0.04	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	6.68	0.96	6.55	5.80	9.30	12
	Aluminum (mg/L)	0.20	0.06	0.20	0.11	0.31	12

NWSV-327 Steel Creek at Road A

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.77	0.64	6.90	4.87	7.45	12
	DO (mg/L)	11.86	3.96	10.44	7.27	20.87	12
	Water Temp (°C)	17.90	6.91	17.26	6.20	25.82	12
	Conductivity (mS/cm)	0.06	0.01	0.06	0.04	0.06	9
Laboratory	Alkalinity (mg/L)	22.67	1.23	22.50	21.00	25.00	12
	Turbidity (NTU)	3.72	1.54	3.05	2.10	6.80	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	5.25	2.72	4.60	2.70	11.00	11
	E. Coli (MPN/100mL)	183.69	133.25	145.30	56.30	461.10	12
	TKN (mg/L)	0.27	0.12	0.22	0.14	0.48	11
	Ammonia (mg/L)	0.08	0.03	0.08	0.06	0.10	2
	Nitrate/Nitrite (mg/L)	0.09	0.06	0.06	0.04	0.23	11
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.02	0.04	2
	Calcium (mg/L)	6.54	0.73	6.75	5.60	7.50	12
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.38	0.15	0.33	0.20	0.71	12
	Magnesium (mg/L)	0.81	0.13	0.79	0.51	0.94	12
	Manganese (mg/L)	0.03	0.01	0.03	0.02	0.05	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	19.67	1.44	20.00	18.00	21.00	12
	Aluminum (mg/L)	0.13	0.07	0.10	0.07	0.28	10

Return to TOC

NWSV-328 Lower Three Runs at Patterson Mill Road

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.31	1.34	6.97	3.41	7.36	12
	DO (mg/L)	11.36	3.33	10.71	7.22	15.88	12
	Water Temp (°C)	16.90	7.12	17.49	6.30	25.44	12
	Conductivity (mS/cm)	0.08	0.01	0.07	0.06	0.09	9
Laboratory	Alkalinity (mg/L)	34.75	5.97	34.50	24.00	44.00	12
	Turbidity (NTU)	3.02	1.34	3.00	1.40	5.90	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	4.74	3.13	3.90	1.20	10.00	11
	E. Coli (MPN/100mL)	323.58	535.43	138.60	62.40	1986.30	12
	TKN (mg/L)	0.21	0.13	0.18	0.10	0.55	11
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.08	0.09	0.06	0.02	0.34	11
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.02	0.04	9
	Calcium (mg/L)	12.66	2.86	13.00	5.90	16.00	12
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.45	0.21	0.43	0.22	1.00	12
	Magnesium (mg/L)	0.58	0.09	0.54	0.51	0.82	12
	Manganese (mg/L)	0.06	0.06	0.04	0.03	0.25	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	34.08	7.00	35.00	18.00	43.00	12
	Aluminum (mg/L)	0.11	0.06	0.10	0.05	0.22	9

NWSV-2027 Upper Three Runs at Road 2-1

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	5.81	0.74	5.94	4.10	6.91	12
	DO (mg/L)	13.39	4.12	12.66	7.45	20.26	12
	Water Temp (°C)	16.42	5.93	18.05	6.10	22.00	12
	Conductivity (mS/cm)	0.02	0.00	0.02	0.01	0.02	9
Laboratory	Alkalinity (mg/L)	1.83	1.71	1.20	1.00	5.70	7
	Turbidity (NTU)	2.31	0.81	2.20	1.20	3.60	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	3.03	1.30	3.20	1.10	4.80	12
	E. Coli (MPN/100mL)	214.78	247.79	133.15	96.00	980.40	12
	TKN (mg/L)	0.21	0.10	0.18	0.13	0.44	7
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.27	0.03	0.27	0.22	0.33	11
	Total Phosphorus (mg/L)	ND	NA	NA	ND	ND	0
	Calcium (mg/L)	0.60	0.14	0.56	0.51	1.00	11
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.35	0.14	0.31	0.17	0.60	12
	Magnesium (mg/L)	0.40	0.02	0.40	0.38	0.43	12
	Manganese (mg/L)	0.02	0.01	0.01	0.01	0.02	3
	Zinc (mg/L)	0.02	NA	0.02	0.02	0.02	1
	Hardness (mg/L)	3.15	0.40	3.00	2.90	4.30	11
	Aluminum (mg/L)	0.12	0.05	0.10	0.08	0.27	12

NWSV-2039 Fourmile Branch at Road A-13.2

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.30	0.88	6.56	4.05	7.28	12
	DO (mg/L)	12.53	3.04	11.89	8.21	18.70	12
	Water Temp (°C)	16.69	6.63	15.46	5.60	24.41	12
	Conductivity (mS/cm)	0.05	0.00	0.05	0.04	0.05	8
Laboratory	Alkalinity (mg/L)	14.39	4.72	14.00	7.50	23.00	12
	Turbidity (NTU)	3.83	1.19	3.70	2.30	6.40	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	3.53	1.95	3.00	1.20	7.30	12
	E. Coli (MPN/100mL)	231.34	376.12	110.65	48.80	1413.60	12
	TKN (mg/L)	0.24	0.09	0.24	0.14	0.42	8
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.56	0.21	0.56	0.11	0.90	12
	Total Phosphorus (mg/L)	0.09	0.04	0.09	0.03	0.17	12
	Calcium (mg/L)	3.91	1.60	3.70	2.60	8.40	12
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.83	0.24	0.81	0.55	1.40	12
	Magnesium (mg/L)	0.55	0.06	0.54	0.48	0.63	12
	Manganese (mg/L)	0.04	0.01	0.04	0.03	0.06	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	12.03	4.08	11.50	8.60	23.00	12
	Aluminum (mg/L)	0.13	0.05	0.11	0.06	0.22	11

NWSV-2047 Pen Branch at Road A-13.2

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.65	0.69	6.72	4.68	7.50	12
	DO (mg/L)	11.66	2.99	11.07	7.43	17.49	12
	Water Temp (°C)	16.83	6.40	16.88	6.30	23.72	12
	Conductivity (mS/cm)	0.06	0.02	0.05	0.04	0.12	9
Laboratory	Alkalinity (mg/L)	19.42	7.27	18.50	11.00	37.00	12
	Turbidity (NTU)	7.45	4.65	5.25	3.30	17.00	12
	BOD (mg/L)	2.00	NA	2.00	2.00	2.00	1
	TSS (mg/L)	9.25	8.27	5.65	1.90	26.00	12
	E. Coli (MPN/100mL)	440.86	492.37	170.90	67.00	1413.60	12
	TKN (mg/L)	0.22	0.12	0.19	0.10	0.50	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.17	0.15	0.13	0.06	0.62	12
	Total Phosphorus (mg/L)	0.04	0.02	0.03	0.02	0.09	11
	Calcium (mg/L)	7.43	2.34	7.50	2.90	12.00	11
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	1.05	0.54	0.85	0.34	2.00	12
	Magnesium (mg/L)	0.54	0.05	0.55	0.47	0.63	12
	Manganese (mg/L)	0.07	0.05	0.05	0.03	0.18	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	20.85	5.89	21.00	9.30	32.00	11
	Aluminum (mg/L)	0.30	0.20	0.24	0.07	0.64	12

NWSV-2055 Meyers Branch at Road 9

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.40	0.87	6.74	4.33	7.27	12
	DO (mg/L)	14.52	5.57	15.84	7.67	25.25	12
	Water Temp (°C)	16.13	6.50	16.60	6.20	23.31	12
	Conductivity (mS/cm)	0.04	0.01	0.04	0.03	0.05	9
Laboratory	Alkalinity (mg/L)	16.31	6.91	15.50	4.70	34.00	12
	Turbidity (NTU)	4.03	3.00	3.00	1.80	13.00	12
	BOD (mg/L)	3.40	1.41	3.40	2.40	4.40	2
	TSS (mg/L)	5.53	4.45	4.65	1.50	18.00	12
	E. Coli (MPN/100mL)	419.14	202.81	387.30	88.20	>2419.6	12
	TKN (mg/L)	0.22	0.09	0.22	0.12	0.39	8
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.14	0.05	0.13	0.08	0.24	12
	Total Phosphorus (mg/L)	0.03	NA	0.03	0.03	0.03	1
	Calcium (mg/L)	5.89	1.00	6.00	3.50	7.20	11
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.52	0.20	0.47	0.30	0.99	12
	Magnesium (mg/L)	0.43	0.04	0.42	0.38	0.52	12
	Manganese (mg/L)	0.08	0.09	0.04	0.03	0.29	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	16.64	2.38	17.00	11.00	20.00	11
	Aluminum (mg/L)	0.20	0.15	0.17	0.08	0.63	11

NWSV-2061 Upper Three Runs at Road 2-1

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.09	0.73	6.22	4.90	7.07	12
	DO (mg/L)	15.31	5.91	15.93	6.97	28.83	12
	Water Temp (°C)	17.03	7.20	17.97	6.10	25.09	12
	Conductivity (mS/cm)	0.03	0.01	0.03	0.02	0.05	9
Laboratory	Alkalinity (mg/L)	4.83	1.95	5.20	1.60	7.50	11
	Turbidity (NTU)	2.92	0.73	3.10	1.70	4.30	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	3.83	1.43	4.00	1.70	6.60	12
	E. Coli (MPN/100mL)	276.70	389.01	143.90	52.00	1413.60	12
	TKN (mg/L)	0.22	0.10	0.20	0.10	0.44	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.06	0.06	0.04	0.02	0.23	11
	Total Phosphorus (mg/L)	0.05	0.02	0.04	0.03	0.07	12
	Calcium (mg/L)	2.67	0.44	2.50	1.80	3.30	11
	Copper (mg/L)	ND	NA	NA	ND	ND	0
	Iron (mg/L)	0.47	0.16	0.46	0.24	0.76	12
	Magnesium (mg/L)	0.36	0.03	0.35	0.33	0.42	12
	Manganese (mg/L)	0.02	0.01	0.02	0.02	0.04	12
	Zinc (mg/L)	ND	NA	NA	ND	ND	0
	Hardness (mg/L)	8.18	1.19	7.70	5.90	10.00	11
	Aluminum (mg/L)	0.20	0.06	0.18	0.12	0.34	12

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Chapter 6 Monitoring of Sediments on and Adjacent to SRS

6.1.0 PROJECT SUMMARY

The accumulation of radiological and non-radiological contaminants in sediment can directly affect aquatic organisms which can lead to human exposure. Impacts to water bodies come through direct discharge, atmospheric fallout, and runoff. These accumulated contaminants may re-suspend in streams and rivers or disperse downstream, potentially affecting drinking water supplies and fish consumed by the public. The transportation of sediments is a dynamic process. Stream flow changes can redistribute contaminants or bury them as part of the natural sedimentation process. Patterns of sediment contamination are strongly affected by hydrologic factors and the physical and chemical characterization of the sediment (EPA, 1987).

Collecting sediment samples from the river bank

SRS streams receive surface water runoff and water from permitted discharges (DOE, 1995). SRS is within the Savannah River watershed, with five major streams feeding into the Savannah River. Dispersal of any contaminants from these streams has the potential to impact the Savannah River.

Collecting sediment samples from a dock

DHEC personnel evaluate sediment samples for radionuclide and non-radionuclide contaminant concentrations in SRS streams, SRS storm-water basins, creek mouths along the boundary of SRS, the Savannah River, and publicly accessible boat landings in the SRS vicinity. Radionuclide detections in sediment are typically the result of accumulation over many years and do not represent yearly depositions. Sediment samples on SRS are routinely split with DOE-SR to compare results.

A complete list of all radiological and non-radiological analytes can be found in List of Tables, Table 1 and Table 2 on page x. DHEC sediment sampling locations are illustrated in Section 6.4.0, Map. DHEC and DOE-SR split samples were collected from nine stream locations on SRS, and from three SRS storm-water basins. A complete list of sample locations is listed in Section 6.5.0, Table 1.

6.2.0 RESULTS AND DISCUSSION

DHEC sediment monitoring summary statistics can be found in Section 6.6.0 and sediment monitoring data can be found in the 2018 DHEC Data File.

6.2.1 Radiological Results

Cesium-137 releases from Z-Area have the potential to contaminate tributaries of McQueen Branch, which flows into Upper Three Runs. The impact for possible contamination warrants long-term monitoring by DHEC along SRS streams and the publicly accessible Savannah River.

The creek mouths of SRS are a conduit for the dispersal of radionuclides into publicly accessible water. Cesium-137 activity was found by DHEC in the sediment within several creek mouths at the Savannah River. Actinium-228, beryllium-7, potassium-40, lead-212, lead-214, radium-226, and thorium-234 are NORM decay products that account for the remaining gamma detections. All other gamma-emitting radionuclides had no detections above their respective MDA.

DHEC had sporadic gross alpha and gross non-volatile beta activity detections in 2018. The summary statistics can be found in Section 6.6.0.

Cesium-137 is the most abundant anthropogenic radionuclide found in the sediment samples. Cesium-137 levels in 2018 data from samples collected outside SRS boundaries are all within the expected range and consistent with previous DHEC background data. Cs-137 in sediment may be attributed, in part, to fallout from past nuclear events in the 1950s and 1960s. The highest level of Cs-137 from all 2018 DHEC and DOE-SR collocated sediment samples occurred at Steel Creek at Hwy 125. DHEC had the highest Cs-137 detections at 8.93 pCi/g in Lower Three Runs (Rd.125), 4.90 pCi/g at Lower Three Runs (Patterson Mill Road), and 1.25 pCi/g at Steel Creek Mouth. DOE-SR had readings of 0.96 pCi/g for Steel Creek. Cesium-137 contamination in this area is well documented and not unexpected. All sample results were well below the Preliminary Remediation Goal (PRG) of 28 pCi/g for Cs-137 (Section 6.5.0, Table 2) (EPA, 2018c).

Sediment is dried before radiological tests can be run

Figure 1 in Section 6.5.0 illustrates the DHEC average Cs-137 activity in sediment samples from SRS storm-water basins, SRS streams, SRS creek mouths, publicly accessible boat landings, and background sampling locations. DHEC Cs-137 data from the SRS creek mouths were trended for 2014-2018 (Section 6.5.0, Figure 2) and were compared to DOE-SR data (Section 6.5.0, Figure 3).

6.2.2 Non-radiological Results

Metals in sediment can be naturally occurring or a result of man-made processes such as those used in SRS operations, which have released elevated amounts into streams on SRS. Re-

distribution of sediment from flooding can carry contaminants to downstream locations. Geological factors in the Savannah River basin contribute to the levels of metals through erosion and sedimentation. All 2018 DHEC samples had averages below the Ecological Screening Values (ESVs) for barium, beryllium, copper, chromium, mercury, nickel, and zinc (EPA, 2018a). All DOE-SR samples averages were below the ESVs with the exception of manganese in creek mouths with an average of 884 mg/kg. DOE-SR did not test for beryllium in 2018.

Comparisons were made to the ESVs for sediment which does not represent remediation goals or cleanup levels but is used to identify constituents of potential concern (WSRC, 2005). The DHEC cadmium Minimum Detection Level (MDL) is higher than the ESV of 0.36 mg/kg, therefore any detections are above the ESV. Cadmium was detected above the ESV by DHEC in one of the on-site streams, three of the creek mouths, two of the storm-water basins, two of the public boat landings, and three of the background locations. DOE-SR did not detect cadmium in any of its collocated samples in 2018.

Sediment is measured out to be tested for non-radiological parameters

Chromium was detected by DHEC above the ESV of 28 mg/kg at one of the on-site streams (Lower Three Runs @ Mile 125) and two of the background locations (Beaufort County and Spartanburg County). DOE-SR detected chromium above the ESV in one on-site stream (LTR-3).

DHEC detected lead above the ESV of 11 mg/kg in one on-site stream, one creek mouth, one storm-water basin, no boat landings, and at two background locations. DOE-SR detected lead above the ESV in one on-site stream (LTR-3).

DHEC detected manganese above the ESV of 220 mg/kg in two on-site locations, all creek mouths, and two boat landings. DOE-SR had one on-site streams and all five creek mouths with results above the ESV of Mn.

Mercury was detected above the ESV of 0.1 mg/kg in one on-site stream sample. DOE-SR had no samples with a result at or above the ESV of mercury.

Zinc was detected by DHEC above the ESV of 46 mg/kg in one on-site stream, one creek mouth, one storm-water basin, and two background locations. DOE-SR detected zinc above the ESV in one stormwater basin and one creek mouth location.

DHEC non-radiological sediment data can be found in the 2018 DHEC Data File and non-radiological summary statistics can be found in Section 6.6.0.

6.3.0 CONCLUSIONS AND RECOMMENDATIONS

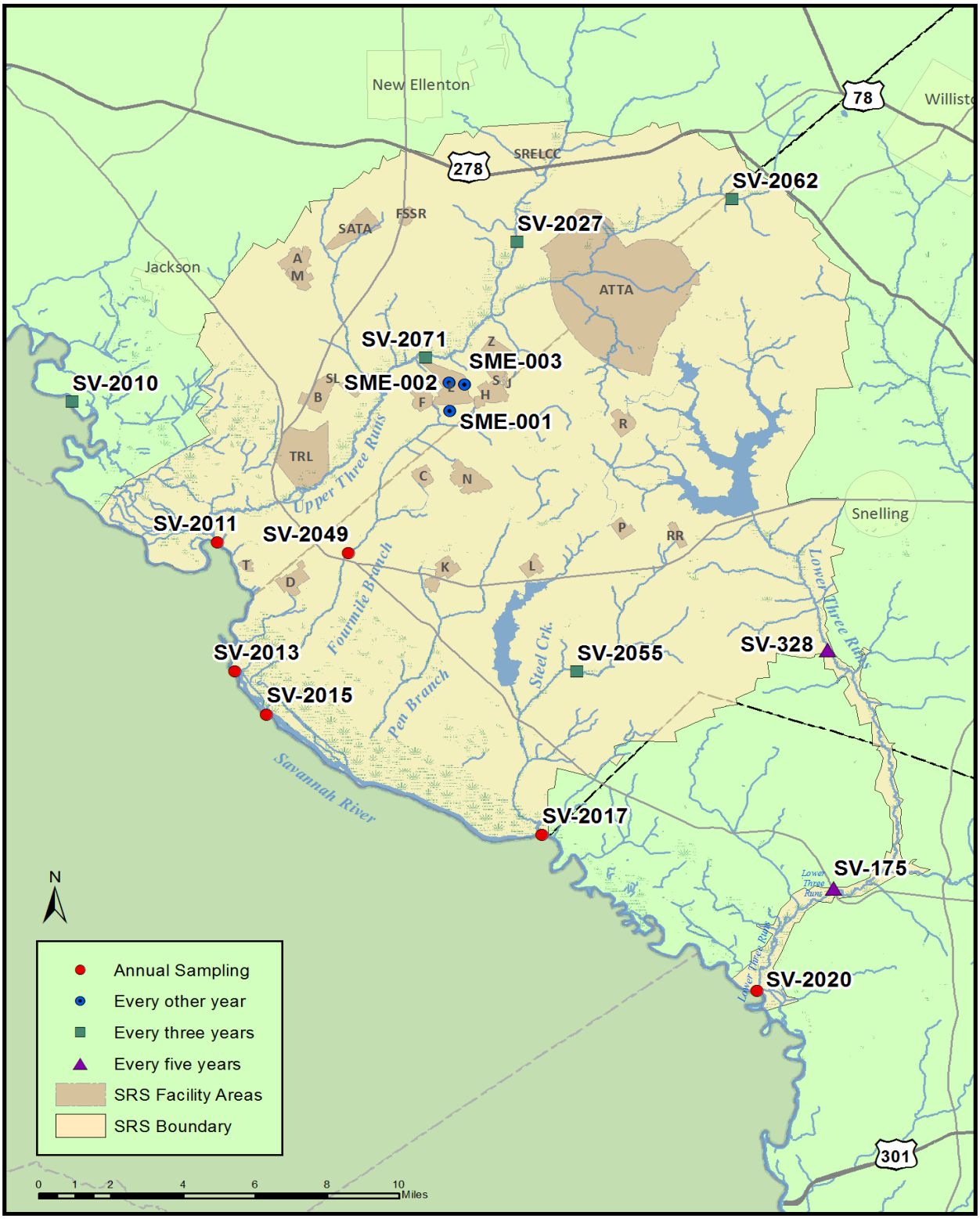
SRS sediments should continue to be monitored due to current releases of contaminants and the potential for future discharges from SRS operations, legacy wastes, and clean-up activities. Year-to-year data comparisons are difficult to interpret due to the nature of sediment accumulation. Differences among samples may be due to the fraction of clays that most effectively retain radionuclides. There is also difficulty in replicating the exact sampling point due to erosion and sedimentation. Monitoring of on-site sediments is of great importance since over-land precipitation and streams transport contaminated sediment with radionuclides outside the SRS boundary.

DHEC will continue to independently monitor sediment on SRS and in the Savannah River to improve our understanding of the presence of radionuclide and non-radionuclide concentrations. DHEC will also periodically evaluate and modify the sampling methodology to better accomplish project goals and objectives.

Trending of data over multiple years demonstrates whether radionuclide concentrations in the SRS area are declining through radioactive decay or possibly increasing due to disturbances on SRS. By comparing data throughout the years, DOE-SR can evaluate its results as well as show the differences between its data and results from samples collected through monitoring by DHEC. Cooperation between DOE-SR and DHEC provides credibility and confidence in the information being provided to the public.

6.4.0 MAP

SRS Sediment Sampling Locations



6.5.0 TABLES AND FIGURES

Table 1. 2018 DHEC Sediment Sample Locations

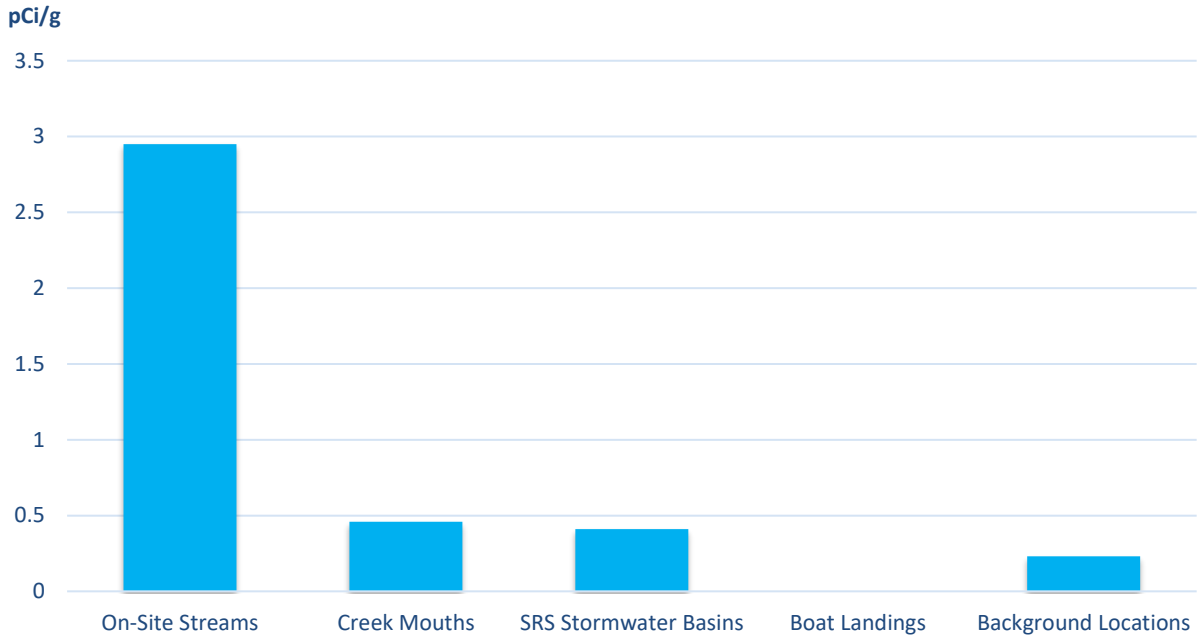
Non-Publicly Accessible Sediment Sample Locations on SRS	
Sample Location ID	**Location Description**
SRS Creek Mouth Samples	
SV-2011	Upper Three Runs Mouth @ RM 157.4
SV-2013	Beaver Dam Creek @ RM 152.3
SV-2015	Fourmile Branch creek mouth @ RM 150.6
SV-2017	Steel Creek mouth @ RM 141.5
SV-2020	Lower Three Runs mouth @ RM 129.1
Non-Publicly Accessible Stream Samples	
SV-175	Lower Three Runs @ Mile 125
SV-328	Lower Three Runs @ Patterson Mill Road
SV-2027	Upper Three Runs @ USFS Road 2-1
SV-2049	Four Mile Creek at Road A
SV-2055	Meyers Branch Road @ Road 9
SV-2062	Tinker Creek @ Kennedy Pond Road
SV-2071	Upper Three Runs Off of Road 4
SRS Stormwater Basin Samples	
SME-001	E-001 E Area stormwater basin
SME-002	E-002 E Area stormwater basin
SME-003	E-003 E Area stormwater basin
Publicly Accessible Sample Locations at the Savannah River Boat Landings	
Sample Location ID	**Location Description**
Upstream of SRS	
SMRVP18	North Augusta Riverview Park Boat Landing
SMSVC18	Steven's Creek Boat Landing
SMJBL18	Jackson Boat Landing
Downstream of SRS	
No downstream locations were sampled in 2018 due to flooding	

Background Locations	
Sample Location ID	**Location Description**
SMBUF18	Beaufort County, SC
SMHOR18	Horry Country, SC
SMMCK18	McCormick County, SC
SMSPA18	Spartanburg County, SC

Table 2. Soil Ingestion Preliminary Remediation Goals of Select Anthropogenic Radionuclides

Radionuclide	PRG (pCi/g)
Americium-241	4.9
Cesium-137	28
Cobalt – 60	83
Iodine-131	6000
Plutonium-238	3.9
Plutonium-239/240	3.9

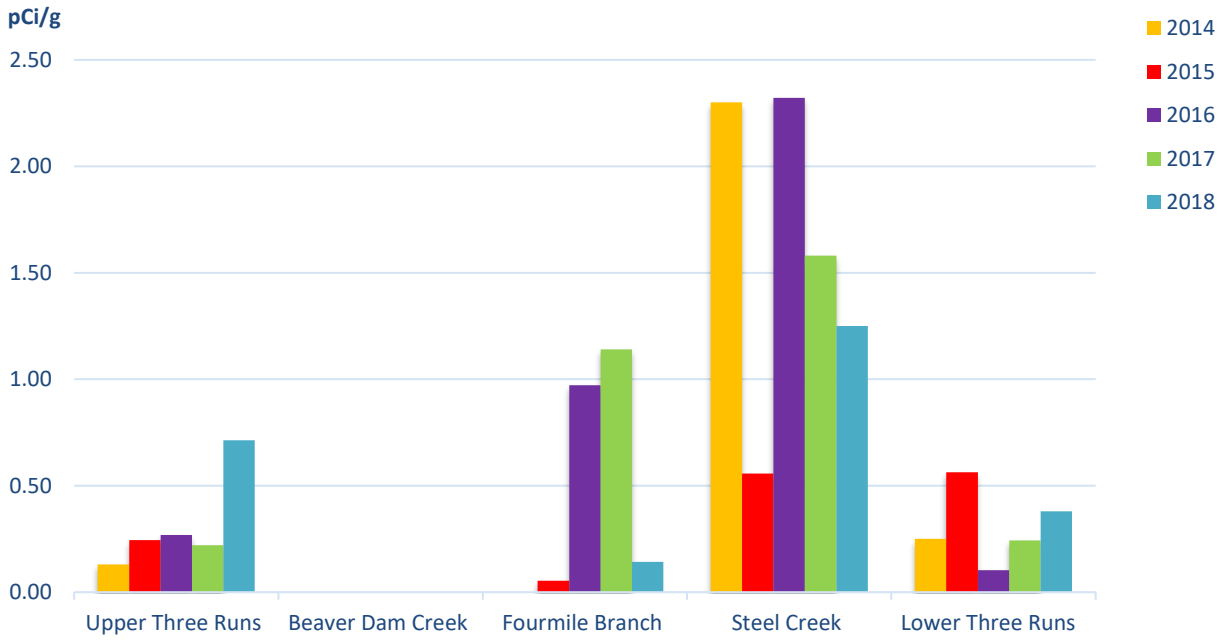
Figure 1. 2018 Comparisons of Cs-137 Average Activity Among Sample Location Type



Note: No bar denotes no detection.

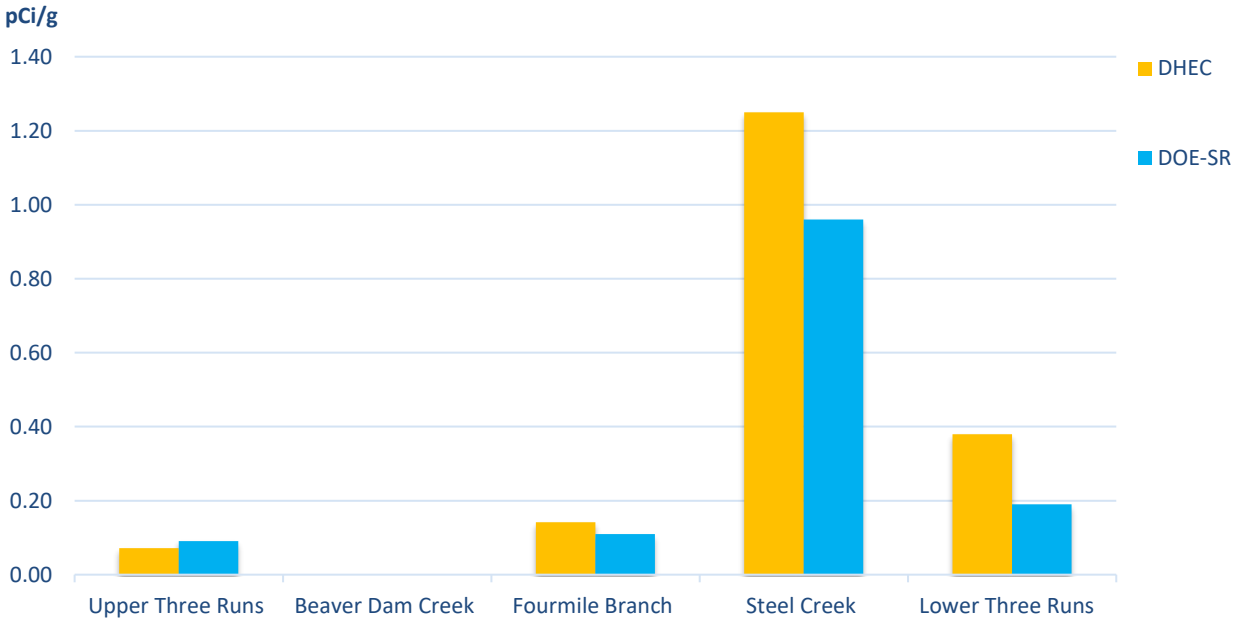
TABLES AND FIGURES

Figure 2. 2014-2018 Trending Data for Cs-137 in SRS Creek Mouth Samples (DHEC, 2015-2018)



Note: No bar denotes no detection for that year.

Figure 3. 2018 Cesium-137 in Savannah River Creek Mouths–DHEC Comparison to DOE-SR Data (SRNS, 2019)



Note: Beaver Dam Creek had no detection from DHEC or DOE-SR.

6.6.0 SUMMARY STATISTICS

2018 DHEC Radiological Data

On-Site Streams

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Cs-137	2.95	3.9	0.79	0.05	8.93	5	22
Gross Alpha	26.08	22.07	17.55	10.9	58.3	4	22
Gross Beta	21.43	17.98	15.25	7.41	47.8	4	22

Creek Mouths

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.46	0.54	0.26	0.07	1.25	4	22
Gross Alpha	9.5	7.06	6.37	5.24	20	4	22
Gross Beta	20.8	3.87	19.6	17.3	27.3	5	22

Storm-water Basins

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.41	0.48	0.41	0.07	0.75	2	22
Gross Alpha	10.96	1.71	10.9	9.29	12.7	3	22
Gross Beta	21.2	NA	21.2	21.2	21.2	1	22

Boat Landings

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Cs-137	ND	NA	NA	ND	ND	0	22
Gross Alpha	ND	NA	NA	ND	ND	0	22
Gross Beta	13.73	8.35	10	7.89	23.3	3	22

Background Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.23	N/A	0.23	0.23	0.23	1	22
Gross Alpha	13.6	4.24	13.6	10.6	16.6	2	22
Gross Beta	27.13	13.48	25.4	14.6	41.4	3	22

Note: ND is Not Detected, NA is Not Applicable

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SUMMARY STATISTICS

2018 DHEC Non-radiological (Metals) Data

On-Site Streams

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	44.8	37.24	30	5.6	110	7	7	330
Beryllium	0.65	0.24	0.58	0.46	0.92	3	7	10
Cadmium	1.3	NA	1.3	1.3	1.3	1	7	0.36
Chromium	10.33	10.82	6.2	1.9	33	7	7	28
Copper	3.06	2.66	1.6	1	6.9	5	7	28
Lead	11.7	6.45	12	5.1	18	3	7	11
Manganese	206	268.06	68	18	760	7	7	220
Mercury	0.13	NA	0.13	0.13	0.13	1	7	0.1
Nickel	5.55	2.64	5.45	2.6	8.7	4	7	38
Zinc	17.61	14.84	14	2.8	47	7	7	46

Creek Mouth Locations

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	91.8	33.12	97	55	140	5	5	330
Beryllium	ND	NA	NA	ND	ND	0	5	10
Cadmium	1.53	0.45	1.5	1.1	2	3	5	0.36
Chromium	15.8	6.65	18	8	24	5	5	28
Copper	5.7	2.89	4.7	3.1	10	5	5	28
Lead	7.8	3.5	6.4	5.4	13	4	5	11
Manganese	914	401.47	970	320	1400	5	5	220
Mercury	ND	NA	NA	ND	ND	0	5	0.1
Nickel	6.94	2.22	7.4	4.4	10	5	5	38
Zinc	34.8	11.48	36	23	50	5	5	46

Storm-water Basins

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	45.3	23.2	42	24	70	3	3	330
Beryllium	0.33	NA	0.33	0.33	0.33	1	3	10
Cadmium	1.1	0	1.1	1.1	1.1	2	3	0.36
Chromium	20.3	4.04	21	16	24	3	3	28
Copper	6.03	3.56	5	3.1	10	3	3	28
Lead	10	1	10	9	11	3	3	11
Manganese	65	30.51	51	44	100	3	3	220
Mercury	ND	NA	NA	ND	ND	0	3	0.1
Nickel	7.07	1.8	7.2	5.2	8.8	3	3	38
Zinc	46.3	33.26	34	21	84	3	3	46

Boat Landings

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	44.67	29.28	40	18	76	3	3	330
Beryllium	ND	NA	NA	ND	ND	0	3	10
Cadmium	1.3	0.42	1.3	1.0	1.6	2	3	0.36
Chromium	8.9	4.46	7	5.7	14	3	3	28
Copper	4.1	1.15	4.2	2.9	5.2	3	3	28
Lead	6.8	NA	6.8	6.8	6.8	1	3	11
Manganese	470	370.27	370	160	880	3	3	220
Mercury	ND	NA	NA	ND	ND	0	3	0.1
Nickel	3.73	1.79	2.8	2.6	5.8	3	3	38
Zinc	33.33	11.02	28	26	46	3	3	46

Background Samples

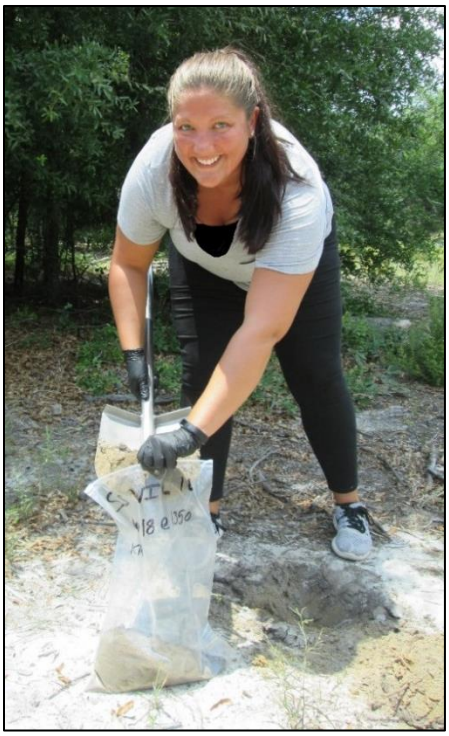
Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	53.95	42.12	49	7.8	110	4	4	330
Beryllium	ND	NA	NA	ND	ND	0	4	10
Cadmium	1.43	0.85	1.7	0.2	2.1	4	4	0.36
Chromium	21.1	18.17	20.8	2.8	40	4	4	28
Copper	10.67	8.02	10	3	19	3	4	28
Lead	12.9	12.36	10.45	1.7	29	4	4	11
Manganese	131.5	71.43	160	26	180	4	4	220
Mercury	ND	NA	ND	ND	ND	0	4	0.1
Nickel	11	7.05	11	3.9	18	3	4	38
Zinc	45.3	40.26	37.5	6.2	100	4	4	46

Note:

1. ND is Not Detected
2. NA is Not Applicable

Chapter 7 Surface Soil Monitoring Adjacent to SRS

7.1.0 PROJECT SUMMARY



Collecting soil samples which will be tested for radiological material and metals

DHEC independently evaluates surface soil adjacent to SRS from ground surface to a 12-inch depth for gross alpha, gross non-volatile beta, and select gamma-emitting radionuclides, as well as specific metals of concern. Soil samples are collected to determine if SRS activities have had an impact on areas outside the site boundary. Radionuclide detections in soil are the result of accumulation over many years.

A 50-mile SRS center point area was chosen for the comparison of DHEC and DOE-SR SRS perimeter radiological data averages. Since DOE-SR environmental monitoring division does not report metals data for surface soil, no direct data comparisons can be made.

DHEC collected samples from nineteen SRS perimeter locations and from four background locations in 2018 (Section 7.5.0, Table 1). SRS perimeter sampling locations are depicted on the Map in Section 7.4.0.

7.2.0 RESULTS AND DISCUSSION

7.2.1 Radiological Parameter Results

Soil Monitoring Summary Statistics for radionuclides and metals can be found in Section 7.6.0 and all Soil Monitoring Data can be found in the 2018 DHEC Data File.

Most samples had detectable amounts of Cs-137, an anthropogenic radionuclide that may be present due to a legacy of releases by SRS and atmospheric fallout from past nuclear weapons testing (EPA 2014). An assessment of Cs-137 activity in 2018 is comparable to levels detected by DHEC in the past. There were no surface soil samples collected in 2018 that were above the EPA Preliminary Remediation Goals (PRGs), which can be found in Section 7.5.0, Table 2 (EPA, 2018b).

Samples being prepped for the oven

DHEC had Cs-137 detections in 16 of 19 SRS perimeter samples and in all four background samples in 2018 (Section 7.6.0). Cesium-137 was the only gamma-emitting radionuclide that DHEC and DOE-SR shared in analytical results. Both DHEC and DOE-SR resulted in similar findings. DHEC had an average Cs-137 concentration of 0.11 pCi/g, which was slightly lower than DOE-SR's findings of 0.19 pCi/g. The PRG for C-137 is 28 pCi/g and all sample results were well below that level. DOE-SR reports in 2018 that Cs-

137 concentrations are consistent with historical results (SRNS, 2019). Trending data for Cs-137 in SRS perimeter samples is in Section 7.5.0, Figures 1 and 2.

All radiological samples are placed in an oven to burn off organic material and bacteria

The results found by both DHEC and DOE-SR are influenced by the number of samples used to determine the average and by collecting samples from different locations. The average level of Cs-137 in surface soil can vary due to the highly variable nature of soils. Radiocesium bioavailability in soil is influenced by soil properties such as clay content, pH, organic matter, and soil microflora (Absalom et al., 2001). In previous years, increases of Cs-137 activity in the perimeter samples could be due to the addition of samples in closer proximity to the boundary of SRS, specifically in the Steel Creek floodplain. Until recently, DHEC only collected samples within 50-miles of the SRS center point to determine the yearly average.

The only other gamma-emitting radionuclides detected in DHEC surface soil samples were potassium-40, lead-212, lead-214, radium-226, actinium-228, and thallium-234. These are NORM decay products (2018 DHEC Data File).

7.2.2 Non-radiological Parameter Results

DOE-SR did not analyze for metals; therefore, no comparisons could be made. DHEC saw no exceedances of the EPA Regional Screening Levels (RSLs) in any of the surface soil samples in 2018 (EPA, 2018c). A complete list of all DHEC non-radiological analytes and RSLs can be found in Section 7.5.0, Table 3.

Barium has been a constituent of the H-Area Hazardous Waste Management Facility (WSRC, 1993). Barium was detected in all SRS perimeter samples.

Beryllium is a strong, lightweight metal used in nuclear weapons work as a shield for radiation and as a neutron source (Till et al., 2001). Beryllium was not detected in the SRS perimeter and background samples in 2018.

Cadmium enters the atmosphere through fuel and coal combustion (Till et al. 2001). Seven of the perimeter surface soil samples yielded detections.

Chromium solutions were used at SRS as corrosive inhibitors. Chromium was a part of wastewater solutions resulting from dissolving stainless steel. It was also used in cleaning solutions in the separations areas (Till et al., 2001). The legal disposal of fly ash on land as a

result of burning coal is a contributor of both chromium and nickel to soils. Fly ash particles can travel considerable distance in the air and contain trace elements of chromium (Alloway, 1995). Chromium was detected in 13 of the 19 SRS perimeter samples.

Copper, while naturally occurring, can also be released to the environment through the combustion of wood, coal, and oil (Alloway, 1995). D-Area and the other coal combustion powerhouses emitted copper and other heavy metals (Till et al., 2001). These mechanisms are possible sources of elevated copper levels in surface soils. Copper was detected in **16** of the SRS perimeter samples.

Atmospheric emissions of lead from SRS occurred through coal and fuel combustion (Till et al., 2001). Lead can deposit in soil and due to its immobility can have a long residence time when compared to other pollutants. Lead can accumulate in soils where its bioavailability can persist long-term (Alloway, 1995). Lead was detected in eight of the SRS perimeter samples.

Manganese has been released in the separations areas processes and discharged to liquid waste tanks (Till et al., 2001). It is also a byproduct of coal burning. Manganese was detected in all 19 of the SRS perimeter samples.

Non-radiological samples are stored on ice before testing occurs

The largest anthropogenic source of nickel globally is the burning of fuels and coal combustion (Alloway, 1995). At SRS, nickel was directly released through M-Area effluent from the plating rinse tanks and through site use of diesel generators (Till et al., 2001). Nickel was detected in 10 SRS perimeter samples.

Zinc was released in relatively small amounts to the separations areas' seepage basins as well as the M-Area seepage basin (Till et al., 2001). Zinc was detected in 16 SRS perimeter samples.

All metals were detected in each of the four background locations in 2018 except for copper being found in only three samples from Horry, McCormick, and Spartanburg Counties.

SRS facilities, such as F- and H- Area, tritium facilities, waste tanks, and the coal-fired power plants have emitted mercury to the atmosphere (Till et al., 2001). Atmospheric fallout contributes to mercury findings in surface soil. There were no mercury detections in surface soil samples collected in 2018.

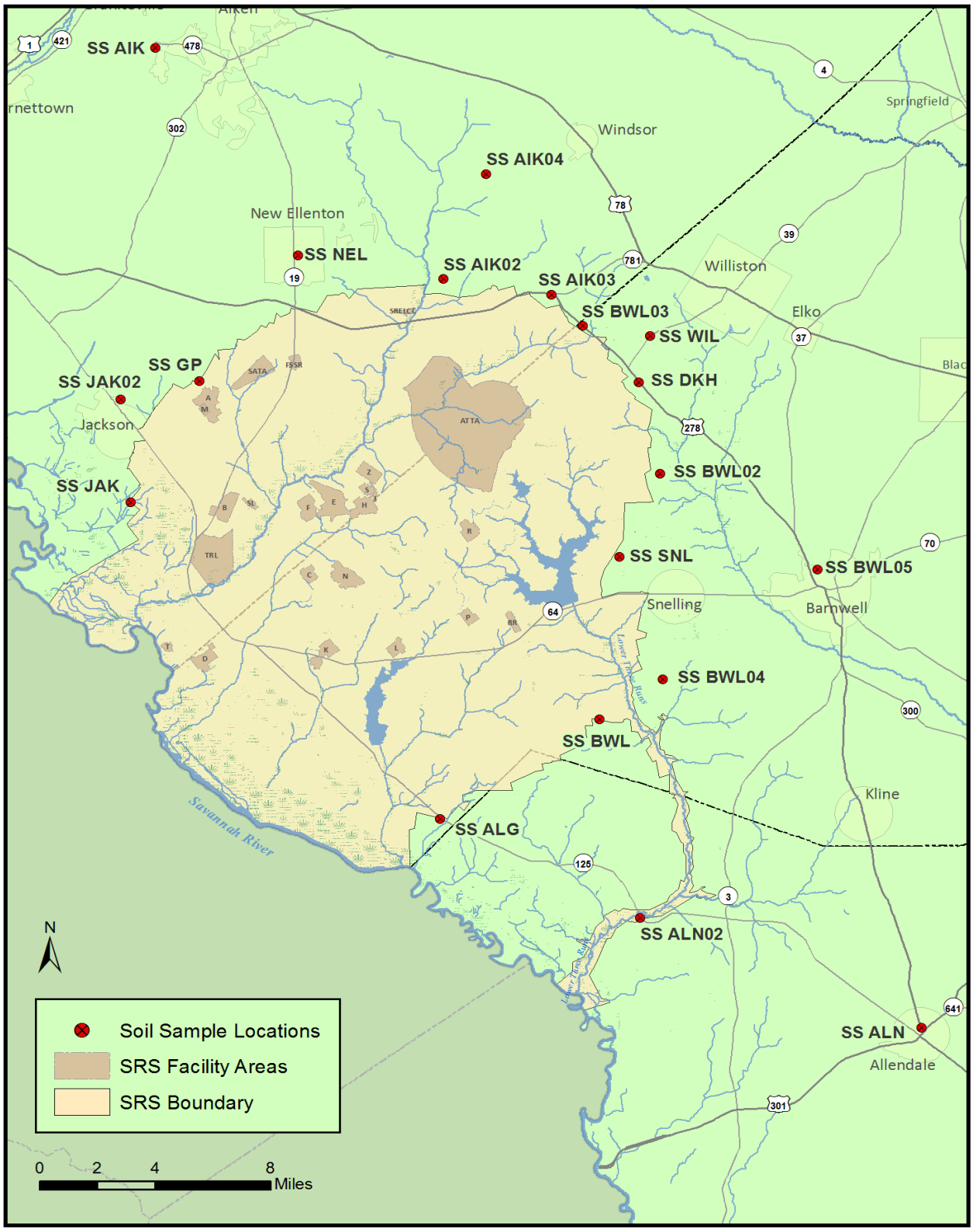
7.3.0 CONCLUSIONS AND RECOMMENDATIONS

Soil samples from DHEC and DOE-SR programs varied by location and in number. When interpreting data, it should be taken into consideration that samples were collected from a variety of soil types and locations.

DHEC will continue to independently monitor SRS perimeter surface soil and will periodically evaluate modification of the monitoring activities to better accomplish project goals and objectives. Monitoring will continue as long as there are activities at SRS that create the potential for contamination to enter the environment. Continued monitoring will provide an improved understanding of radionuclide and non-radionuclide activity in SRS perimeter surface soils and the surrounding areas. Additional monitoring will impart valuable information to human health exposure pathways. Trending of data over multiple years will give a more definitive answer as to whether radionuclide concentrations in the SRS area are declining due to radioactive decay or possibly increasing due to flooding, soil disturbances and prescribed burns on SRS. The comparison of data allows for independent data verification of DOE-SR monitoring activities. Cooperation between DOE-SR and DHEC provides credibility and confidence in the information being provided to the public.

7.4.0 MAP

SRS Perimeter Surface Soil Monitoring



2018 ESOP Soil Monitoring Map www.scdhec.gov

7.5.0 TABLES AND FIGURES

Table 1. Soil Sample Locations for in 2018

Perimeter Soil Samples		
Sample ID	**Location**	**County**
SS AIK 18	Aiken	Aiken
SS AIK02 18	Boggy Gut Road	Aiken
SS AIK03 18	Collocated at VG site AIK 0903	Barnwell
SS AIK04 18	Upper Three Runs at Barnwell Rd	Aiken
SS ALG 18	Allendale Gate	Allendale
SS ALN 18	Allendale	Allendale
SS ALN02 18	Allendale	Allendale
SS BWL 18	Collocated at VG site BWL-004	Barnwell
SS BWL02 18	Collocated at VG site BWL-002	Barnwell
SS BWL03 18	Collocated at VG site BWL-001	Barnwell
SS BWL04 18	Collocated at VG site BWL-003	Barnwell
SS BWL05 18	Barnwell Lake Edgar Brown	Barnwell
SS DKH 18	Darkhorse	Barnwell
SS GP 18	Green Pond	Aiken
SS JAK 18	Jackson	Aiken
SS JAK02 18	Jackson	Aiken
SS NEL 18	New Ellenton	Aiken
SS SNL 18	Snelling Gate	Barnwell
SS WIL 18	Williston Plum Location EVBWL-02	Barnwell
Background Soil Samples		
Sample ID	**Location**	**County**
SS BUF 18	Beaufort County	Beaufort
SS HOR 18	Horry County	Horry
SS MCK 18	McCormick County	McCormick
SS SPA 18	Spartanburg County	Spartanburg

TABLES AND FIGURES

Table 2. Soil Ingestion Preliminary Remediation Goals of Select Anthropogenic Radionuclides (EPA, 2018b)

Radionuclide	PRG (pCi/g)
Americium-241	4.9
Cesium-137	28
Cobalt – 60	83
Iodine-131	6000
Plutonium-238	3.9
Plutonium-239/240	3.9

Table 3. Regional Screening Levels of Metals (EPA, 2018c)

Analyte	RSL (mg/kg)
Barium	15,000
Beryllium	160
Cadmium	70
Chromium	230
Copper	3,100
Lead	400
Manganese	1,800
Mercury	400
Nickel	1,500
Zinc	23,000

TABLES AND FIGURES

Figure 1. 2014-2018 DHEC and DOE-SR Trending Averages for Cesium-137 (SRNS, 2015-2019; DHEC, 2015-2018)

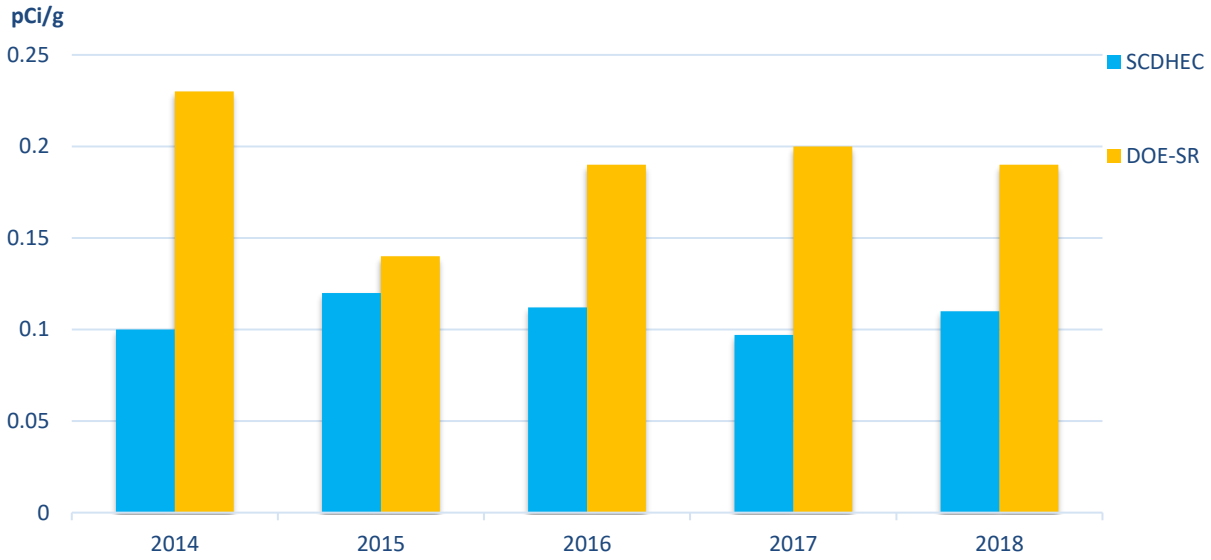
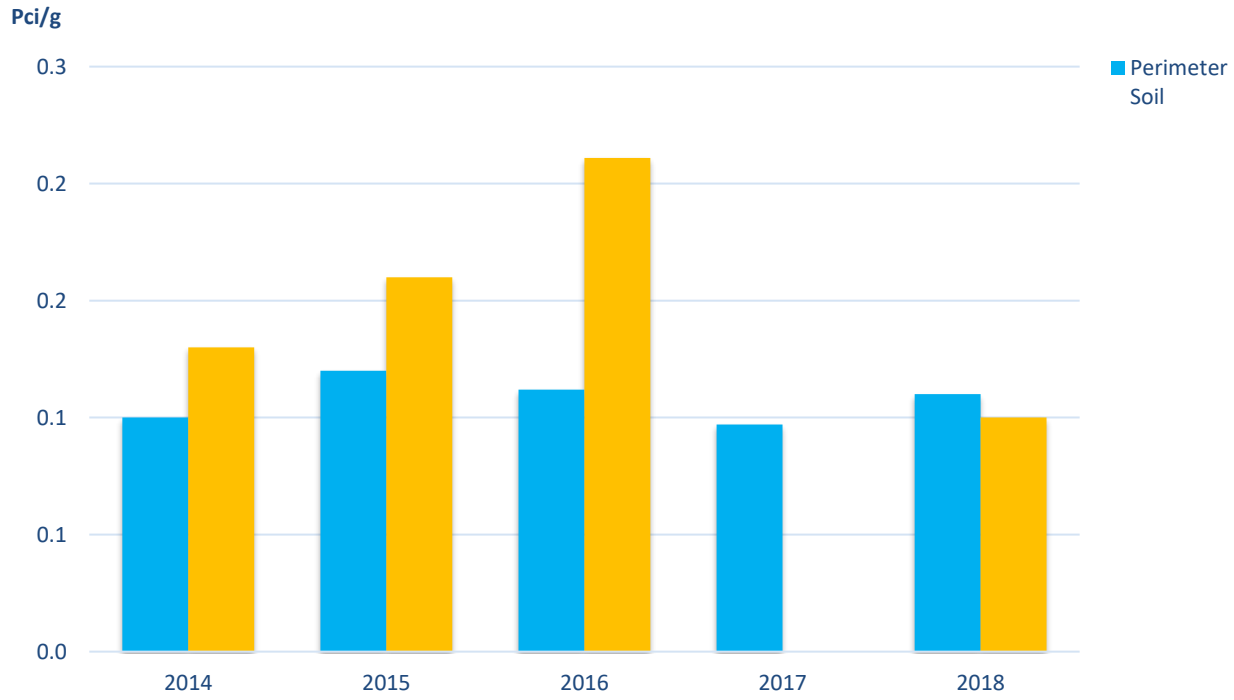


Figure 2. 2014-2018 Perimeter and Background Trending Averages for Cesium-137 (DHEC 2015 – 2018)



***Background samples were not collected in 2017

7.6.0 SUMMARY STATISTICS

2018 DHEC Radiological Statistics -- SRS Perimeter Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Gross Alpha	7.07	4.84	5.99	3.61	20	10	19
Gross Beta	7.43	3.05	5.96	5.04	12.2	5	19
Cs-137	0.11	0.06	0.1	0.03	0.25	16	19

2018 DHEC Radiological Statistics -- Background Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
Gross Alpha	15.7	NA	15.7	15.7	15.7	1	4
Gross Beta	20.69	9.49	25.4	9.76	26.9	3	4
Cs-137	0.1	0.07	0.09	0.03	0.18	4	4

2018 DHEC Non-radiological (Metals) Statistics -- SRS Perimeter Samples

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples
Barium	21.0	11	20	6.7	52	19	19
Cadmium	6.3	5.91	4.1	1.4	19	7	19
Chromium	4.6	2.7	4.6	1.4	12	13	19
Copper	1.9	0.8	1.6	1	3.9	16	19
Lead	8.3	3.2	7.15	5.2	13	8	19
Manganese	59.8	52	37	11	180	19	19
Nickel	3.6	1.68	3.1	2	7.6	10	19
Zinc	9.7	5.4	9.1	3.5	27	16	19

2018 DHEC Non-radiological (Metals) Statistics -- Background Samples

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Number of Detections	Number of Samples
Barium	66.0	11	62	58	83	4	4
Cadmium	1.2	0.17	1.15	1	1.4	4	4
Chromium	26.3	10	25.5	15	39	4	4
Copper	8.0	3.89	9.4	3.6	11	3	4
Lead	15.6	11.5	11.3	7.6	32	4	4
Manganese	330.3	392	180	51	910	4	4
Nickel	8.825	4.72	7.75	4.8	15	4	4
Zinc	39.5	20.9	40	19	59	4	4

Note: NA is Not Applicable

Chapter 8 Radiological Monitoring of Terrestrial Vegetation Adjacent to SRS

8.1.0 PROJECT SUMMARY

DOE-SR contracts for the collection and analysis of terrestrial vegetation, primarily Bermuda grass, to determine concentrations of radionuclides (SRNS, 2017). The samples are obtained from 10 locations at the SRS perimeter, one onsite location at the burial grounds, and three locations 25 miles from the center of SRS. DHEC monitors for the presence of radionuclides in vegetation collecting leaves from broad-leafed evergreen trees and shrubs, such as wax myrtle (*Myrica cerifera*), laurel oak (*Quercus laurifolia*), or Carolina laurel cherry (*Prunus caroliniana*). The type of plant sampled each year is dependent upon its availability at the separate locations.

Collecting leaves from a Carolina Laurel Cherry

In 2018, DHEC conducted independent vegetation monitoring at 17 perimeter, two background locations, and three 25-mile locations. These 25-mile samples allow comparisons to be made between tritium levels at the SRS perimeter and in the general SRS area. DHEC and DOE-SR perimeter stations sampled in 2018 are shown in Section 8.4.0, Map.

8.2.0 RESULTS AND DISCUSSION

Terrestrial Vegetation Data

Terrestrial Vegetation Monitoring Summary Statistics can be found in Section 8.6.0 and all Terrestrial Vegetation Monitoring Data can be found in the 2018 DHEC Data File.

In 2018, eleven of the seventeen vegetation perimeter sites had a detection of tritium that averaged 2020 pCi/L (Section 8.6.0). Tritium was detected at two of the three 25-mile stations with an average of 253.3 pCi/L.

Additional samples are collected as background samples in Pickney Island, South Carolina and at the Old Sheldon Church ruins in Beaufort County. Pickney Island did not yield a detection, whereas Sheldon Church had a tritium reading of 234 pCi/L.

Tritium analysis results from DHEC and DOE-SR sampling are presented in Section 8.5.0, Table 1. However, differences between the two programs in sampling dates, vegetation sampled, and analysis methods should be considered during comparison. Provided there are detections, data comparison of associated locations from the two programs was conducted by converting from pCi/g to pCi/L.

DHEC and DOE-SR had three collocated sampling locations (Patterson Mill Road, Allendale Gate, and Talatha Gate). For Patterson Mill Road, DHEC detected tritium at 223 pCi/L and DOE-SR had no detections. At Talatha Gate, DHEC had a tritium average of 2981 pCi/L and DOE-SR had an average of 706.9 pCi/L. DOE-SR did not detect tritium at the Allendale Gate, but DHEC had one sample with a detection of 193 pCi/L.

DOE-SR and DHEC sampled vegetation at nine comparable locations, including collocations, in 2018. At these locations, DOE-SR reported five detections with a combined average of 1014.3 pCi/L, while DHEC had eight detections at six of the comparable locations with a total average of 2933 pCi/L. DHEC sampled two times during the year, whereas DOE-SR only sampled in the spring.

Gamma

In 2018, DHEC detected actinium-228, beryllium-7, potassium-40, and lead-214. These isotopes are NORM; therefore, the results will not be discussed in this section, but are presented in the 2018 DHEC Data File. A list of radionuclides in the gamma spectroscopy analysis are in List of Tables, Table 1, page x.

DOE-SR detected Cs-137 at three of the nine sampling stations that had a comparable DHEC location or collocation. DHEC had detections at three of nine comparable locations in 2018. Gamma analysis results for Cs-137 from DHEC and DOE-SR sampling in 2018 are presented in Section 8.5.0, Table 2.

The man-made isotopes Co-60 and Am-241 were not detected in the DHEC 2018 samples.

Carolina Laurel Cherry leaf samples ready to be processed

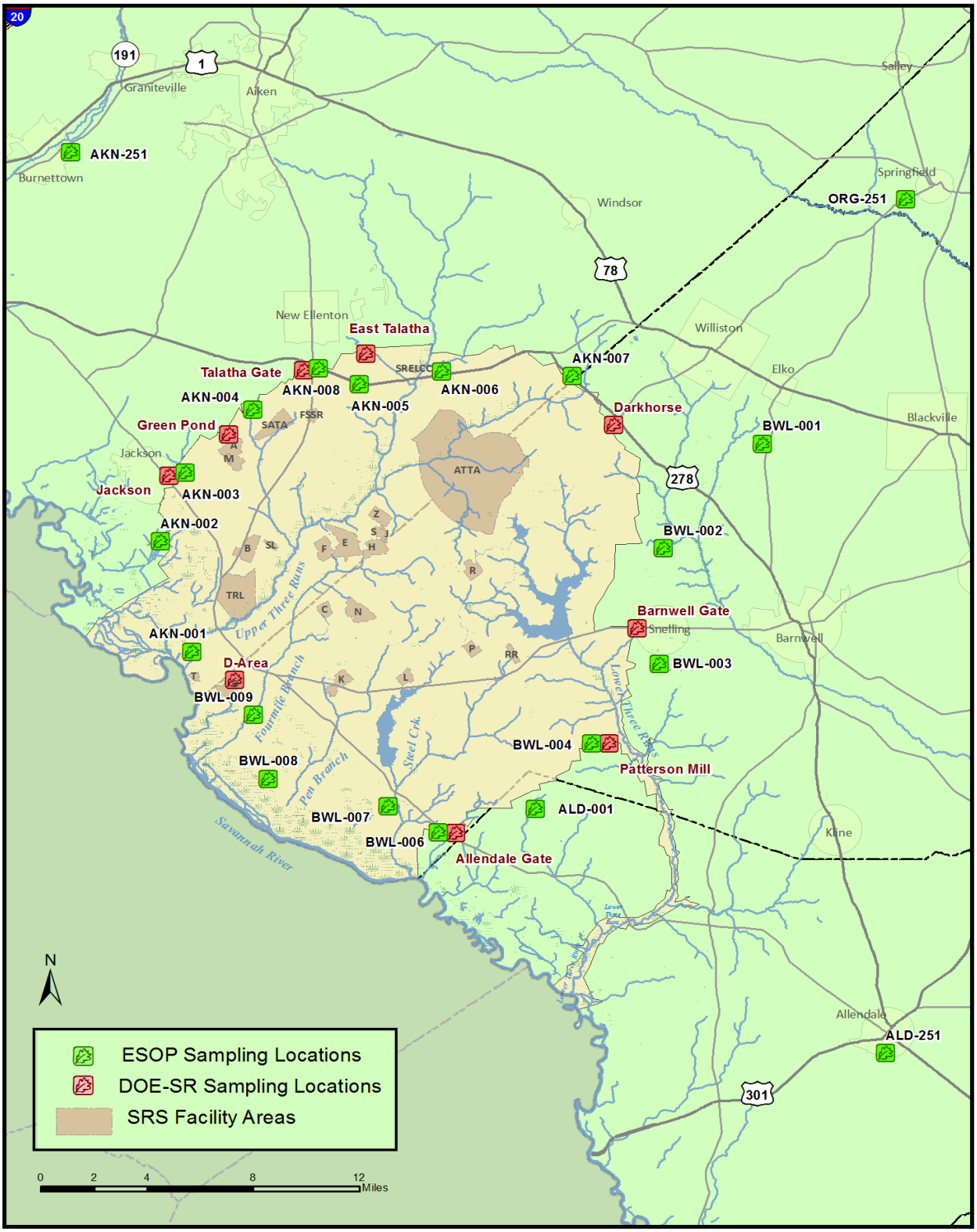
8.3.0 CONCLUSIONS AND RECOMMENDATIONS

DHEC and DOE-SR collect a different suite of terrestrial vegetation (e.g., DHEC collects leaves from trees, whereas DOE-SR conducts annual grass collections). Both sample sets are complimentary and allow indirect comparisons to be made. Differences in analysis, sampling methods, and the date samples were obtained may account for observed differences in detection levels.

In 2019, DHEC will be revising the terrestrial vegetation project by collecting grass on an annual basis in order to parallel the DOE-SR sampling techniques.

8.4.0 MAP

Terrestrial Vegetation Sampling Locations



2018 ESOP Terestrial Vegetation Monitoring Map www.scdhec.gov

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8.5.0 TABLES AND FIGURES

Table 1. 2018 Tritium Data Comparison for DHEC and DOE-SR Sampling Locations (SRNS, 2019)

DOE-SR Data		DHEC Data	
Station	**Average Results (pCi/L)**	**Station**	**Average Results (pCi/L)**
D-Area	249.5[c]	**BWL-009[a]**	ND
Jackson	202.6	**AKN-003[a]**	3240[c]
Green Pond	182.9[c]	**AKN-004[a]**	8950[c]
Talatha Gate	706.9	**AKN-008[b]**	2981
East Talatha	3614.3[c]	**AKN-005[a]**	2448
Darkhorse	ND	**BWL-001[a]**	ND
Barnwell Gate	ND	**BWL-003[a]**	ND
Patterson Mill Road	ND	**BWL-004[b]**	223[c]
Allendale Gate	ND	**BWL-006[b]**	193[c]
Average	838.0	**Average**	2933
Standard Deviation	1280.7	**Standard Deviation**	3292.7
Median	218.6	**Median**	1761

Notes:

1. Total averages were calculated using the raw data and not the averages in the chart
2. NS is No Sample
3. ND is Not Detected
4. [a] Comparable DHEC Location
5. [b] Collocation
6. [c] Average based on one detection

8.5.0 TABLES AND FIGURES

Table 2. 2018 Cesium-137 Data Comparison for DHEC and DOE-SR Sampling Locations (SRNS, 2019)

DOE-SR Data		DHEC Data	
Station	**Average Result (pCi/g)**	**Station**	**Average Result (pCi/g)**
D-Area	ND	**BWL-009[a]**	NS
Jackson	ND	**AKN-003[a]**	0.045[c]
Green Pond	ND	**AKN-004[a]**	NS
Talatha Gate	ND	**AKN-008[b]**	0.041
East Talatha	0.270[c]	**AKN-005[a]**	0.168
Darkhorse	0.204[c]	**BWL-001[a]**	NS
Barnwell Gate	ND	**BWL-003[a]**	NS
Patterson Mill Road	ND	**BWL-004[b]**	<MDA
Allendale Gate	0.165[c]	**BWL-006[b]**	<MDA
Average	0.213	**Average**	0.092
Standard Deviation	0.053	**Standard Deviation**	0.110
Median	0.204	**Median**	0.045

Notes:
1. Total averages were calculated using the raw data and not from the averages in the chart above
2. NS is No Sample
3. ND is Not Detected
4. [a] Comparable DHEC Location
5. [b] Collocation
6. [c] Average based on one detection

TABLES AND FIGURES

Figure 1. 2014-2018 Tritium in Vegetation at SRS Perimeter (DHEC, 2015-2018)

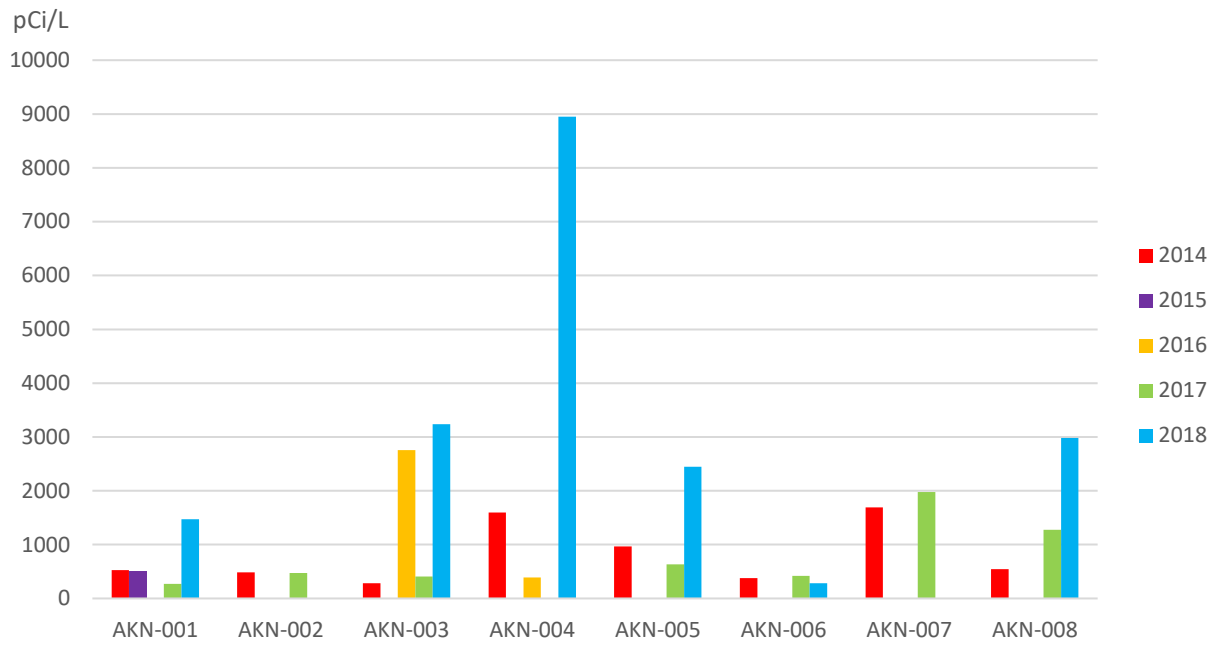


Figure 2. 2014-2018 Tritium in Vegetation at SRS Perimeter (DHEC, 2015-2018)

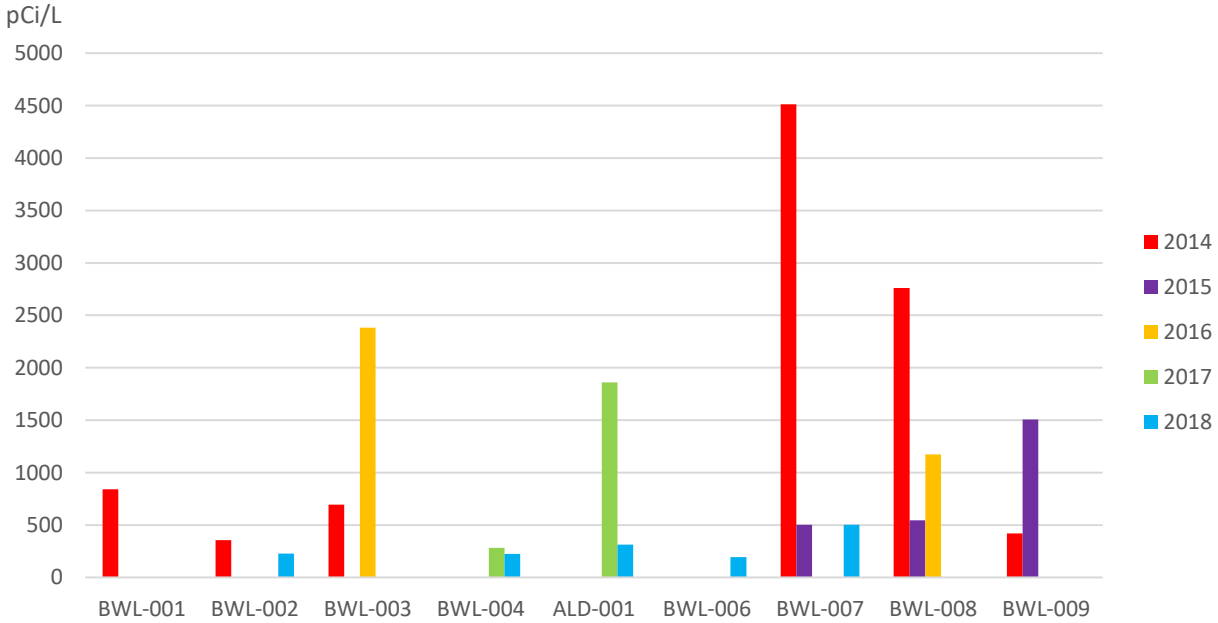
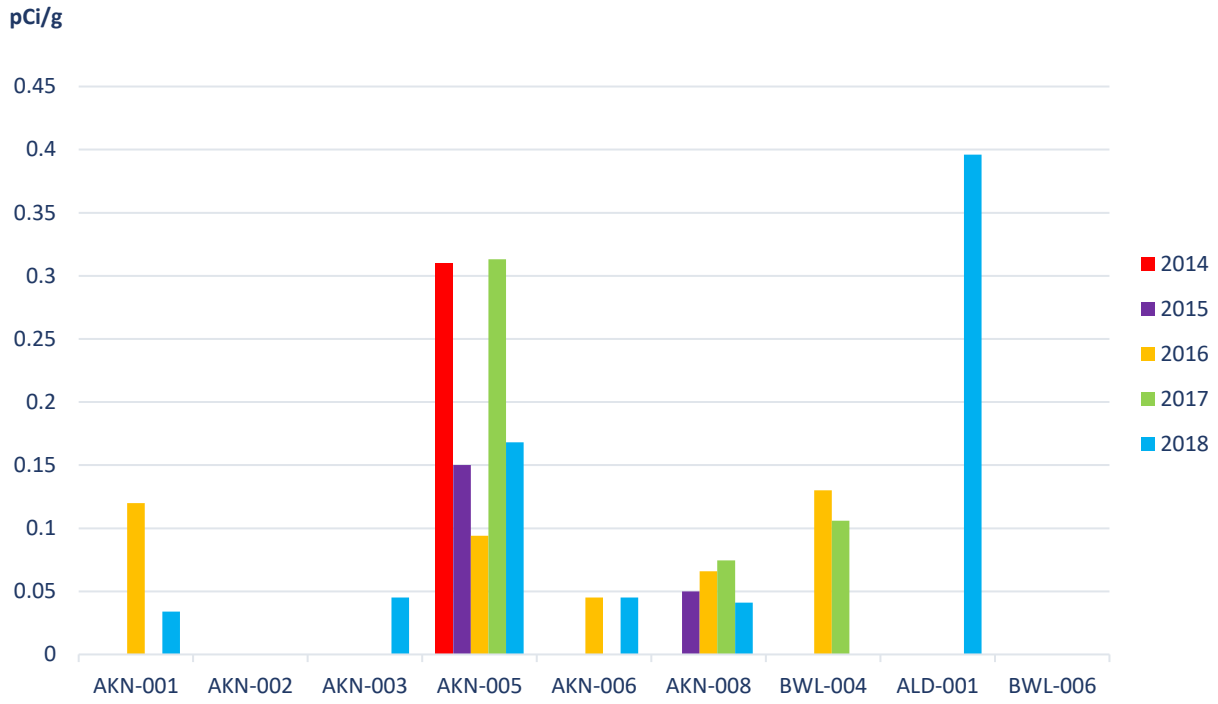


Figure 3. 2014-2018 Cs-137 in Vegetation at SRS Perimeter (DHEC, 2015-2018)



Notes:
1. Missing bars indicate an average that was less than the minimum detectable activity
2. Some bars may be based on a single detection

8.6.0 SUMMARY STATISTICS

2018 SRS Perimeter and 25-Mile Radius Locations-Tritium

Sample Location	Average (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
Sample Perimeter Locations - Tritium					
AKN-001	1470	1470	1470	1	2
AKN-002	ND	ND	ND	0	2
AKN-003	3240	3240	3240	1	2
AKN-004	8950	8950	8950	1	2
AKN-005	2448	246	4650	2	2
AKN-006	284	284	284	1	2
AKN-007	ND	ND	ND	0	2
AKN-008	2981	282	5680	2	2
BWL-001	ND	ND	ND	0	2
BWL-002	228	228	228	1	2
BWL-003	ND	ND	ND	0	2
BWL-004	223	223	223	1	2
ALD-001	312	312	312	1	2
BWL-006	193	193	193	1	2
BWL-007	502	502	502	1	2
BWL-008	ND	ND	ND	0	2
BWL-009	ND	ND	ND	0	2
25-Mile Radius Locations - Tritium					
AKN-251	ND	ND	ND	0	2
ALD-251	223	223	223	1	2
ORG-251	268.5	215	322	2	2

Notes:
1. ND is Not Detected
2. NA is Not Applicable

SUMMARY STATISTICS

2018 SRS Perimeter-Cesium-137

Sample Location	Average (pCi/g)	Median (pCi/g)	Minimum Detect (pCi/g)	Maximum Detect (pCi/g)	Number of Detections	Number of Samples
AKN-001	0.034	NA	0.034	0.034	1	2
AKN-002	ND	NA	ND	ND	0	2
AKN-003	0.045	NA	0.045	0.045	1	2
AKN-005	0.168	0.168	0.046	0.290	2	2
AKN-006	0.045	NA	0.045	0.045	1	2
AKN-008	0.041	0.041	0.0408	0.0409	2	2
BWL-004	ND	NA	ND	ND	0	2
ALD-001	0.396	NA	0.396	0.396	1	2
BWL-006	ND	NA	ND	ND	0	2
Total	0.117	0.045	0.034	0.396	8	18

Notes:
1. Total average was calculated using the raw data not from the averages in the chart above
2. “Number of Detections” and “Number of Samples” “Totals” were summations instead of averages
3. Total “Minimum Detect” and “Maximum Detect” are not averages, but the overall minimum and maximum detection for all the sample locations
4. pCi/g is picocuries per gram
5. ND is Not Detected
6. NA is Not Applicable
7. Averages may be based on one detection and exclude non-detections

Chapter 9 Radiological Monitoring of Edible Vegetation Adjacent to SRS

9.1.0 PROJECT SUMMARY

The Radiological Monitoring of Edible Vegetation Project is a component of the DHEC ESOP that monitors edible vegetation from SRS perimeter and background locations.

DHEC defined a study area comprised of grids radiating out to 25 miles from the SRS center point, 25 miles to 50 miles, and background locations greater than 50 miles from the SRS center point (Map in Section 9.4.0). DOE-SR, as compared to DHEC, has five defined quadrants where samples are collected annually: four quadrants are within 10 miles of SRS in each direction (NE, NW, SE, SW), along with one quadrant located within 25 miles SE. Direct comparisons between DOE-SR and DHEC could not be made due to variation in sampling and analysis methodologies.

Edible vegetation is collected based solely on availability and is directly dependent upon the growing season. Certain farmers, gardeners, and/or businesses surrounding the perimeter of SRS contribute domestically grown crops. Wild, edible vegetation, such as muscadines and plums, are also collected. References to vegetation in this section pertain to the edible parts of plants.

DHEC background sampling helps to separate atomic test fallout contamination levels and other sources (e.g. ongoing permitted releases at other nuclear facilities) from SRS source potential contamination. However, fallout dispersion patterns and concentrations are weather related and not uniform, and no assignment of a specific source can be made.

9.2.0 RESULTS AND DISCUSSION

Edible Vegetation Monitoring Summary Statistics can be found in Section 9.5.0 and all Edible Vegetation Monitoring Data can be found in the 2018 DHEC Data File.

The U.S. Food and Drug Administration (FDA) has guidance levels for specific radionuclides called Derived Intervention Levels (DILs). The FDA adopted DILs to help determine whether domestic food in interstate commerce or food offered for import into the United States presents a safety concern (FDA, 2005a).

DHEC detected tritium in seven out of the ten samples of fruits/nuts but did not detect tritium in the two greens/vegetable samples or the two fungi samples (Section 9.5.0, Table 2). DHEC had the highest tritium detection from a fruit sample in Edgefield County (NW-2; EV-469) at 1,060 pCi/L. DOE-SR detected tritium in eight of the twenty samples collected in 2018 with an average of 0.085 pCi/L. The highest detection was 0.220 pCi/L from corn harvested in the NW Quadrant 0-10 miles (SRNS, 2019).

In 2018, DOE-SR edible vegetation exhibited radiological detections of strontium-89/90, uranium-234, uranium-235, uranium-238, curium-244, and technetium-99 (SRNS, 2019). All the detected gamma radionuclides, except Cs-137, originated from naturally occurring radioactive material. NORM radionuclides were the source of most detections in edible vegetation and are not discussed further as radionuclides of concern unless greater than a South Carolina background.

DHEC detected Cs-137 only in fungi samples in 2018. Of the fourteen samples, only one sample at EV-475 in Aiken County had a detection of 0.154 pCi/g in fungi for Cs-137, which is well below the FDA-derived Guidance Level of 32.4 pCi/g for Cs-137 (FDA, 2005b). DOE-SR had detections in four of the twenty samples collected in 2018 at an average of 0.023 pCi/g (the highest detection being greens in the SE Quadrant 25 Miles at 0.032 pCi/g).

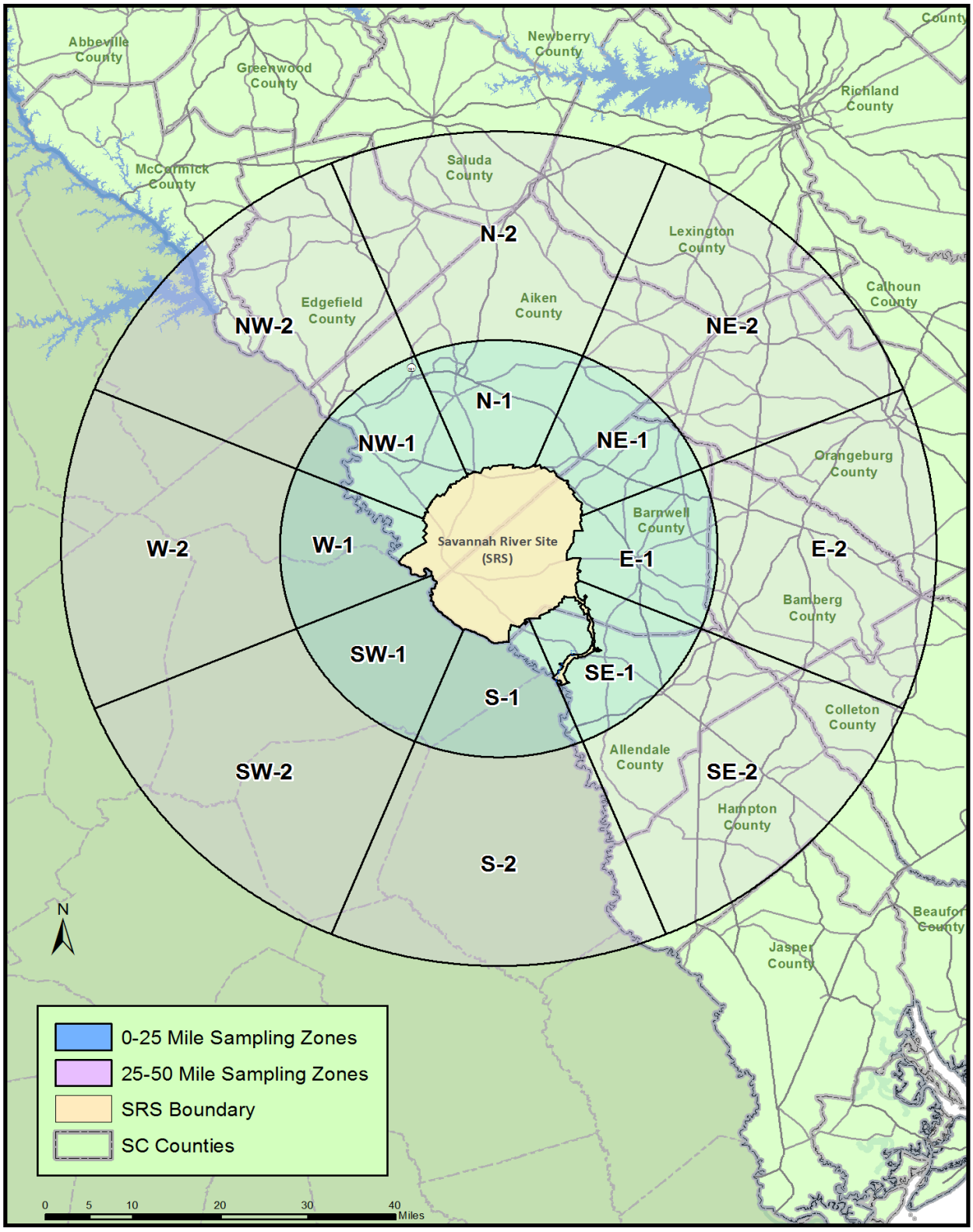
9.3.0 CONCLUSIONS AND RECOMMENDATIONS

DHEC and DOE-SR have different edible vegetation sampling schemes. DOE-SR samples primarily domestic plants collected from annual contributors in quadrants at zero to 10 miles from the perimeter of the SRS border and one quadrant at 25 miles; whereas, DHEC accepts domestic plants as donations from citizens and collects perennial, wild, edible vegetation and fungi found within 50 miles of the SRS center point and background locations (Section 9.4.0).

In the future, DHEC will explore opportunities to split samples with DOE-SR and attempt to establish collocated sampling locations for better comparisons between the two. In addition, DHEC will continue to collect wild fungi due to its inherent ability to bioconcentrate Cs-137.

9.4.0 MAP

DHEC Edible Vegetation Monitoring



2018 Edible Vegetation Monitoring www.scdhec.gov

9.5.0 Summary Statistics

Table 1. 2018 Tritium Detections in Edible Vegetation by Grid

Grid	Average (pCi/L)	Standard Deviation (pCi/L)	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
W-1	NS	NA	NA	NA	NA	0	0
NW-1	NS	NA	NA	NA	NA	0	0
NW-2	770.5	409.4	770.5	481	1060	2	2
N-1	926	NA	926	926	926	1	2
N-2	NS	NA	NA	NA	NA	0	0
NE-1	ND	NA	NA	ND	ND	0	1
NE-2	NS	NA	NA	NA	NA	0	0
E-1	480	393.2	480	202	758	2	6
E-2	394	NA	394	394	394	1	1
SE-1	NS	NA	NA	NA	NA	0	0
S-1	289	NA	289	289	289	1	2
Background	NS	NA	NA	NA	NA	0	0
Total	587.1	330.0	481	202	1060	7	14

Note:
1). Total averages were calculated using the raw data and not the averages in the chart
2). NS is Not Sampled
3). NA is Not Applicable
4). ND is Not Detected
5). Total “Minimum Detect” and “Maximum Detect” did not calculate an average, but shows the overall minimum and maximum detection

Table 2. 2018 Tritium Detections in Edible Vegetation by Type

Type	Average (pCi/L)	Standard Deviation (pCi/L)	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Greens/Vegetables	ND	NA	NA	ND	ND	0	2
Fruits/Nuts	587.1	330.0	481	202	1060	7	10
Fungi	ND	NA	NA	ND	ND	0	2

Note:
1). ND is Not Detected
2). NA is Not Applicable

Chapter 10 Radiological Monitoring of Dairy Milk

10.1.0 PROJECT SUMMARY

Operations at SRS have resulted in the potential for radiological constituents to be released to the surrounding environment (Till et al., 2001). Consumption of milk products containing radioactive materials can be a human exposure pathway. When an atmospheric release occurs, radionuclides can be deposited on pastures and ingested by grazing dairy animals. The animals may release a portion of the radionuclides into their milk that could be consumed by humans (CDC, 2001). Radionuclides could also enter milk through the irrigation of a pasture using groundwater containing radioactive materials and through uptake by plants from soil containing radioactive materials.

In 2018, DHEC collected milk from four dairies within South Carolina (Section 10.4.0, Map). All four of these locations are within a 50-mile radius of the SRS center point. This project provides analytical data for trending and comparison to published DOE-SR data.

DHEC personnel collected unpasteurized milk samples on a quarterly basis in 2018. All milk samples from each quarter were analyzed for tritium, Sr-89/90, and gamma-emitting radionuclides. While a select group of gamma-emitting radionuclides (iodine-131 (I-131), Cs-137, and cobalt-60 (Co-60)) are analytes of concern in dairy milk for this project, all other detections such as Potassium-40 (K-40) are considered NORM. Naturally-occurring radionuclides are the source of most public exposure; however, they are not discussed in this report unless detections are significantly greater than those of the background location detections. In 2018, DHEC did not sample any background dairy locations. DHEC analyzes samples for total strontium (Sr-89/90) instead of only Sr-90. This is done to provide a more conservative result, and it is assumed the total strontium detected is in the form of Sr-90.

10.2.0 RESULTS AND DISCUSSION

None of the 16 DHEC milk samples collected in 2018 exhibited tritium activity above the LLD (2018 DHEC Data File). DOE-SR did not detect tritium in any of the samples collected in 2018 from the South Carolina dairies.

DHEC analyzed for gamma-emitting radionuclides (K-40, I-131, Cs-137, and Co-60) in 16 milk samples collected in 2018. All analytical results for these radionuclides were below the sample MDA except for naturally occurring K-40. These results can be found in the 2018 DHEC Data File. These results are consistent with past gamma results and no summary statistics were calculated for these radionuclides due to a lack of numerical data. Out of 16 samples from South Carolina, DOE-SR had two detections of Cs-137 in cow milk with an average of 3.73 pCi/m^3. DOE-SR had detections of both Cs-137 and Sr-90 in a sample of goat milk; however, to have a more comparable data set since DHEC does not collect goat milk, this data was not included when calculating the averages for DOE-SR.

None of the 16 DHEC milk samples collected in 2018 exhibited strontium activity above the MDA. Section 10.5.0, Figure 1 shows the trend for DHEC strontium detections for the last five years. All strontium averages have been below the EPA established MCL of 8 pCi/L for Sr-90 since testing initiated in 1998 (EPA, 2002b). DOE-SR detected Sr-89/90 in two of 16 samples

collected in 2018 in South Carolina, which found the average activity level to be 1.08 pCi/L in cow milk (SRNS, 2019).

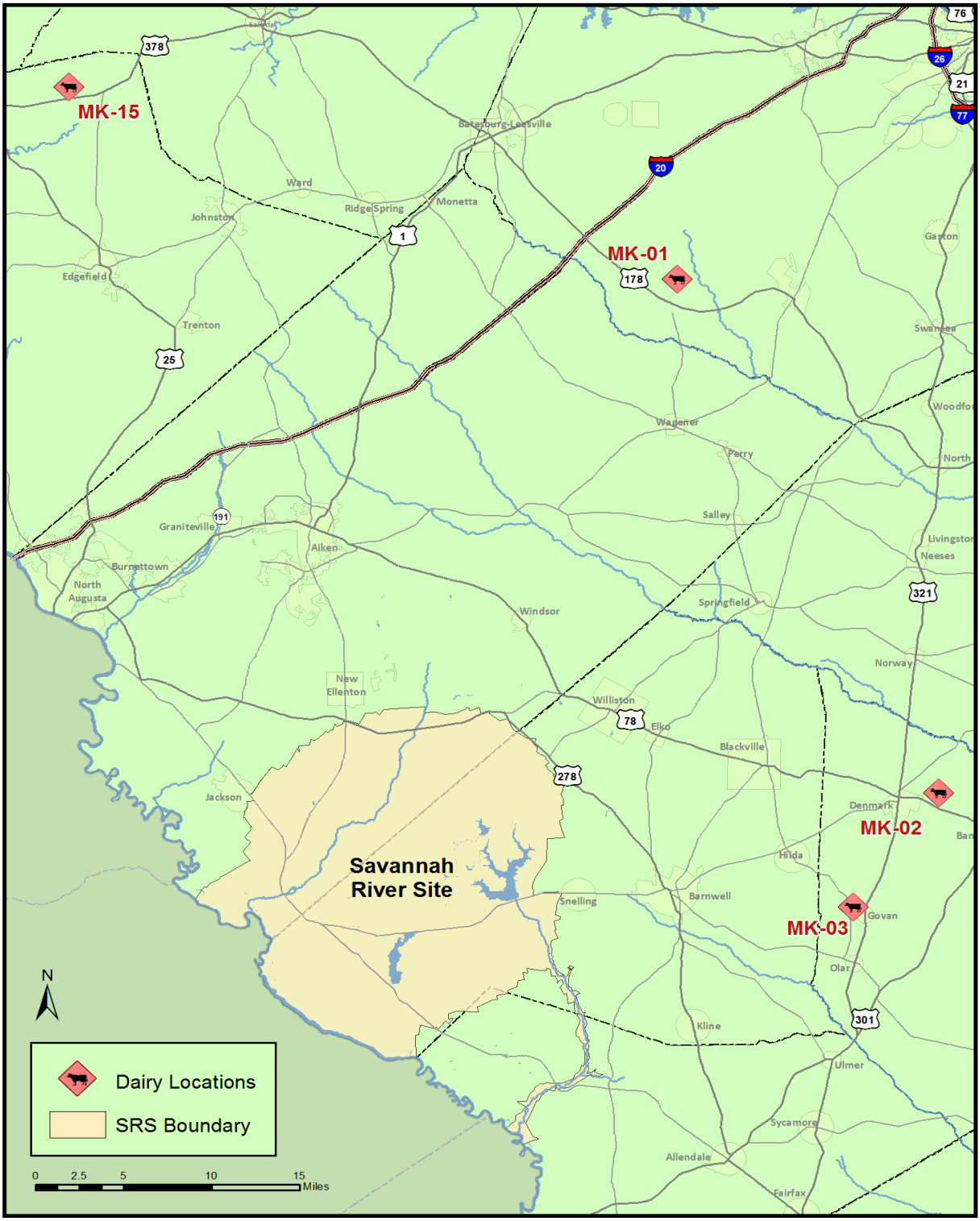
10.3.0 CONCLUSIONS AND RECOMMENDATIONS

A large portion of the radiological activity observed in milk samples can be attributed to fallout from past nuclear testing (Kathren, 1984). Also, radionuclides within soil and plants can potentially be redistributed because of farming practices and fires. Due to strontium's ability to be stored in bones and cesium building up in muscles, DHEC will continue to monitor tritium, gamma-emitting radionuclides, and strontium in milk to ensure the safety of milk consumption by the public.

The dairies in DHEC's study area appear to be stable with no indication of closing in the foreseeable future. DHEC will continue to seek opportunities to add additional dairies to the sampling program for better coverage of the study area.

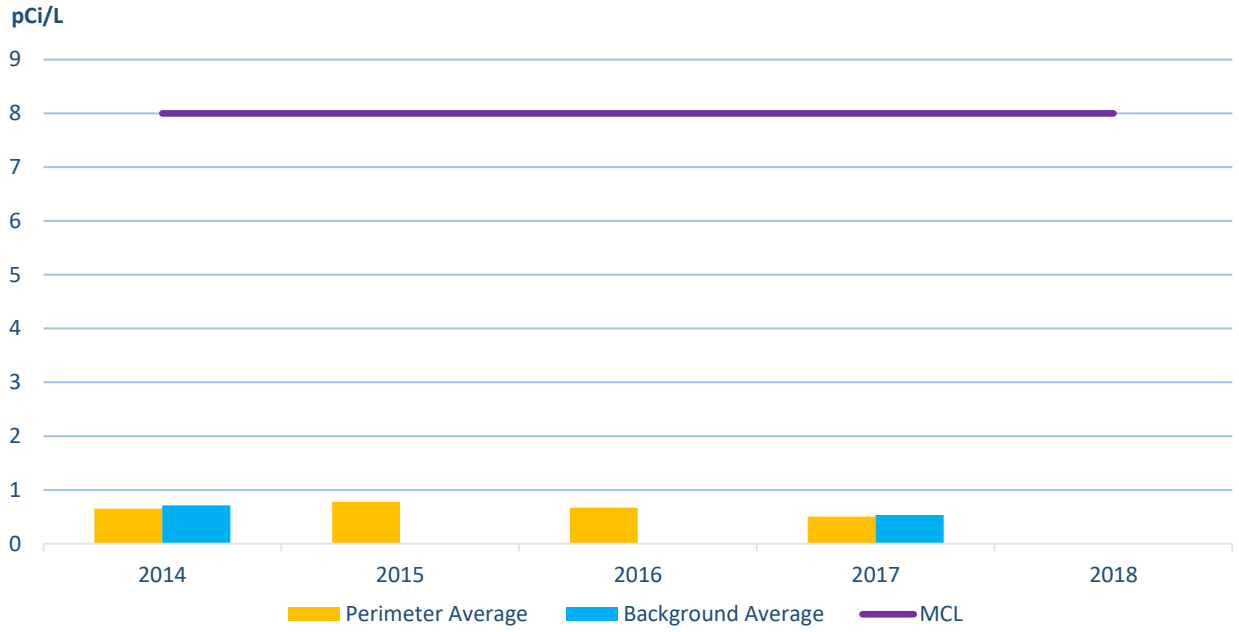
10.4.0 MAP

Radiological Dairy Milk Monitoring Sampling Locations



10.5.0 TABLES AND FIGURES

Figure 1. DHEC Average Strontium-89/90 Data Trends for 2014-2018 (DHEC, 2015-2018)



Note: 1). No bar indicates <MDA
2). No background location was collected in 2018

Chapter 11 Fish Monitoring Associated with SRS

11.1.0 PROJECT SUMMARY

DHEC ESOP conducts non-regulatory, independent monitoring and surveillance of fish to determine the magnitude, extent, and trend levels for radionuclides and selected metals.

Preparing the electroshocking equipment

In 2018, DHEC collected largemouth bass (*Micropterus salmoides)* and channel catfish (*Ictalurus punctatus*) from four stations where creeks from SRS meet the Savannah River: Upper Three Runs Creek (SV-2011), Fourmile Branch (SV-2015), Steel Creek (SV-2017), and Lower Three Runs Creek (SV-2020). Samples were also collected from the background station on the Combahee river between Beaufort and Colleton counties (MD-119), one Savannah River station upstream of SRS (New Savannah Bluff Lock and Dam (NSBLD SV-2028)), and two stations downstream of SRS (Highway 301 (SV-118) and Highway 17 saltwater (SV-2091 – the only area where striped mullet (*Mugil cephalus*) and red drum (*Sciaenops ocellatus*) are caught)). Stations sampled in 2018 are shown in Section 11.4.0, Map. These stations are accessible to the public.

Front view of the boat and probes

A total of five largemouth bass and five channel catfish were collected from all Savannah River stations and the Combahee River background site. Five red drum and five striped mullet were collected from the saltwater station (SV-2091). Non-edible portions (bone) were tested for Sr-89/90. Edible portions (muscle tissue) were analyzed for mercury and other selected metals and gamma-emitting isotopes. Recently, tritium was found to contribute to "less than 1% of the estimated total fisherman dose" (SRNS, 2016b). This is due to tritium's ability to reach concentration equilibrium (the ability of a chemical to balance out) in both water and fish flesh resulting in no bioaccumulation (build up) in fish muscle (SRNS, 2016b). With this discovery, DOE-SR and DHEC have at this time discontinued its testing of tritium in fish flesh.

Attempting to bring in fish

11.2.0 RESULTS AND DISCUSSION

Fish Monitoring Summary Statistics can be found in Section 11.6.0 and all Fish Monitoring Data can be found in the 2018 DHEC Data File.

11.2.1 Radiological Data Comparison

DHEC bass and catfish data collected in 2018 were compared to DOE-SR data (SRNS, 2019). Data comparisons are in Section 11.5.0. One difference between the two programs is that DHEC analyzes one composite from each species for each station, whereas the DOE-SR program analyzes three composites per station for Cs-137. Therefore, a single composite for a DHEC station was compared to the average of the three DOE-SR composites reported. For Sr-89/90, DOE-SR reports individual sample results. To compare Sr-89/90 data, the average of these individual DOE-SR samples for each location are compared to the one composite sample of DHEC.

Trending graphs for 2018 activity levels of Cs-137 and Sr-89/90 are reported in Section 11.5.0.

Channel Catfish (left) and Largemouth Bass (right) being weighed and length being measured

DHEC largemouth bass samples from two stations and DOE-SR bass samples from all stations exhibited Cs-137 activity (Section 11.5.0, Table 1). Three of the DHEC catfish composites from the Savannah River stations exhibited a detectable level of Cs-137 in 2018. DOE-SR detected Cs-137 in catfish at all five sampling locations (Section 11.5.0, Table 2). Both DHEC's bass and catfish background samples displayed Cs-137, while saltwater stations did not exhibit Cs-137 activity in any samples (Section 11.5.0, Figure 1). No mullet collected by DOE-SR had detectable levels of Cs-137 in 2018.

Strontium-89/90 was detected in one station for both the DHEC bass and catfish samples, but it was found in all stations for DOE-SR in both bass and catfish (SRNS, 2019) (Section 11.5.0, Table 3 & 4 and Figure 2). Sr-89/90 was also detected in DOE-SR mullet samples.

11.2.2 Non-radiological Data Comparison

DHEC and DOE-SR analyzed fish for arsenic, cadmium, manganese, mercury, chromium, copper, lead, nickel, and zinc. DHEC also analyzed for antimony. Due to differences in sampling

Individual fish parts are combined to form composite samples which are tested for strontium (bones) and gamma and metals (muscles)

methodology, direct comparisons were not made between DHEC and DOE-SR for these non-radiological constituents; however, since mercury tends to be a public health focus with fish consumption, a comparison was made for both bass and catfish (Section 11.5.0, Table 5 and 6). Mercury was detected in all DHEC bass and catfish composite samples from all six Savannah River stations (Section 11.5.0, Figure 3). DOE-SR detected mercury in 42 bass and 41 catfish samples. DOE-SR detected mercury in no mullet samples. Mercury was also detected by DHEC in red drum from the Hwy 17 saltwater location.

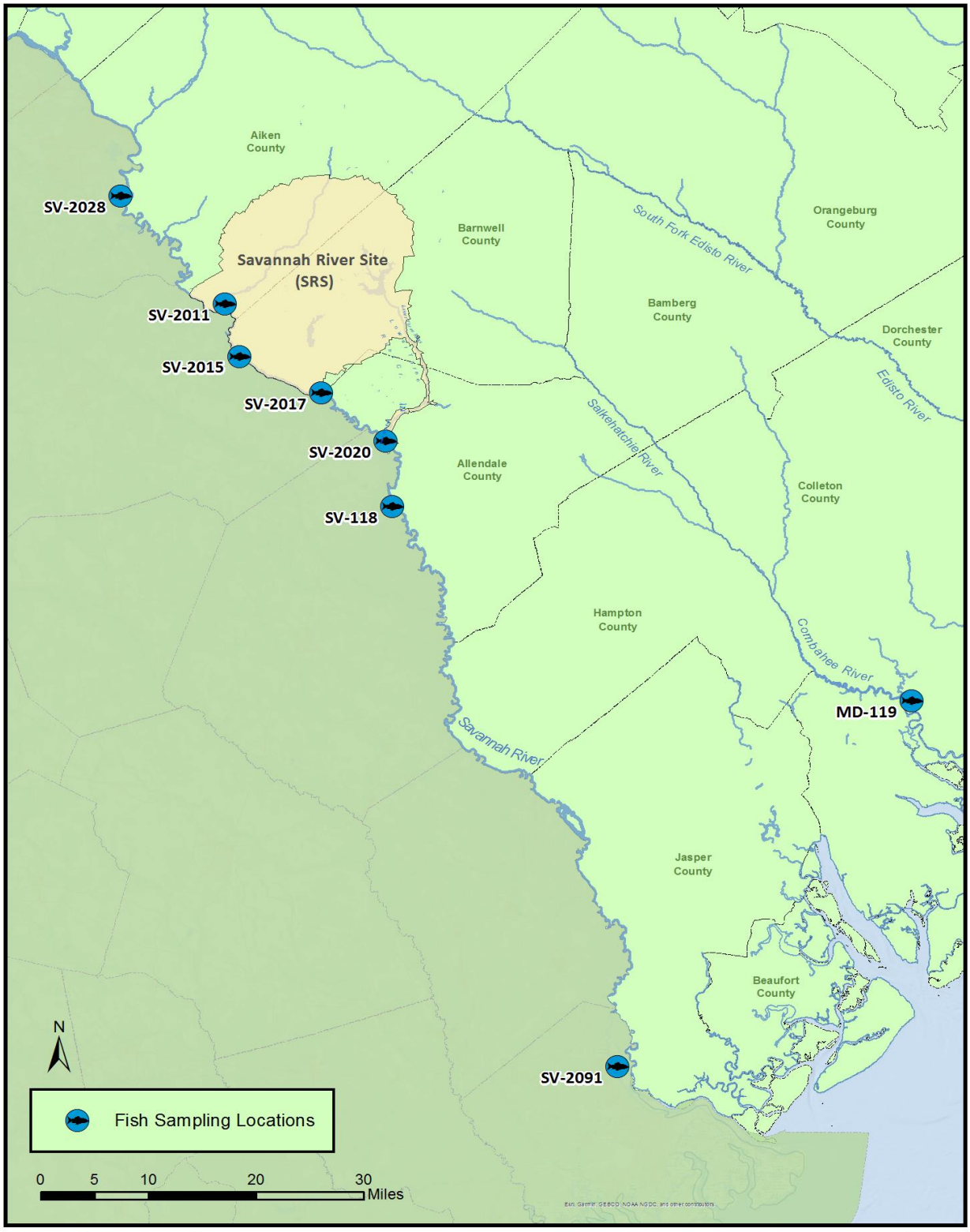
11.3.0 CONCLUSIONS AND RECOMMENDATIONS

Higher levels of radionuclides are found in Savannah River fish collected adjacent to and downstream of SRS compared to upstream. Therefore, independent monitoring of radionuclide levels in Savannah River fish will continue along with evaluating the DOE-SR Radiological Fish Monitoring Program. Continued monitoring will provide a better understanding of actual radionuclides, their extent, and trends. This data will allow DHEC to advise and inform the public. Data comparison will also be part of the further evaluation of the DOE-SR program. This independent evaluation will provide credibility and confidence in the DOE-SR data and its uses.

Future analyses of the target species will continue to include mercury and selected metals. This will augment the existing data on Savannah River fish, provide information for human health assessment, and provide another basis for comparison of results with DOE-SR data.

11.4.0 MAP

Fish Monitoring Sampling Locations



2018 ESOP Fish Monitoring Map www.scdhec.gov

11.5.0 TABLES AND FIGURES

2018 DHEC and DOE-SR Data Comparison (SRNS, 2019)

Table 1. Cesium-137 in Edible Bass

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	2	0.024
Upper Three Runs	DHEC	0	ND
	DOE-SR	2	0.420
Fourmile Branch	DHEC	1	0.107
	DOE-SR	3	0.062
Steel Creek	DHEC	1	0.056
	DOE-SR	3	0.124
Lower Three Runs	DHEC	0	ND
	DOE-SR	3	0.337
Hwy. 301	DHEC	0	ND
	DOE-SR	3	0.03

Table 2. Cesium-137 in Edible Catfish

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	3	0.032
Upper Three Runs	DHEC	0	ND
	DOE-SR	3	0.037
Fourmile Branch	DHEC	1	0.046
	DOE-SR	3	0.039
Steel Creek	DHEC	1	0.060
	DOE-SR	3	0.040
Lower Three Runs	DHEC	1	0.095
	DOE-SR	3	0.042
Hwy. 301	DHEC	0	ND
	DOE-SR	3	0.037

Table 3. Strontium-89/90 in Non-Edible Bass

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	4	0.55
Upper Three Runs	DHEC	0	ND
	DOE-SR	4	0.55
Fourmile Branch	DHEC	0	ND
	DOE-SR	5	0.59
Steel Creek	DHEC	1	0.016
	DOE-SR	4	0.58
Lower Three Runs	DHEC	0	ND
	DOE-SR	3	0.36
Hwy. 301	DHEC	0	ND
	DOE-SR	3	0.56

Table 4. Strontium-89/90 in Non-Edible Catfish

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	4	0.62
Upper Three Runs	DHEC	0	ND
	DOE-SR	3	0.75
Fourmile Branch	DHEC	0	ND
	DOE-SR	3	0.73
Steel Creek	DHEC	0	ND
	DOE-SR	5	0.36
Lower Three Runs	DHEC	1	0.015
	DOE-SR	3	0.48
Hwy. 301	DHEC	0	ND
	DOE-SR	4	0.41

Return to TOC

TABLES AND FIGURES

2018 DHEC and DOE-SR Data Comparison (SRNS, 2019)

Table 5. Mercury in Edible Bass

Location	Agency	Number of Detects	Result (mg/kg)
NSBLD	DHEC	1	0.28
	DOE-SR	7	0.26
Upper Three Runs	DHEC	1	0.34
	DOE-SR	7	0.33
Fourmile Branch	DHEC	1	0.36
	DOE-SR	7	0.31
Steel Creek	DHEC	1	0.59
	DOE-SR	7	0.60
Lower Three Runs	DHEC	1	0.28
	DOE-SR	7	0.96
Hwy. 301	DHEC	1	0.66
	DOE-SR	7	0.53

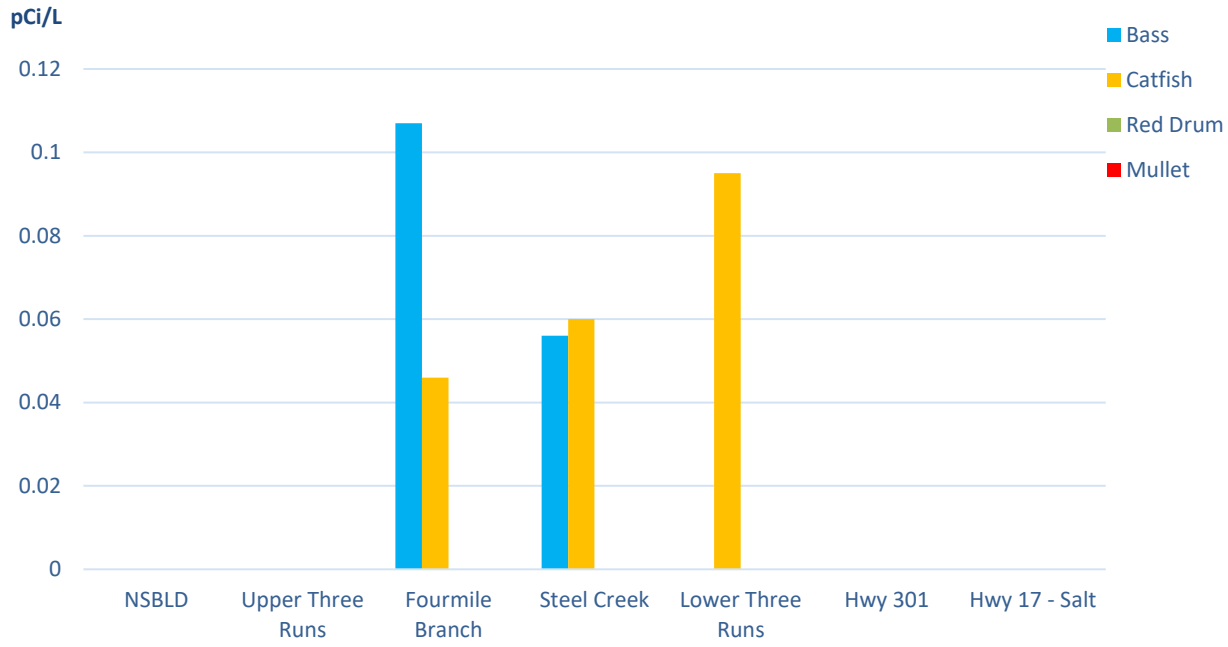
Table 6. Mercury in Edible Catfish

Location	Agency	Number of Detects	Result (mg/kg)
NSBLD	DHEC	1	0.13
	DOE-SR	6	0.05
Upper Three Runs	DHEC	1	0.13
	DOE-SR	7	0.17
Fourmile Branch	DHEC	1	0.14
	DOE-SR	7	0.13
Steel Creek	DHEC	1	0.25
	DOE-SR	7	0.16
Lower Three Runs	DHEC	1	0.13
	DOE-SR	7	0.19
Hwy. 301	DHEC	1	0.19
	DOE-SR	7	0.20

Note:
1). DOE-SR data are averages
2). DHEC only takes one sample at each location whereas DOE-SR collects three samples for Cs-137, six samples for Sr-89/90, and seven samples for Mercury at each location
3). ND is Not Detected

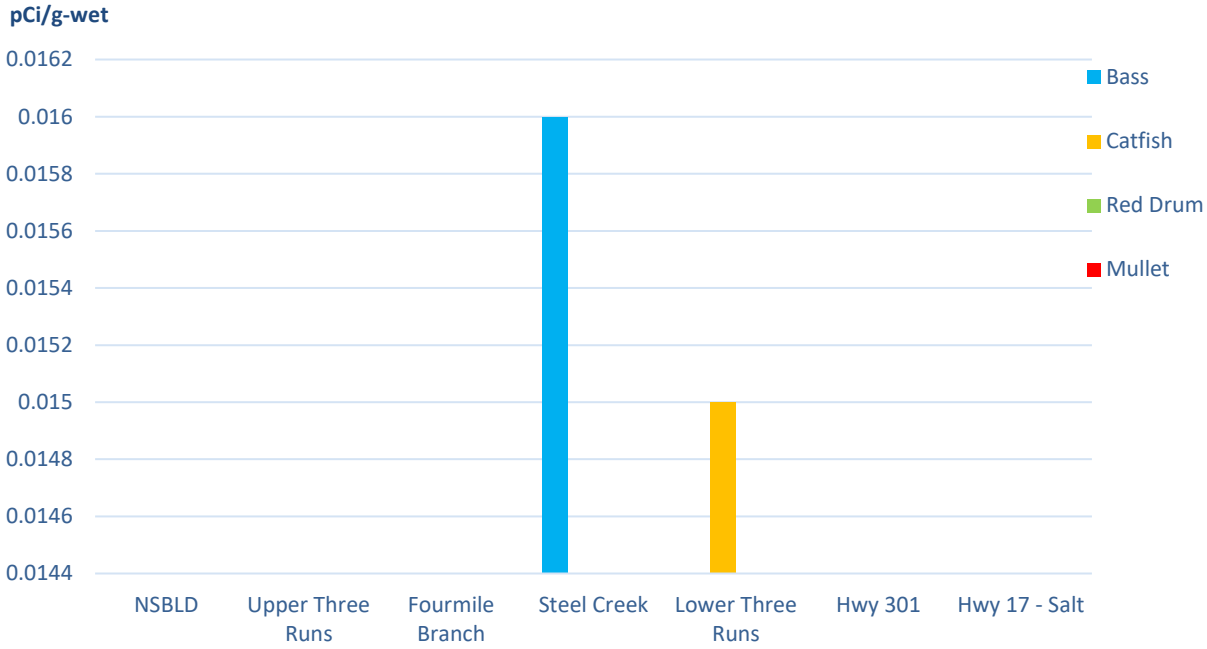
TABLES AND FIGURES

Figure 1. 2018 Cesium-137 in Fish Composites



Note: Missing bars indicate <MDA

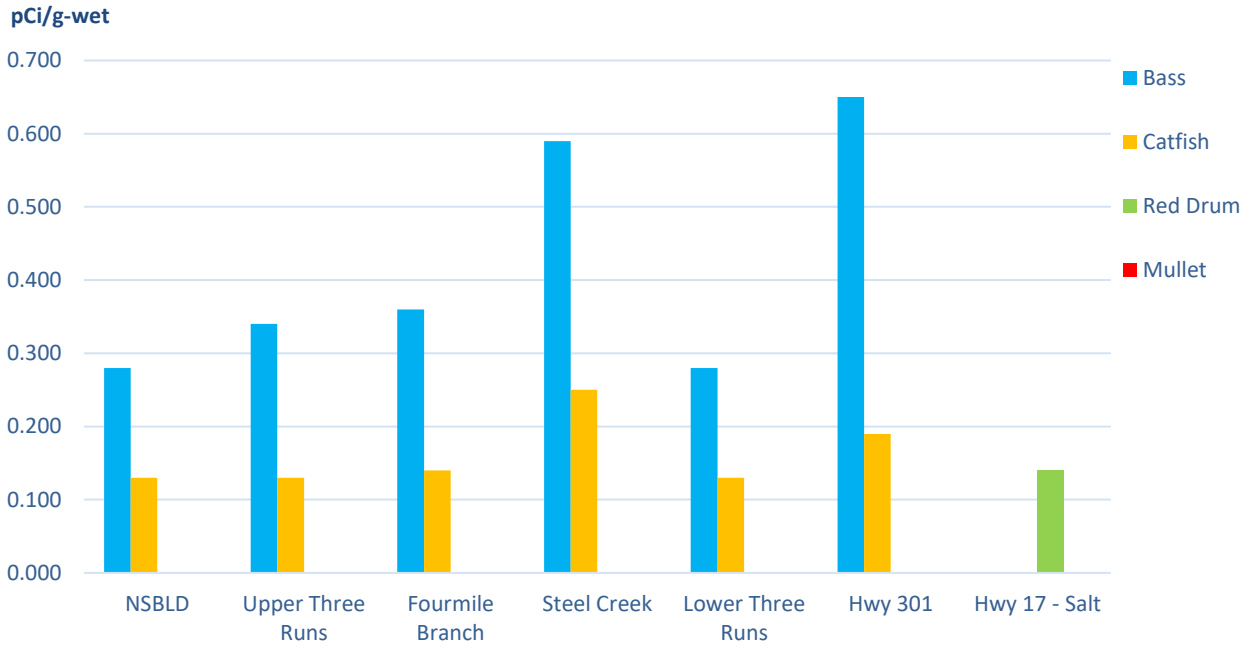
Figure 2. 2018 Strontium-89/90 in Fish Bone Composites



Note: Missing bars indicate <MDA

TABLES AND FIGURES

Figure 3. 2018 Mercury in Fish



Note: Missing bars indicate <LLD
DHEC did not sample a background location for mercury in 2018

11.6.0 SUMMARY STATISTICS

2018 DHEC Cesium-137 Levels in Savannah River Fish (pCi/g–wet)

Edible	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects	Number of Samples
Bass	0.081	0.036	0.081	0.056	0.107	2	6
Catfish	0.067	0.026	0.060	0.046	0.095	3	6

2018 DHEC Strontium-89/90 Levels in Savannah River Fish (pCi/g–wet)

Non-Edible	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects	Number of Samples
Bass	0.016	NA	NA	0.016	0.016	1	6
Catfish	0.015	NA	NA	0.015	0.015	1	6

2018 DHEC Mercury Levels in Savannah River Fish (mg/kg)

Edible	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects	Number of Samples
Bass	0.418	1.165	0.35	0.28	0.66	6	6
Catfish	0.162	0.049	0.135	0.13	0.25	6	6

Notes:
1. ND is Not Detected
2. NA is Not Applicable
3. Cs-137 results represent the activity level in fish tissue
4. Sr-89/90 results represent the activity level in an aliquot of fish bone
5. Some samples were below the MDA and are not displayed in these charts

Chapter 12 Game Animal Monitoring Adjacent to SRS

12.1.0 PROJECT SUMMARY

Due to white-tailed deer and feral hogs having the highest potential of mammalian species for human exposure pathway from Cs-137 (Haselow, 1991), DHEC conducts game animal monitoring activities around SRS. The game animal project addresses concerns of potentially contaminated white-tailed deer and feral hogs migrating off SRS. It also provides valuable information concerning potential exposure to Cs-137 from consuming game animals harvested around SRS.

White-tailed deer and feral hogs have access to several contaminated areas on and off SRS which allows them to be a vector for the redistribution of contaminants (primarily Cs-137). A five-mile study area was established based on a typical white-tailed deer upper limit home range to ensure that potentially contaminated deer residing at or near the SRS boundary would be included in the sample set. Cesium-137 is of concern because of its 30-year half-life, its availability to game animals, and associated health risk to humans (Haselow, 1991).

Cesium-137 is the isotope of focus for game due to its ability to accumulate in an animal's skeletal muscles (Brisbin & Smith, 1975). When contaminated game is eaten by hunters, Cs-137 is readily incorporated into the human body because of its similarity to K-40 in physiological processes (Davis, 1963). Once Cs-137 is consumed, the human body will experience both internal and external radiation. Cs-137's emission of both beta and gamma radiation can result in a person having gastrointestinal, genetic, hematopoietic, and central nervous system damage (Bond et al., 1965).

12.2.0 RESULTS AND DISCUSSION

Game Monitoring Summary Statistics can be found in Section 12.6.0 and all Game Monitoring Data can be found in the 2018 DHEC Data File.

DHEC analyzed muscle tissue collected in 2018 for Cs-137 from 25 deer and four hogs collected from area hunters via hunting clubs, plantations, and Crackerneck Wildlife Management Area within a five-mile study area adjacent to SRS (Section 12.4.0, Map). Additionally, five deer tissue samples were collected and analyzed from a background location 85 miles southeast of SRS in Beaufort County, South Carolina. Sample size, location, and collection dates were dependent on the participating hunters.

Cesium-137 and the naturally occurring isotope K-40 were the only isotopes detected in game samples collected in 2018. Naturally occurring isotopes will not be discussed in this report. Cesium-137 concentrations from deer and hogs collected in the SRS perimeter study area are shown in Section 12.5.0, Figure 1.

DOE-SR does not collect game animal samples within the DHEC study area, and off-site hunter doses are based on DOE-SR models. DHEC data presents a challenge for direct comparisons to DOE-SR data because the perimeter area is heavily baited. Therefore, the uptake of Cs-137 by these animals will be reduced based on the increased K-40 levels in the corn from fertilizers (Heckman & Kamprath, 1992).

12.3.0 CONCLUSIONS AND RECOMMENDATIONS

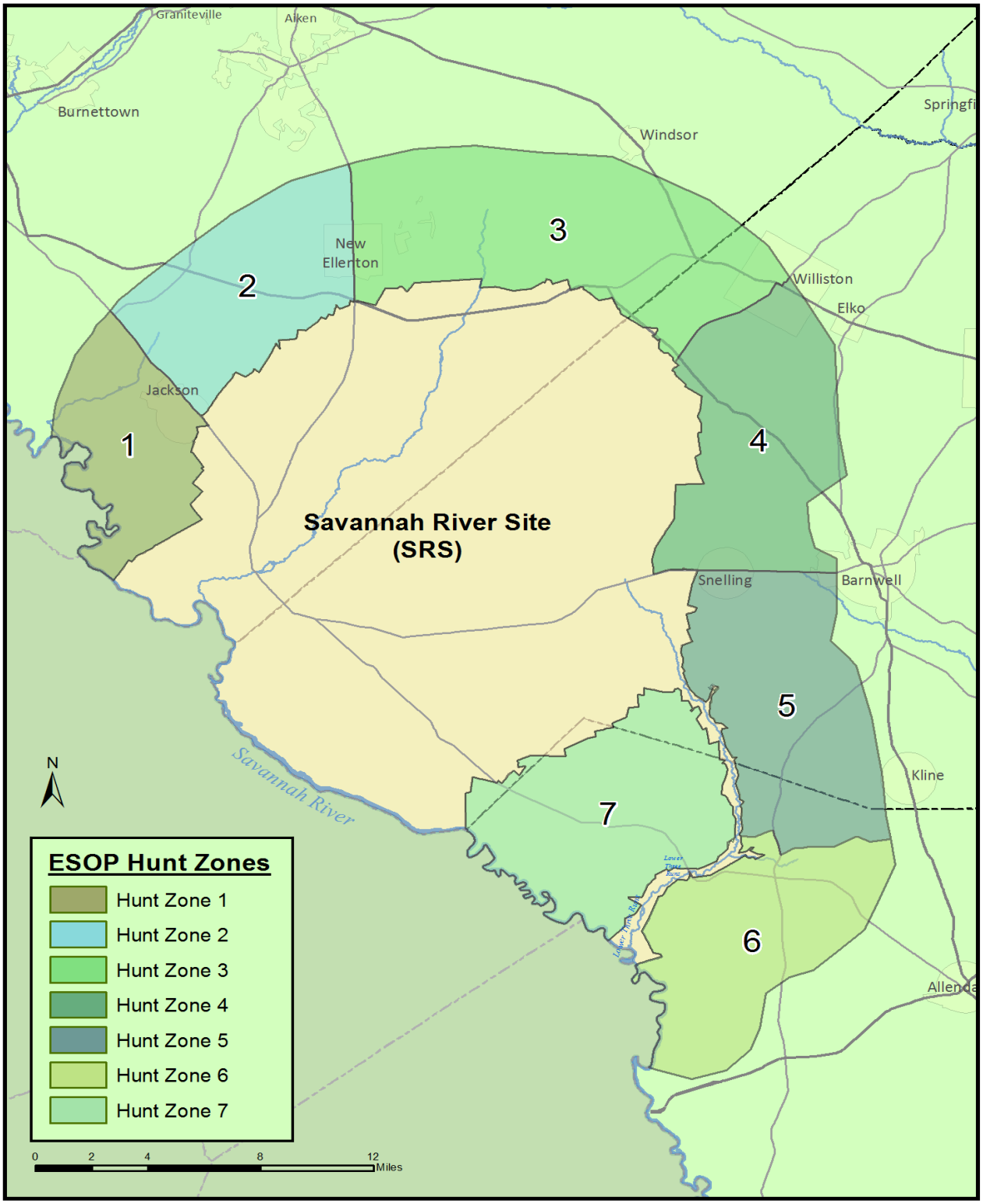
Historic SRS operations released known Cs-137 contamination to Steel Creek, Par Pond, Lower Three Runs, their floodplains, and the Savannah River swamp (Till et al., 2001), all of which impact hunt zones four, five, six, and seven (Section 12.4.0, Map). Although a portion of Cs-137 was deposited on SRS from site operations, levels found in the study area and background location are likely results of above ground nuclear weapons testing (Haselow, 1991).

Age, sex, body weight, soil type, diet, and collection location may affect the Cs-137 activities found in white-tailed deer and hogs (Haselow, 1991). A hunter consuming deer from SRS, the study area, or background locations would most likely ingest a portion of the activity associated with these animals. Refer to the 2018 DHEC Critical Pathway Dose report for a better understanding of the contamination found in game versus other food sources.

DHEC will continue to monitor Cs-137 levels in deer and hogs within the established study area and background locations to assess trends. DHEC will continue to pursue new hunters within the five-mile study area to ensure adequate sample numbers can be achieved each year. DHEC will also put additional efforts into trapping wild hogs within the study area.

12.4.0 MAP

Game Monitoring Sampling Locations



2018 ESOP Game Animal Monitoring

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12.5.0 TABLES AND FIGURES

Figure 1. 2018 DHEC Hunt Zone Average Cs-137 Concentration in Game

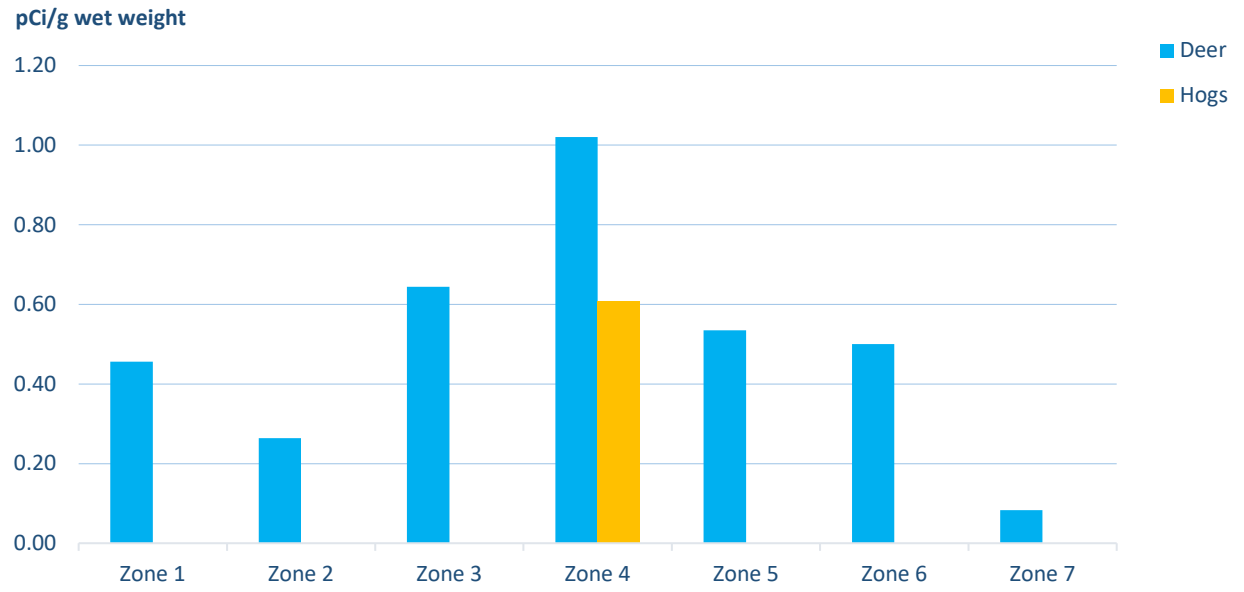
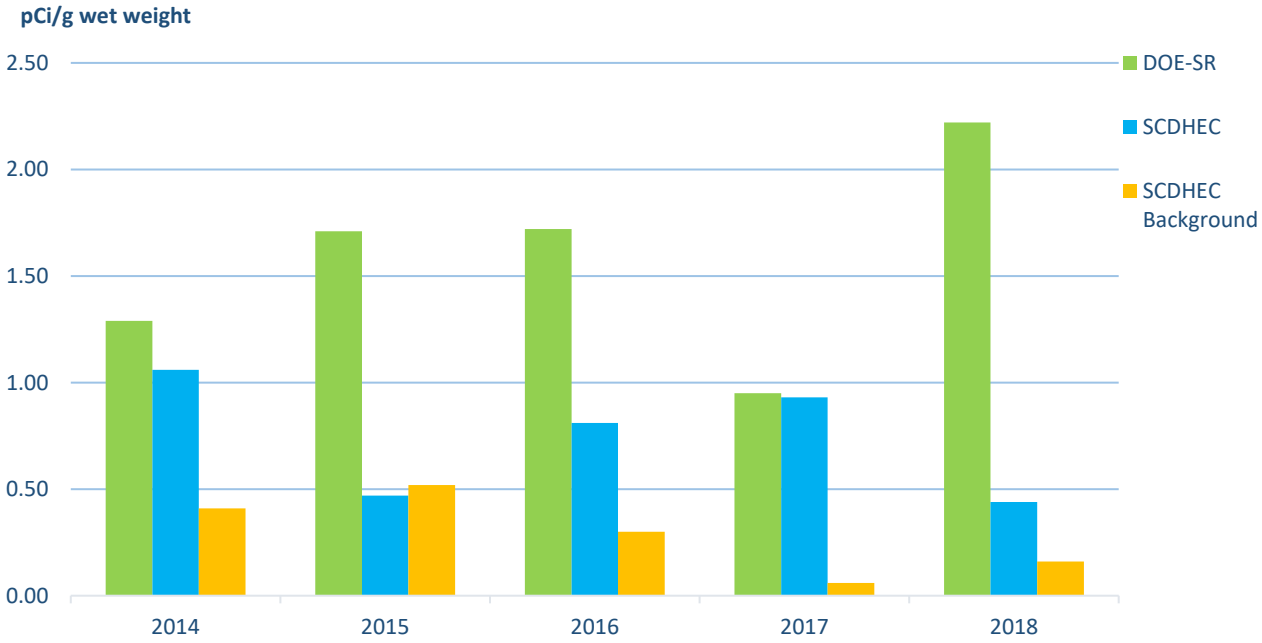


Figure 2. 2014-2018 Average Cs-137 Concentration in Deer (SRNS, 2015-2019; DHEC, 2015-2018)



Notes:
1). 2014-2018 background location was Pinckney Island National Wildlife Refuge
2). SRS data is from on-site deer only and DHEC data is from SRS 5-mile perimeter only
3). DOE-SR data is the gross average concentration of Cs-137 calculated from field averages, which is used in an algorithm to provide a comparable dose to DHEC. DOE-SR lab's average Cs-137 concentration was 2.21 pCi/g.

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12.6.0 SUMMARY STATISTICS

2018 Cs-137 Concentration (pCi/g wet weight) in Deer

	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Study Area Deer	0.438	0.380	0.323	0.068	1.486	22	25
Background Deer	0.159	0.089	0.120	0.069	0.296	5	5

2018 Cs-137 Concentration (pCi/g wet weight) in Deer DHEC Hunt Zones

Hunt Zone	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Zone 1 Deer	0.456	0.364	0.332	0.171	0.987	4	5
Zone 2 Deer	0.264	0.239	0.133	0.119	0.540	3	3
Zone 3 Deer	0.644	0.449	0.589	0.174	1.224	4	5
Zone 4 Deer	1.022	0.656	1.022	0.558	1.486	2	2
Zone 5 Deer	0.535	0.144	0.586	0.323	0.645	4	5
Zone 6 Deer	0.500	0.489	0.388	0.077	1.036	3	3
Zone 7 Deer	0.083	0.021	0.083	0.068	0.098	2	2

2018 Cs-137 Concentration (pCi/g wet weight) in Hogs DHEC Hunt Zones

Hunt Zone	Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Zone 4 Hogs	0.608	0.307	0.538	0.315	1.04	4	4

Chapter 13 Critical Pathway Dose Report

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13.1.0 PROJECT SUMMARY

The South Carolina Department of Health and Environmental Control (DHEC) implemented a Radionuclide Dose Calculation Project/Critical Pathway Project to calculate the potential exposure or dose to the public within 50-miles of a SRS center point. This study area was chosen for comparison to the Department of Energy-Savannah River (DOE-SR) 80-km (50-mile) radius dose results. Individual project managers chose differing sample locations/schemes within this study area to establish trends in media radionuclide concentrations.

DHEC and DOE-SR programs were evaluated based on media potential exposure in mrem (Section 13.2.0). The figures in Section 13.4.0 illustrate the trends and central tendencies in the critical pathway potential dose exposures. The annual dose is calculated on average exposed individual (AEI) and maximum exposed individual (MEI) bases which are summarized in Section 13.4.0, Table 1.

13.2.0 RESULTS AND DISCUSSION

All 2018 Dose Data can be found in Section 13.5.0.

The DHEC MEI is a hypothetical subsistence and survivalist type of individual who resides in the downriver swamp area below all SRS contributions to the Savannah River, visits the entire 50-mile perimeter study area, and receives the MEI dose based on the single highest detection per radionuclide per media detected in the environment. The 2018 data and dose results are discussed under the following headings in this section: 2018 AEI and MEI Dose, Critical Pathways 2018 Summary, and DOE-SR and DHEC 2018 Comparisons. Total AEI Dose covers the 2009-2018 period, whereas other headings discuss only 2018 data. Not all media were collected for all years during this summary period (2009-2018).

The critical pathways were analyzed both on a millirem (mrem) basis and percentage of dose basis (Section 13.4.0, Table 4). Percentages denote relative importance, whereas mrem denotes potential exposure levels. The dose critique attempts to point out the limits of this dose estimate and why any DOE-SR and DHEC estimates may or may not be similar.

2018 AEI and MEI Dose

The basis for dose calculations is not limited to any particular pathway of dose exposure based on lifestyle or media encountered, but it is simply a tabulation of all detected dose found in all media sampled regardless of applicability to an individual. Table 1 in Section 13.4.0 summarizes all DHEC detections by media on an AEI and MEI detection basis. Background readings are not subtracted before dose calculations are performed.

The AEI dose is a conservative estimate based on consumption rates, represented by the consumption rate column in the data tables, average dose per media (Section 13.5.0), and is based on sample results only with no modeling. In 2018, the calculated AEI dose was 1.732 mrem (Section 13.4.0, Table 1), with 1.718 mrem from food dose. If wild game is not consumed, the AEI dose falls to 0.072 mrem. The AEI dose skews high, as only detections are used in the dose calculations. For a typical person in the study area, the dose they receive should be lower than the AEI dose.

In 2018, the total calculated MEI dose was 6.215 mrem, of which 6.087 mrem was attributable to food consumption. If wild game is not consumed, the MEI dose falls to 0.465 mrem. The MEI basis column uses the single highest detection for a media radionuclide and calculates dose as if the high dose occurrence was somehow stored and the exposure continued throughout the year. If the individual did not store the media at the location, date, and time of DHEC sample collection and achieve a full year's exposure to that media, then the MEI estimate represents a sizable overestimate.

Only speciated doses for specific radionuclides were included in the estimated doses for 2018. The use of detections only in determining AEI dose per radionuclide per media, the calculation of dose based on the MEI detection for each radionuclide/media, and conservative consumption references provided a protective dose estimate. Each media radionuclide dose, excluding Naturally Occurring Radioactive Material (NORM), was considered as part of a critical pathway with contributions through the inhalation, ingestion, and direct exposure routes.

The MEI dose can be received by only one individual, since that individual had to consume the specific dose basis animals. Two elevated dose bases (AEI and MEI) were used because they were measured and protective without the inclusion of screening value assumptions for alpha and beta. The assumption of all alpha as plutonium-239 (Pu-239) and all beta as strontium-90 (Sr-90) may double the calculated dose without evidence for that assumption in speciated data. Nonspeciated dose assignments were discontinued in 2009 and replaced by calculating a MEI dose potential from the single highest detection per radionuclide per media.

Critical Pathways 2018 Summary

Atmospheric Pathway 2018 Summary

The DHEC 2018 atmospheric pathway contributed dose to the individual through the inhalation of tritium (H-3) in air, the consumption of food (predominantly from wild game), and direct exposure from farm soil. Section 13.4.0, Table 2 illustrates the dominance of the atmospheric pathway, which accounted for 1.696 mrem, at 97.92 percent, of dose to the AEI and 5.913 mrem, at 95.14 percent, of dose to the MEI. The primary contributor to the atmospheric pathway was Cs-137 in wild game.

Liquid Pathway 2018 Summary

The DHEC 2018 liquid pathway estimated AEI dose to the individual was from the consumption of fish, drinking water from the Savannah River and groundwater, incidental swimming ingestion, and direct exposure from swimming and wading (Section 13.4.0, Table 1). The liquid pathway contributions to dose exposure were second to those contributed by the atmospheric pathway. In 2018, the liquid pathway contribution to the AEI was 0.036 mrem, accounting for 2.08 percent of dose. The contribution to the MEI dose was 0.302 mrem, at 4.86 percent. The primary contributor to dose in the liquid pathway was Cs-137 in fish.

Food Sub-pathway 2018 Summary

The food sub-pathway was covered under the atmospheric and liquid pathways except for these

additional observations. The annual 2018 DHEC AEI food sub-pathway dose order, highest to lowest for averages, was wild game (hog), wild game (deer), fungi, fish, and edible vegetation. Milk and incidental soil ingestion did not contribute any quantifiable dose.

The 2018 MEI food pathway order was wild game (deer), wild game (hog), fish, fungi, and edible vegetation. Milk and incidental soil ingestion did not contribute any quantifiable dose. Cs-137 was the predominant dose contributor to food through the consumption of hog (0.99 mrem) for the AEI and the consumption of deer (3.05 mrem) for the MEI. It should be noted that deer and hog consumption rates are based on the edible portions of the relevant harvested animals and they vary from year to year. Tritium also contributed to dose from edible vegetation in both the AEI and the MEI.

Isotopic Contribution Summary

Most of the AEI dose exposure in 2018 was due to Cs-137: 1.715 mrem (99.02 percent) of the 1.732 mrem total. The primary contributor to the Cs-137 AEI dose was wild game (hog). Tritium was the second highest dose contributor in 2018 at 0.017 mrem (0.98 percent). Cesium-137 and H-3 were both found in the atmospheric and the liquid pathways.

Cs-137 was also the primary contributor to the MEI, at 6.071 mrem (97.68 percent) of the 6.215 mrem total, with H-3 second, at 0.144 mrem. Cs-137 in wild game (deer) was the single largest dose contributor to the MEI.

2009-2018 Total AEI Dose

Section 13.4.0, Table 4 summarizes dose associated with all media on an AEI basis from 2009-2018. The critical pathway basis of comparison for DHEC detected dose comes from samples that were collected outside of the SRS boundary and within 50-miles of the SRS center-point, although animals that are harvested offsite may have migrated from onsite.

Table 4 illustrates the dominance of the atmospheric pathway accumulated dose which accounted for 90.64 percent, over the liquid pathway, at 9.36 percent. The food sub-pathway was the dominant route, accounting for 99.30 percent of accumulated exposure. The AEI received a 3.158 mrem average dose per year during the 2009-2018 year period.

Section 13.4.0, Figures 1-3 and Table 4 illustrate the various pathways of dose exposure. The AEI basis critical pathway dose for 2018, 1.732 mrem, is less than the 7.00 mrem dose an individual typically receives from living in a brick house for one year (Wahl, 2011). Section 13.4.0, Figures 1-3 illustrate the media exposure trends via line graphs.

The predominant source of AEI exposure from 2009-2018 was wild game (deer and hog). In total it accounted for 22.235 mrem, which amounts to 70.40 percent of the total accumulated AEI exposure (31.583 mrem) during that time period. Following wild game were fungi (4.929 mrem; 15.61 percent), fish (2.762 mrem; 8.75 percent), and edible vegetation (1.221 mrem; 3.87 percent). Furthermore, wild game accounted for 77.67 percent of the accumulated dose from the atmospheric pathway and 70.90 percent of the food sub-pathway.

The predominant routes of accumulated exposure from 2009-2018 for water sources were public system water from the Savannah River (0.098 mrem) and public system water from groundwater (0.024 mrem). The primary routes for minor sources of accumulated dose were accidental ingestion from swimming (0.037 mrem) and from the inhalation of tritium in air (0.018 mrem).

DOE-SR and DHEC 2018 Comparisons

DOE-SR calculates potential doses to members of the public from atmospheric and liquid releases, as well as from special-case exposure scenarios, on an annual basis (SRNS, 2018). These include liquid pathway and air pathway doses, an all-pathway dose, a sportsman dose, on-site and off-site hunter doses, and an off-site fisherman dose. The DOE-SR dose estimates are analogous to DHEC dose estimates as follows, although it must be noted that there are differences between DOE-SR and DHEC sampling and dose estimation protocols:

1. The DOE-SR all-pathway dose and the sum of the DHEC fish, wading, swimming, public system drinking water from the Savannah River, vegetation, and milk doses serve as a means of comparison of the dose that a typical member of the public in the study area (an individual who doesn't consume wild game or gather edible mushrooms) could receive from SRS activities during a given year.

2. The sum of the DOE-SR offsite hog consumption, offsite deer consumption, and swamp fisherman doses and the sum of the DHEC hog, deer, and fish doses at Steel Creek serve as a means of comparison of the dose a survivalist type of individual who consumes fish from the Savannah River and wild game could receive in a given year.

The DOE-SR total representative person dose and the DHEC Public Scenario basis were the most relevant dose estimates that represent the potential dose exposure for the general public in 2018. The DOE-SR representative person dose for 2018 was 0.27 mrem (Section 13.4.0, Table 3). The sum of the DHEC AEI fish, wading, swimming, public system drinking water from the Savannah River, vegetation, and milk doses was 0.039 mrem in 2018. The DHEC public scenario dose estimate for 2018 is 0.039 percent of the DOE all-pathway dose standard of 100 mrem/yr (SRNS, 2018).

The sum of the DOE-SR offsite hog consumption, offsite deer consumption, and Steel Creek fish consumption doses was 11.57 mrem in 2018, of which the single largest contributor was the DOE-SR offsite deer consumption dose, at 7.01 mrem. It should be noted that the DOE-SR dose summations are only done for comparison to DHEC results. The sum of the DHEC hog, deer, and Steel Creek fish doses was 5.82 mrem. DOE-SR also calculates a soil dose of 2.08 mrem from Savannah River swamp soil on Steel Creek plantation.

Dose Critique

Many of the samples collected in 2018 resulted in less than minimum detectable activity (MDA) determinations and were not included in the DHEC summary statistics, which used detections only. The use of detections only in calculations was protective (Gilbert, 1987) and biases the measures of central tendency higher.

The NORM averages and maximums were not included in the dose estimates since this dose was considered to be part of the background dose for the study area. The yearly dose averages were based on DHEC detections only and are inflated since most sample results were less than MDA. The justification for selecting higher source consumption levels was due to the conceptualization of the DHEC MEI as a survivalist type who consumed natural media at a greater than typical use rate. The basis for both considerations was to be protective of the public and environment.

The inclusion of alpha and beta assumed dose in the past provided an excessively high dose estimate and was not supported by media radionuclide species detections. The inclusion of calculations based on a single highest maximum detection for each radionuclide/media was a more definable basis for establishing an upper bound rather than the dose assumption of unknown alpha as Pu-239 and unknown beta as Sr-90. This upper bound is not practically achievable by the MEI due to the unlikely exposure to all maximums at a constant rate throughout the year (via storage of media). However, since most of the dose was due to wild-type food (whether animal or plant) consumption containing Cs-137, then a single individual who ate all of the worst-case deer, hog, and edible plant and mushrooms could approach the MEI dose if these contaminated media were stored and consumed over the entire year.

The DHEC 2009 Critical Pathway Dose Report noted that 38.50 percent of the dose was assigned and represented a potential dose overestimate that may in fact be NORM detections (alpha and beta). The DHEC dose calculations since then were still protective due to the use of detections only in determining dose, the calculation of a maximum dose for the MEI based on a single maximum detection for each radionuclide/media, and the use of conservative consumption rates.

The AEI was given prominence as protective for general dose considerations, and the reader should be aware that the AEI dose estimate was conservative or biased high due to the use of detections only for dose calculation. For example, the omission of less than MDA assignments from calculations would raise any calculated number to a higher value. Alternatively, less than MDA actually represents an undetermined low number that may be zero or any number up to the given MDA value for that analysis.

This project used dose instead of risk so that direct comparisons of dose magnitude can be made with similar media data published in the SRS Environmental Reports. DOE-SR modeled radionuclide releases for a particular year were not directly comparable to DHEC yearly-detected dose in some media due to bioaccumulation.

13.3.0 CONCLUSIONS AND RECOMMENDATIONS

The 2018 results indicated that monitoring of the primary inhalation, ingestion, and direct exposure routes from the atmospheric and liquid pathways should continue. Ground water, surface water, sediments, plants, and animals should be carefully monitored for any signs of the contaminants that are associated with past and present SRS operations. Early detection is paramount to protecting the public and the environment if a release to offsite streams or groundwater occurs. DHEC will continue to monitor SRS and adjacent areas for the primary radionuclide contributors to dose potentially associated with DOE-SR operations.

13.4.0 TABLES AND FIGURES

TABLES AND FIGURES

Table 1. DHEC Dose Estimates (mrem) for all Media: AEI and MEI

Pathway	Route	Source of Exposure	AEI	MEI
Atmospheric	Inhalation	Surface Soil Resuspension	0.000	0.000
Atmospheric	Inhalation	Inhalation of H-3 in Air	0.005	0.068
Air Inhalation Total			**0.005**	**0.068**
Liquid	Ingestion	Fish	0.027	0.243
Atmospheric	Ingestion	Cow Milk	0.000	0.000
Atmospheric	Ingestion	Wild Game (Deer)	0.67	3.05
Atmospheric	Ingestion	Wild Game (Hog)	0.99	2.70
Atmospheric	Ingestion	Vegetation (Fruit, Vegetables, and Nuts)	0.003	0.017
Atmospheric	Ingestion	Fungi	0.028	0.077
Atmospheric	Ingestion	Soil Ingestion with Food	0.000	0.000
Food Ingestion Total			**1.718**	**6.087**
Liquid	Ingestion	Public System Drinking Water-Savannah River	0.009	0.057
Liquid	Ingestion	Public System Drinking Water-Groundwater	ND	ND
Liquid	Ingestion	Private Wells	ND	ND
Liquid	Ingestion	Ingestion from Swimming	0.000	0.002
Drinking Water Total			**0.009**	**0.059**
Liquid	Direct	Direct Exposure from Swimming	0.000	0.000
Liquid	Direct	Direct Exposure from Wading	0.000	0.000
Atmospheric	Direct	Direct Exposure from Farm Soil	0.000	0.001
Direct Exposure Total			**0.000**	**0.001**
Overall Total Dose			**1.732**	**6.215**

Note: ND is No Detections in 2018

Table 2. DHEC Dose Estimates (mrem) for the Atmospheric and Liquid Pathways: AEI and MEI

Critical Pathway Summary	AEI	MEI
The Atmospheric Pathway Totals	1.696	5.913
The Liquid Pathway Totals	0.036	0.302
Combined Dose	**1.732**	**6.215**

TABLES AND FIGURES

Table 3. DHEC/DOE-SR Dose Comparisons

Pathway	Comparison Basis	DOE-SR[1]	DHEC[2]
All-Pathway	DHEC All Pathway Approximation[3]	0.27	0.32
Sportsman	Onsite Hunter	11.1	NS
	Onsite Turkey	ND	NS
	Swamp Fisherman[4]	0.159	0.067
	Creek Mouth Fisherman[5]	0.398	0.114
	Offsite Hunter Deer	7.01	3.05
	Offsite Hunter Hog	4.40	2.70
	Edible Fungi	NS	0.077

Notes:
1. DOE-SR data from Table 6-5a and Table 6-6 (SRNS 2018)
2. DHEC maximums or single highest detection basis for all media per route of exposure (Table 1.)
3. Sum of DHEC fish, wading exposure, swimming ingestion, Savannah River derived drinking water (treated only), vegetation, and milk (all MEI)
4. Compares DOE-SR and DHEC bass results from the mouth of Steel Creek (DHEC location SV-2017).
5. Compares DOE-SR and DHEC fish results from the mouth of Lower Three Runs (DHEC location SV-2020; DHEC used catfish as opposed to DOE-SR's bass as there were no detections for DHEC bass at this location).

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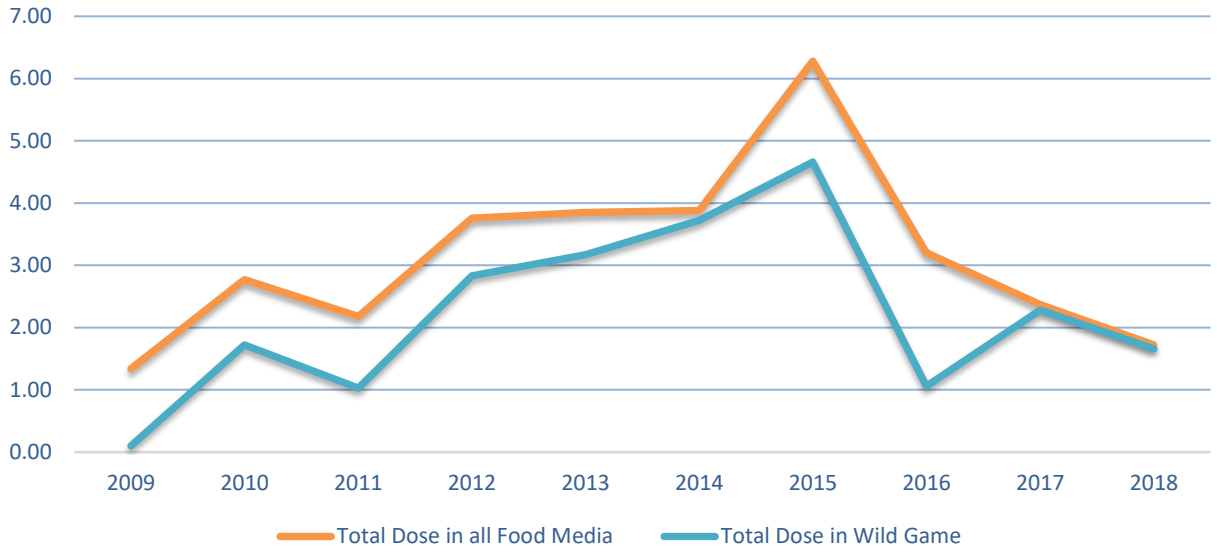
Table 4. 2009-2018 AEI Exposure: Total AEI Dose (mrem) and Percentage

Pathway	AEI Media Categories	2018[1]	2009-2018[2]	2009-2018 % AEI[3]
Atmospheric	Surface Soil Resuspension Inhalation	0.000	0.009	0.03
Atmospheric	H-3 Inhalation	0.005	0.018	0.06
Atmospheric	Cow Milk	0.000	0.215	0.68
Atmospheric	Wild Game	1.660[4]	22.235	70.40
Atmospheric	Vegetation (Leafy, Fruit, and Nuts)	0.003	1.221	3.87
Atmospheric	Fungi	0.028	4.929	15.61
Atmospheric	Direct Exposure from Farm Soil	0.000	0.001	0.00
Atmospheric	Soil Ingestion with Food	0.000	0.000	0.00
Totals for Atmospheric Pathway		**1.696**	**28.628**	**90.65%**
Liquid	Fish	0.027	2.762	8.75
Liquid	Public System Water from the Savannah River	0.009	0.098	0.31
Liquid	Public System Water from Groundwater	ND[5]	0.024	0.08
Liquid	Private Wells	ND[5]	0.022	0.07
Liquid	Ingestion from Swimming	0.000	0.037	0.12
Liquid	Direct Exposure from Swimming	0.000	0.000	0.00
Liquid	Direct Exposure from Wading	0.000	0.012	0.04
Totals for Liquid Pathway		**0.036**	**2.955**	**9.37%**
Totals for Atmospheric and Liquid Pathway		**1.732**	**31.583**	**100%[6]**

Notes:
1. The 2018 column is average dose in mrem during 2018.
2. The 2009-2018 column is total dose in mrem over the 2009-2018 ten-year period.
3. The AEI % basis column is the percentage of the 2009-2018 total dose due to a given media.
4. Deer and hog in 2018.
5. There were no detections in 2018.
6. Sum of percentages is slightly greater than 100 percent due to rounding error.

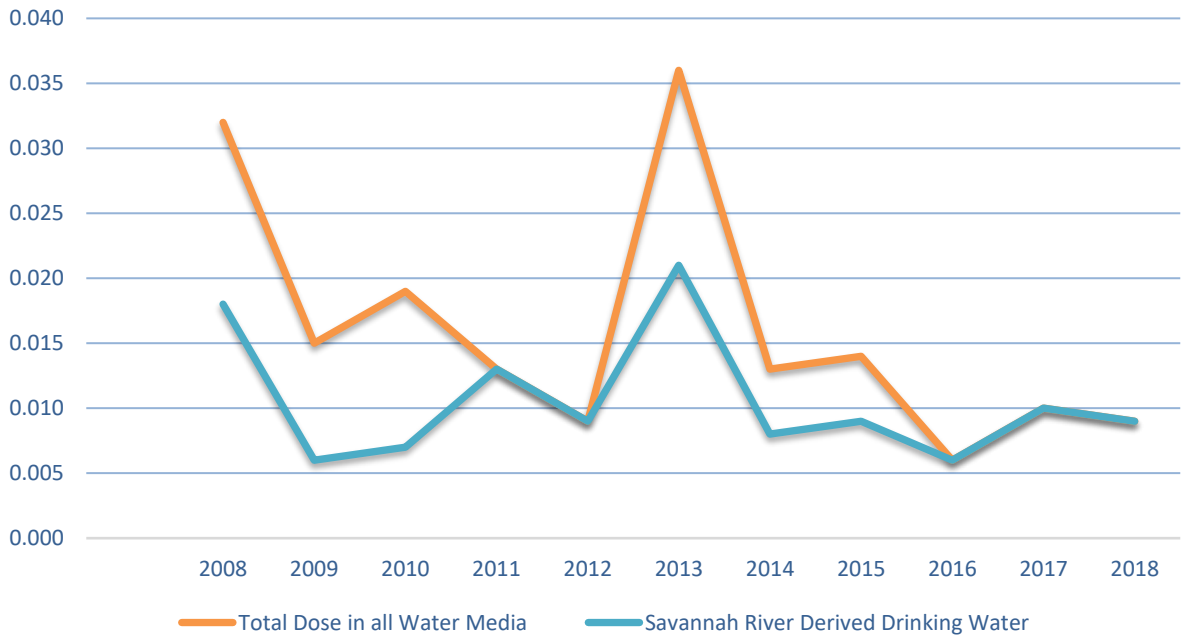
TABLES AND FIGURES

Figure 1. 2009-2018 DHEC AEI Food Dose



Note: This graph shows the total food AEI dose trend and the trend for the primary contributor to that dose for 2018 in mrem.

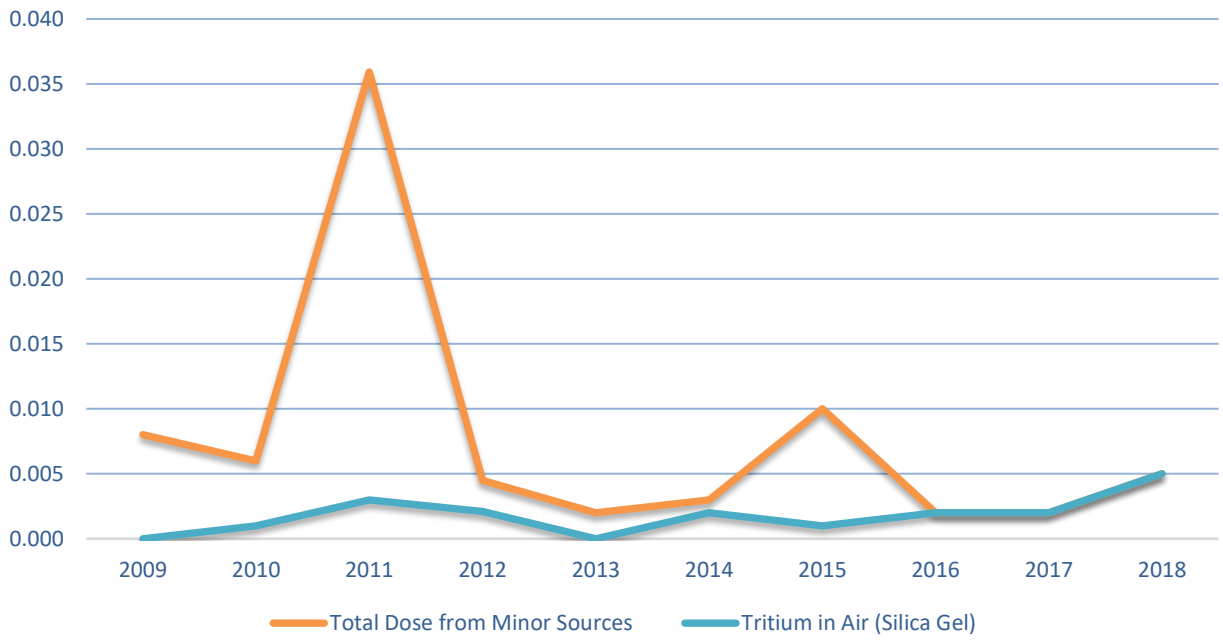
Figure 2. 2009-2018 DHEC AEI Water Dose



Note: This graph shows the total water AEI dose trend and the trend for the primary contributor to that dose from 2018 in mrem.

TABLES AND FIGURES

Figure 3. 2009-2018 DHEC AEI Dose from Minor Sources



Note: This graph shows the total minor sources AEI dose trend and the trend for the primary contributor to that dose from 2018 in mrem.

13.5.0 2018 DOSE DATA

Notes:
1. ND is No Detects
2. NA is Not Applicable
3. NS is Not Sampled
4. All consumption rates are from Aranceta et al., 2006; Botsch et. al., 2000; USEPA, 2011; and SRNS, 2014.

2018 DOSE DATA

AEI Fish Dose

Dose from Fish Ingestion (AEI)				
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
		pCi/g	kg/yr	mrem
Bass	Cs-137	0.081	3.7	0.015
Bass	Sr-89/90	0.016	3.7	0.000
Catfish	Cs-137	0.067	3.7	0.012
Catfish	Sr-89/90	0.015	3.7	0.000
Fish Total				0.027

Note: Mullet and red drum were sampled in 2018 but there were no detections.

MEI Fish Dose

Dose from Fish Ingestion (MEI)				
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
		pCi/g	kg/yr	mrem
Bass	Cs-137	0.107	24.0	0.129
Bass	Sr-89/90	0.016	24.0	0.000
Catfish	Cs-137	0.095	24.0	0.114
Catfish	Sr-89/90	0.015	24.0	0.000
Fish Total				0.243

Note: Mullet and red drum were sampled in 2018 but there were no detections.

2018 DOSE DATA

AEI Milk Dose

Dose from Milk (AEI)				
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
		pCi/L	kg/yr	mrem
Milk	H-3	ND	69.0	NA
	Sr-89/90	ND	69.0	NA
	I-131	ND	69.0	NA
Milk Total				**0.000**

MEI Milk Dose

Dose from Milk (MEI)				
Media	Radionuclide	**Activity**	**Consumption Rate**	**Dose**
		pCi/L	kg/yr	mrem
Milk	H-3	ND	260.0	NA
	Sr-89/90	ND	260.0	NA
	I-131	ND	260.0	NA
Milk Total				**0.000**

AEI Wild Game Dose

Dose from Wild Game (AEI)		
Media	**Radionuclide**	**Dose**
Deer	Cs-137	0.67
Hog	Cs-137	0.99
Game Total		**1.66**

Note: Deer AEI is based on an edible portion of 58 lbs.; Hog AEI is based on an edible portion of 60 lbs.

MEI Wild Game Dose

Dose from Wild Game (MEI)		
Media	**Radionuclide**	**Dose**
Deer	Cs-137	3.05
Hog	Cs-137	2.70
Game Total		**5.75**

Note: Deer MEI is based on an edible portion of 137 lbs.; Hog MEI is based on an edible portion of 117 lbs.

2018 DOSE DATA

AEI Edible Vegetation Dose

Dose in Edible Vegetation (AEI)				
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
		pCi/g	kg/yr	mrem
Fruit and Vegetables	H-3	0.587	92	0.003
	Cs-137	ND	92	NA
Fruit and Vegetable Total				**0.003**
Nuts	H-3	NS	NA	NA
	Cs-137	NS	NA	NA
Nuts Total				**NA**
Fungi	H-3	ND	3.65	0.000
	Cs-137	0.154	3.65	0.028
Fungi Total				**0.028**
Combined Vegetation Total				**0.031**

2018 MEI Edible Vegetation Dose

Dose in Edible Vegetation (MEI)				
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
		pCi/g	kg/yr	mrem
Fruit and Vegetables	H-3	1.06	248	0.017
	Cs-137	ND	248	NA
Fruit and Vegetable Total				**0.017**
Nuts	H-3	NS	NA	NA
	Cs-137	NS	NA	NA
Nuts Total				**NA**
Fungi	H-3	ND	10	0.000
	Cs-137	0.154	10	0.077
Fungi Total				**0.077**
Combined Vegetation Total				**0.094**

2018 DOSE DATA

2018 AEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells (AEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Savannah River Sourced Drinking Water		pCi/L	L/yr	mrem
Surface Water	**H-3**	**460**	**300**	**0.009**
Groundwater Sourced Drinking Water		pCi/L	L/yr	mrem
Groundwater	**H-3**	**ND**	**300**	**0.000**
Private Wells Groundwater		pCi/L	L/yr	mrem
Groundwater	**H-3**	**ND**	**300**	**0.000**
Ingestion from Surface Water and Wells Total				**0.009**

Note: Non-potable drinking water is no longer evaluated for dose.

2018 MEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Savannah River Sourced Drinking Water		pCi/L	L/yr	mrem
Surface Water	**H-3**	**1114**	**800**	**0.057**
Groundwater Sourced Drinking Water		pCi/L	L/yr	Mrem
Groundwater	**H-3**	**ND**	**800**	**NA**
Private Wells Groundwater		pCi/L	L/yr	mrem
Groundwater	**H-3**	**ND**	**800**	**NA**
Ingestion from Surface Water and Wells Total				**0.057**

Note: Non-potable drinking water is no longer evaluated for dose.

2018 DOSE DATA

AEI Incidental Water Ingestion from Swimming

Incidental Water Ingestion and Direct Exposure from Water (AEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Swimming at Savannah River Creek Mouths				
Surface Water Swimming	H-3	pCi/L	L/yr	mrem
Ingestion		**1371**	**0.189**	**0.000**
Surface Water Swimming	H-3	pCi/L	hrs/yr	mrem
Surface Water Immersion		**1371**	**9**	**0.000**
Savannah River Creek Mouth Total				**0.000**

MEI Incidental Water Ingestion from Swimming

Incidental Water Ingestion and Direct Exposure from Water (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Swimming at Savannah River Creek Mouths				
Surface Water Swimming	H-3	pCi/L	L/yr	mrem
Ingestion		**11298**	**2.57**	**0.002**
Surface Water Swimming	H-3	pCi/L	hrs/yr	mrem
Surface Water Immersion		**11298**	**36**	**0.000**
Savannah River Creek Mouth Total				**0.002**

2018 DOSE DATA

AEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings (AEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Sediment Dose		pCi/g	hrs/yr	mrem
Creek Mouths	**Cs-137**	**0.461**	**9**	**0.000**
Boat Landings	**Cs-137**	**NS**	**NA**	**NA**
Sediment Total				**0.000**

MEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Sediment Dose		pCi/g	hrs/yr	mrem
Creek Mouths	**Cs-137**	**1.25**	**36**	**0.000**
Boat Landings	**Cs-137**	**NS**	**NA**	**NA**
Sediment Total				**0.000**

2018 DOSE DATA

AEI Surface Soil Ingestion Dose

Surface Soil Ingestion (AEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil		pCi/g	Mg/day	mrem
Ingestion	Cs-137	0.113	20	0.000
Soil Ingestion Total				**0.000**

Note: This represents soil inadvertently consumed with plants.

MEI Surface Soil Ingestion Dose

Surface Soil Ingestion (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil		pCi/g	Mg/day	mrem
Ingestion	Cs-137	0.252	20	0.000
Soil Ingestion Total				**0.000**

Note: This represents soil inadvertently consumed with plants.

AEI Soil Shine Dose

Soil Shine (AEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil		pCi/g	hrs/yr	mrem
Ingestion	Cs-137	0.113	2602	0.000
Soil Shine Total				**0.000**

Note: The consumption rate is from Iowa State university, 2012 (Edwards et. al., 2012).

2018 MEI Soil Shine Dose

Soil Shine (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil		pCi/g	hrs/yr	mrem
Ingestion	Cs-137	0.252	2602	0.001
Soil Shine Total				**0.001**

Note: The consumption rate is from Iowa State university, 2012 (Edwards et. al., 2012).

2018 DOSE DATA

AEI Atmospheric Inhalation Dose

Atmospheric Inhalation (AEI)				
Surface Soil Resuspension and Air Inhalation				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil Resuspension		**pCi/g**	**m3/yr**	**mrem**
Inhalation	Cs-137	0.113	5000	0.000
Surface Soil Resuspension Total				**0.000**
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**mrem**
Inhalation	H-3	16.78	5000	0.005
Atmospheric Inhalation Total				**0.005**

MEI Atmospheric Inhalation Dose

Atmospheric Inhalation (MEI)				
Surface Soil Resuspension and Air Inhalation				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil Resuspension		**pCi/g**	**m3/yr**	**mrem**
Inhalation	Cs-137	0.252	6400	0.000
Surface Soil Resuspension Total				**0.000**
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**Mrem**
Inhalation	H-3	165.74	6400	0.068
Atmospheric Inhalation Total				**0.068**

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