ESOP

Environmental Surveillance and Oversight Program

2019 DATA REPORT

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Healthy People. Healthy Communities.

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DOE-SR Environmental Quality Management Division

Purpose

PURPOSE OF THIS REPORT

WHAT: South Carolina's Department of Health and Environmental Control (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 personnel have been sampling multiple media for many years. However, to verify the data being collected on and around SRS, DHEC 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 DHEC as part of a 1995 Agreement in Principle (AIP) to create the Environmental Surveillance and Oversight Program (ESOP). ESOP is a division of 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 the 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.

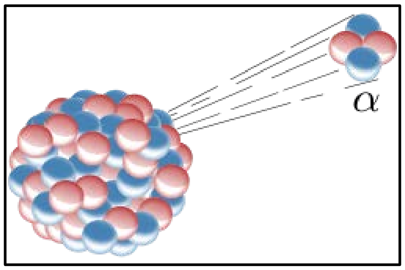
TYPES OF RADIATION

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.

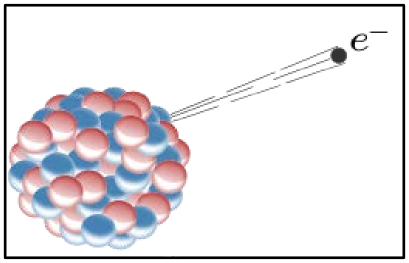
BETA – occurs when an atom releases an electron (negative charge). Since it is lighter in mass and faster moving, it can travel greater distances and can be stopped by a layer of wood or metal but can penetrate the outer layer of skin. It can cause skin burns.

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.

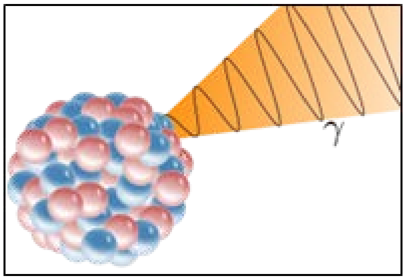
ALPHA RADIATION:



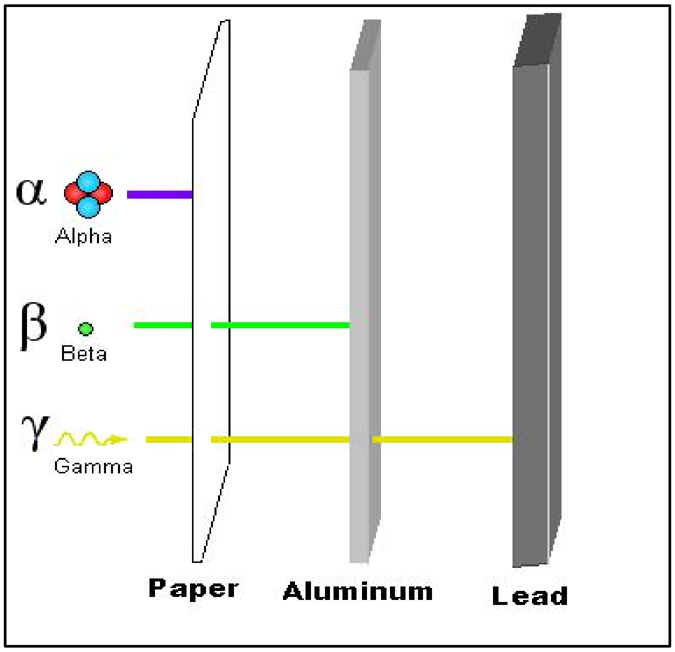
BETA RADIATION:



GAMMA RADIATION:



RADIATION:



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List of Analytes

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
AIP	Agreement in Principle
AKN	Sample locations in Aiken County
ALD	Sample locations in Allendale County
ALN	Allendale
ARESD	Analytical and Radiological Environmental Services Division
ATSDR	Agency for Toxic Substances and Disease Registry
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
DW	Drinking Water
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
MPN	Most Probable Number
NA	Not Applicable
ND	Not Detected
NEL	New Ellenton
NORM	Naturally Occurring Radioactive Material
NRC	National Regulatory Commission
NS	No Sample
NSBLD	New Savannah Bluff Lock & Dam

Acronyms and Units of Measure

PCB	Polychlorinated Biphenyls
PRG	Preliminary Remediation Goals
RM	River Mile
RSL	Regional Screening Level
RSW	Radiological Surface Water
SCAT	South Carolina Advanced Technology
SRNL	Savannah River National Laboratory
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

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Acronyms and Units of Measure

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 (F and H), but there are other areas of releases as a result of the varied processes at SRS.

P 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 waste into streams. 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 failures.

H Canyon at SRS – Still in operation at the site

Photo by DOE-SR. CC BY 2.0

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 Principle (AIP) with the South Carolina Department of Health and Environmental Control (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 risk of 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.

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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. Air monitoring capabilities in 2019 included 19 dosimeter 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, and silica gel distillates of atmospheric moisture are sampled and analyzed monthly for tritium. Dosimeters 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 the SRS perimeter, and three are found outside of the site boundary within public areas. Thirteen of the dosimeters 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 2019 DHEC Data File.

1.2.1 Total Suspended Particulates

DHEC and the Department of Energy-Savannah River (DOE-SR) had both gross alpha and gross beta detections in 2019. Small seasonal variations at each monitoring location have been consistent with historically reported DHEC values (DHEC, 2019). Section 1.5.0 illustrates trends for the last five years for average gross alpha activity (Figure 1) and average gross beta activity (Figure 2) at SRS perimeter locations.

1.2.2 Ambient Beta/Gamma

DHEC conducts ambient beta/gamma monitoring through the deployment of dosimeters around the perimeter of SRS. In 2019, ambient beta/gamma average quarterly totals ranged from 19.98 (TLD-07) to 33.37 (TLD-02) mrem. Section 1.5.0, Figure 3 shows data trends at the SRS perimeter for average ambient beta/gamma values in dosimeters 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, 2020**).**

Example of dosimeters present at 19 locations

<u>Tritium in Air</u>

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 2019, 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 (6.88 pCi/m^3) was lower than the DOE-SR perimeter average activity (10.33 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 2019 was lower than reported in 2018 and has fluctuated over the last five years. DOE-SR also reported a decrease in tritium from 2018 to 2019 with fluctuations over the past five 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.

<u>Tritium in Precipitation</u>

In 2019, 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, 2019). 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 2019 sampling period, tritium detected in precipitation ranged from 228 pCi/L to 6099 pCi/L (found on-site at Burial Ground North (BGN) in October). The maximum reported value for DHEC perimeter locations was collected at the DKH air station with 430 pCi/L for the month of

Inside View of Air Monitoring Station

Silica Gel Column

April. The DHEC average measured activity for perimeter locations above the lower limit of detection for tritium in precipitation was 331 (± 101.1) pCi/L. The DOE-SR average measured value for tritium activity in precipitation at the SRS perimeter locations was 431 (± 87.6) pCi/L (SRNS, 2020).

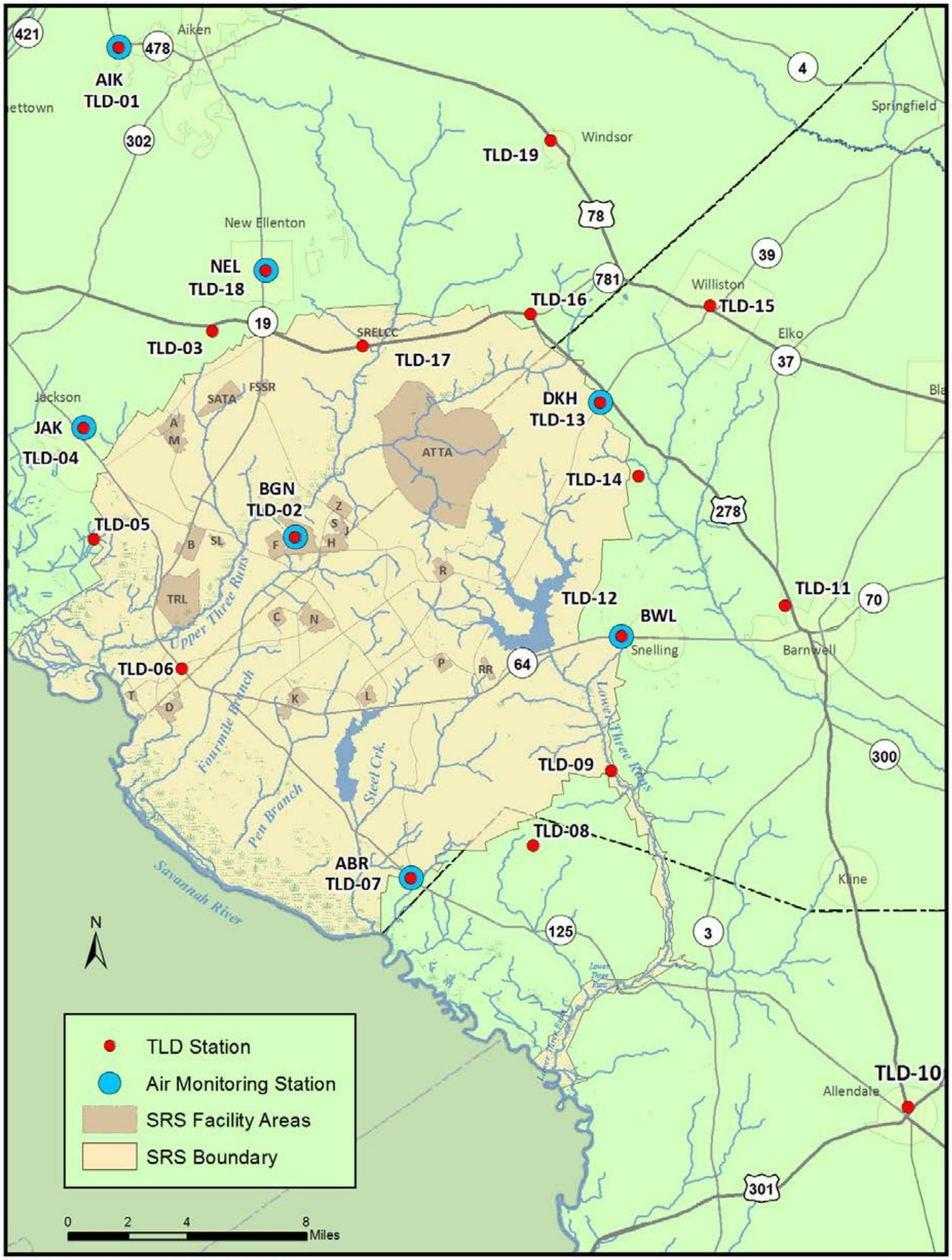
1.3.0 CONCLUSIONS AND RECOMMENDATIONS

All DHEC data collected in 2019 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.

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



2019 ESOP Radiological Air Monitoring Map www.scdhec.gov

1.5.0 TABLES AND FIGURES

Table 1. Radiological Atmospheric Monitoring Locations

Dosimeter 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	Ellenton Memorial 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	Allendale Health Department	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	Darkhorse	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, 2016a-2020; DHEC, 2016-2019)

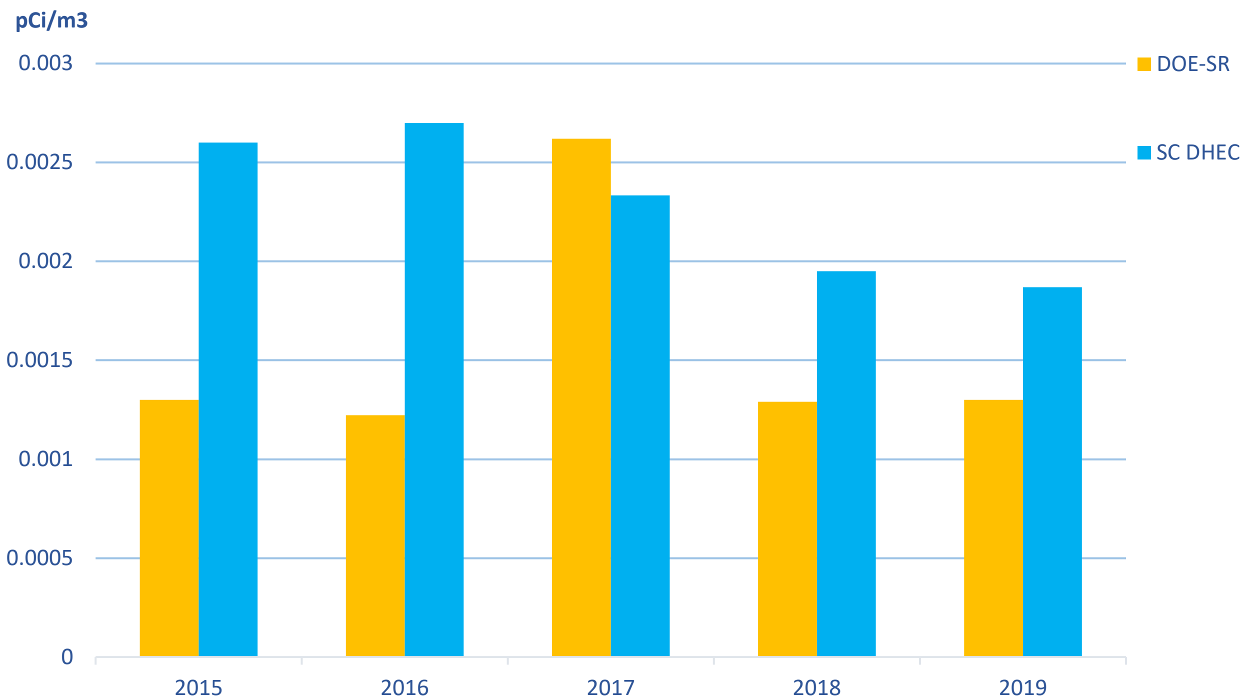


Figure 2. DOE-SR and DHEC Comparison of Average Gross Beta for Total Suspended Particulates at the SRS Perimeter (SRNS, 2016a-2020; DHEC, 2016-2019)

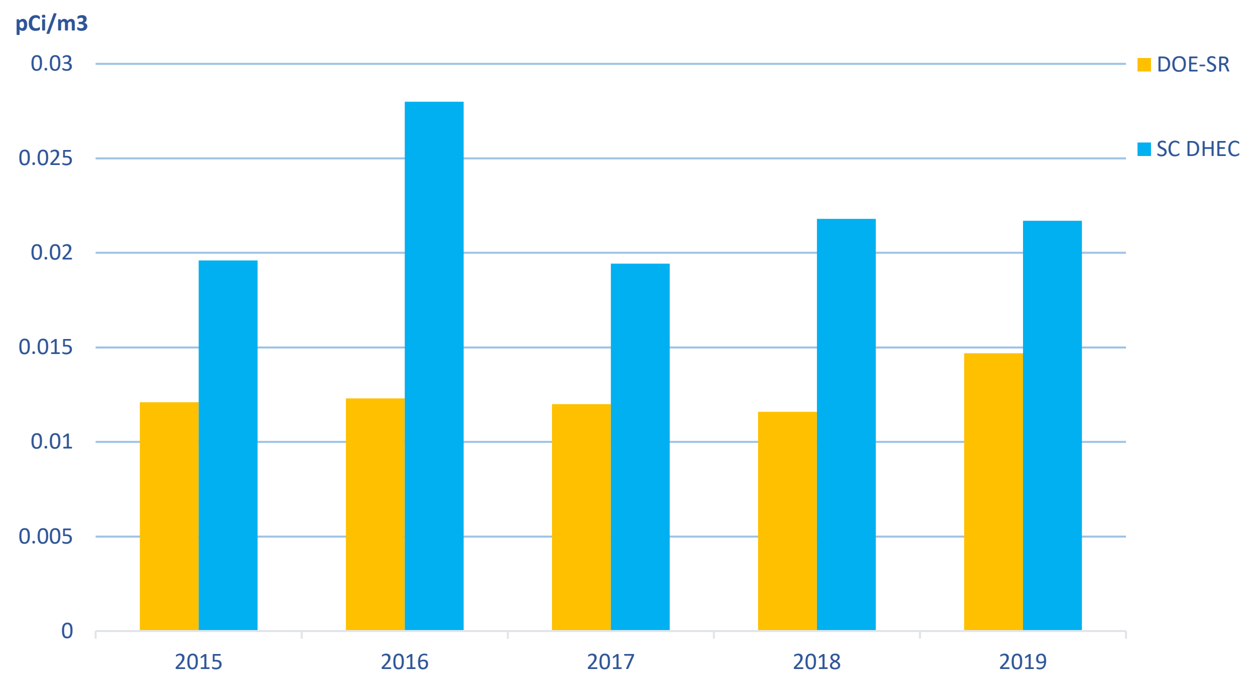


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Figure 3. DOE-SR and DHEC Comparison of Yearly Average Ambient Beta/Gamma in Dosimeters at the SRS Perimeter (SRNS, 2016a-2020; DHEC, 2016-2019)

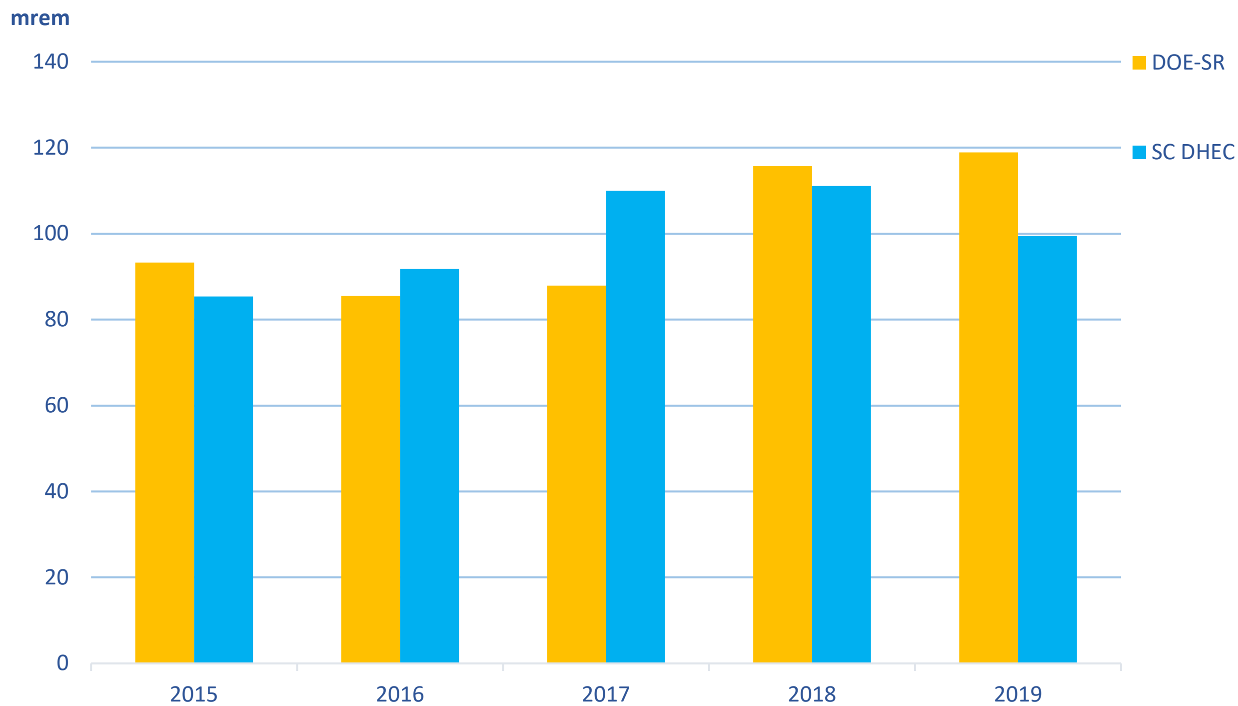
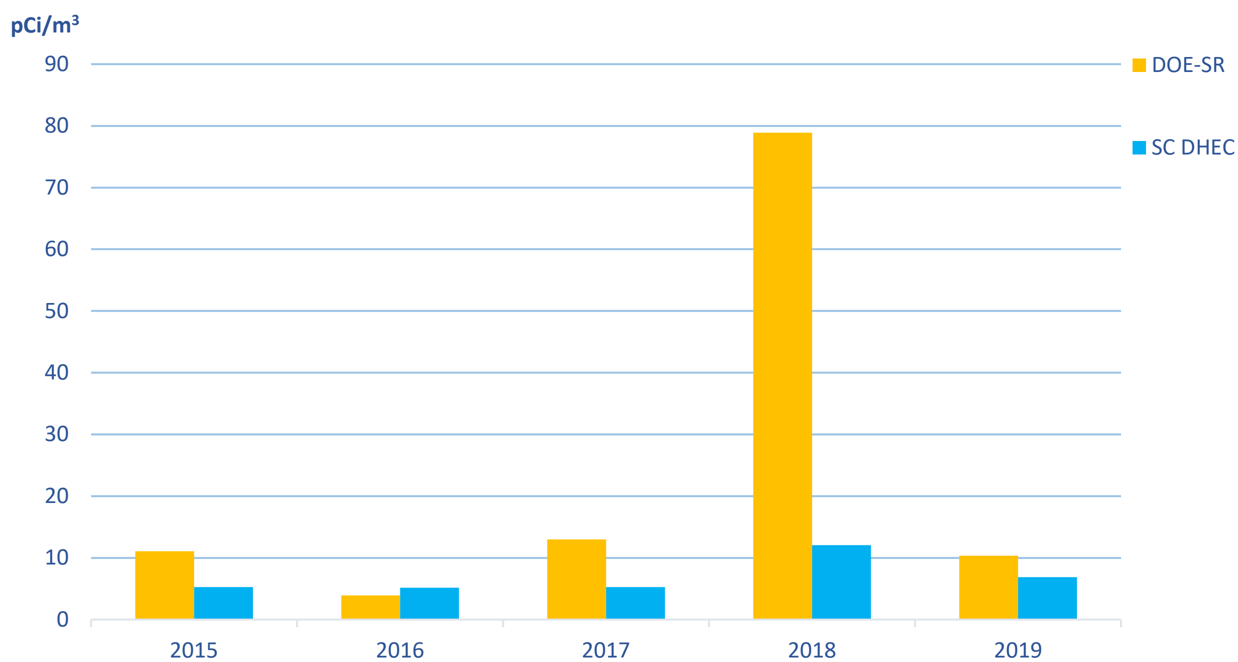


Figure 4. DOE-SR and DHEC Comparison of Average Tritium in Air at the SRS Perimeter (SRNS, 2016a-2020; DHEC, 2016-2019)



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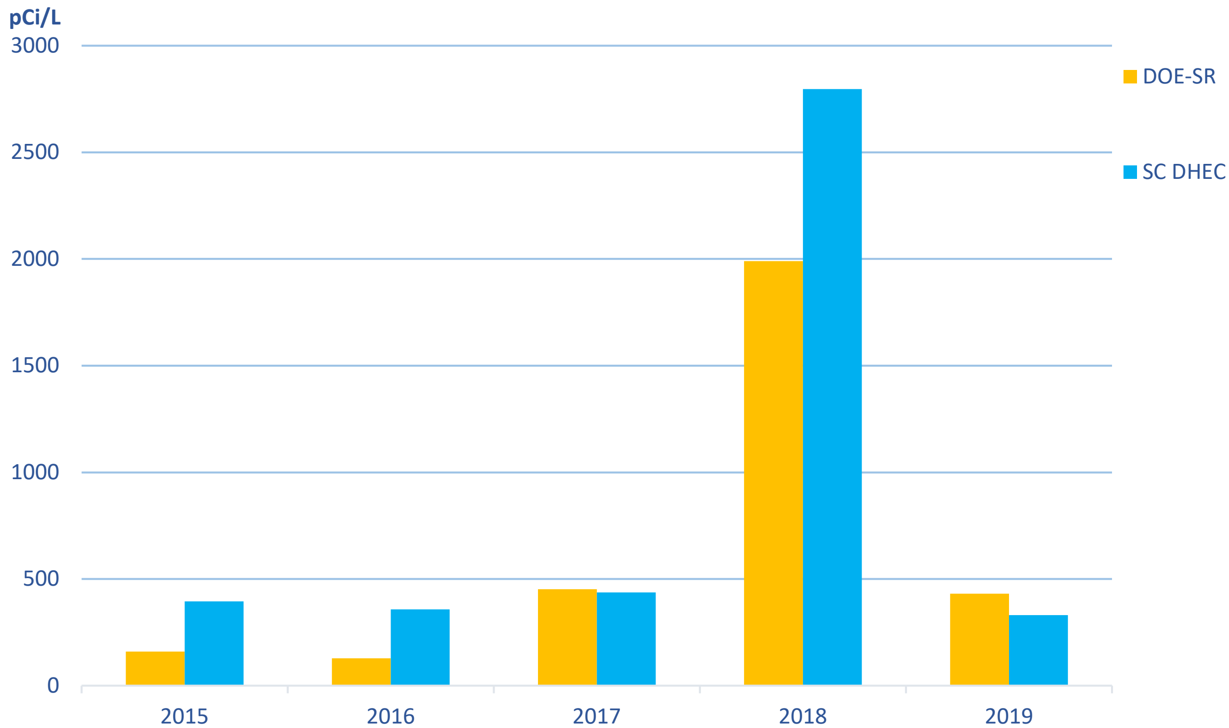
TABLES AND FIGURES

Figure 5. DOE-SR and DHEC Comparison of Average Tritium in Precipitation at the SRS Perimeter (SRNS, 2016a-2020; DHEC, 2016-2019)



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1.6.0 SUMMARY STATISTICS

2019 DHEC Quarterly Averages of Ambient Dosimeter Beta/Gamma Data

Sample ID	Average (mrem)	Standard Deviation (mrem)	Median (mrem)	Minimum (mrem)	Maximum (mrem)
TLD-01	20.23	1.63	20.70	18.00	21.50
TLD-02	33.37	2.76	34.60	30.20	35.30
TLD-03*	24.58	1.38	24.70	23.10	25.80
TLD-04*	21.18	2.58	21.35	18.20	23.80
TLD-05*	27.90	1.89	28.10	25.40	30.00
TLD-06*	23.93	2.77	24.30	21.00	26.50
TLD-07*	19.98	1.90	20.50	17.40	21.50
TLD-08*	27.25	2.58	26.55	25.00	30.90
TLD-09*	29.03	5.71	27.90	23.70	36.60
TLD-10	25.40	3.19	25.80	21.20	28.80
TLD-11	28.15	3.48	27.15	25.30	33.00
TLD-12*	24.43	3.28	24.85	20.20	27.80
TLD-13*	24.48	5.98	23.35	18.60	32.60
TLD-14*	29.13	2.54	29.25	25.90	32.10
TLD-15	27.70	2.83	27.35	25.10	31.00
TLD-16*	24.28	3.40	24.45	20.20	28.00
TLD-17*	26.33	3.00	25.80	23.80	29.90
TLD-18*	26.75	3.61	27.30	22.20	30.20
TLD-19	26.75	2.03	26.95	24.20	28.90

NOTE:
1). * DENOTES A PERIMETER LOCATION

SUMMARY STATISTICS

2019 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	0.0007	0.0019	0.0005	0.0038	48	49
Darkhorse (DKH)	0.0017	0.0007	0.0018	0.0004	0.0037	52	52
Aiken Elementary Water Tower (AIK)	0.0017	0.0008	0.0017	0.0008	0.0039	50	50
New Ellenton, S.C. (NEL)	0.0019	0.0008	0.0019	0.0006	0.0046	50	50
Jackson, S.C. (JAK)	0.0021	0.0009	0.0019	0.0009	0.0049	52	52
Burial Ground North (BGN)	0.0017	0.0008	0.0017	0.0006	0.0045	48	49
Barnwell Barricade (BWL)	0.0017	0.0006	0.0017	0.0007	0.0033	52	52

2019 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)	0.0242	0.0071	0.0232	0.0131	0.0421	49	49
Darkhorse (DKH)	0.0206	0.0057	0.0192	0.0110	0.0346	52	52
Aiken Elementary Water Tower (AIK)	0.0199	0.0058	0.0186	0.0117	0.0362	50	50
New Ellenton, S.C. (NEL)	0.0211	0.0058	0.0198	0.0090	0.0351	50	50
Jackson, S.C. (JAK)	0.0227	0.0065	0.0211	0.0125	0.0429	52	52
Burial Ground North (BGN)	0.0017	0.0007	0.0018	0.0004	0.0037	49	49
Barnwell Barricade (BWL)	0.0202	0.0054	0.0185	0.0121	0.0329	52	52

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

SUMMARY STATISTICS

2019 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)	7.38	5.47	6.31	2.89	18.46	7	12
Darkhorse (DKH)	6.31	3.08	5.52	2.77	12.14	9	12
Aiken Elementary Water Tower (AIK)	5.12	1.78	5.54	2.69	7.11	5	12
New Ellenton, S.C. (NEL)	5.84	3.56	4.89	3.24	16.12	12	12
Jackson, S.C. (JAK)	5.61	3.37	3.93	2.61	11.41	11	12
Burial Ground North (BGN)	226.53	107.41	218.80	75.08	423.05	12	12
Barnwell Barricade (BWL)	10.01	11.77	4.98	3.08	38.82	9	12

2019 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
Darkhorse (DKH)	430	NA	430	430	430	1	11
Aiken Elementary Water Tower (AIK)	316	78	324	231	414	6	12
New Ellenton, S.C. (NEL)	ND	NA	ND	<LLD	<LLD	0	12
Jackson, S.C. (JAK)	282	76	281.5	228	335	2	12
Burial Ground North (BGN)	2582	1713	2078	691	6099	11	11
Barnwell Barricade (BWL)	ND	NA	ND	<LLD	<LLD	0	12

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

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.

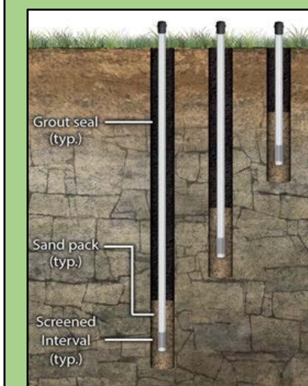
Monitoring these wells allows DHEC to evaluate groundwater quality adjacent to SRS, compare results with historical data, determine any potential SRS contaminant migration off-site, expand current ambient water quality databases, and provide the public with independently generated, region-specific groundwater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

Groundwater samples are collected from wells within a 10-mile site boundary. 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 2019. DHEC evaluates four aquifer zones (Upper Three Runs, Gordon, Crouch Branch, and McQueen Branch).

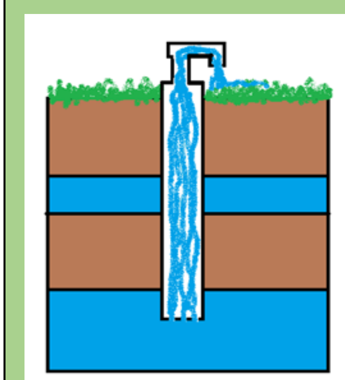
An **AQUIFER** is soil and/or rock containing water below the ground surface.

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 Data can be found in Section 2.6.0 and in the 2019 DHEC Data File.

DHEC collected groundwater from 21 C-Well Cluster wells (C-05, C-06, C-07, C-10, and C-13). Based on a review of the tritium, gross alpha, non-volatile beta, and gamma-emitting radioisotope analytical data provided by the DHEC Analytical and Radiological Environmental Services Division (ARESD) laboratories, the only gamma-emitting radioisotope detected was Lead-214 (Pb-214). Pb-214 is a naturally occurring radioactive or NORM contaminant and was detected in five out of the 21 groundwater wells sampled. See Section 2.5.0, Table 1 for a list of the network of sampling wells with their assigned aquifer.

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

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). 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, 2019). In 2019, DHEC did not detect tritium in any of the wells. Seven wells in four different aquifers (Gordon, Upper Three Runs, Crouch Branch, and McQueen Branch) had gross alpha detects below the EPA MCL. Nine wells in three different aquifers (Gordon, Crouch Branch, and McQueen Branch) had non-volatile beta detects well below the EPA MCL. Results for 2019 were compared to the data collected in 2014 which was the previous cycle year for the locations sampled. 2014 and 2019 had comparable data for both gross alpha and non-volatile beta detects. Those results can be found in Section 2.6.0.

2.3.0 CONCLUSIONS AND RECOMMENDATIONS

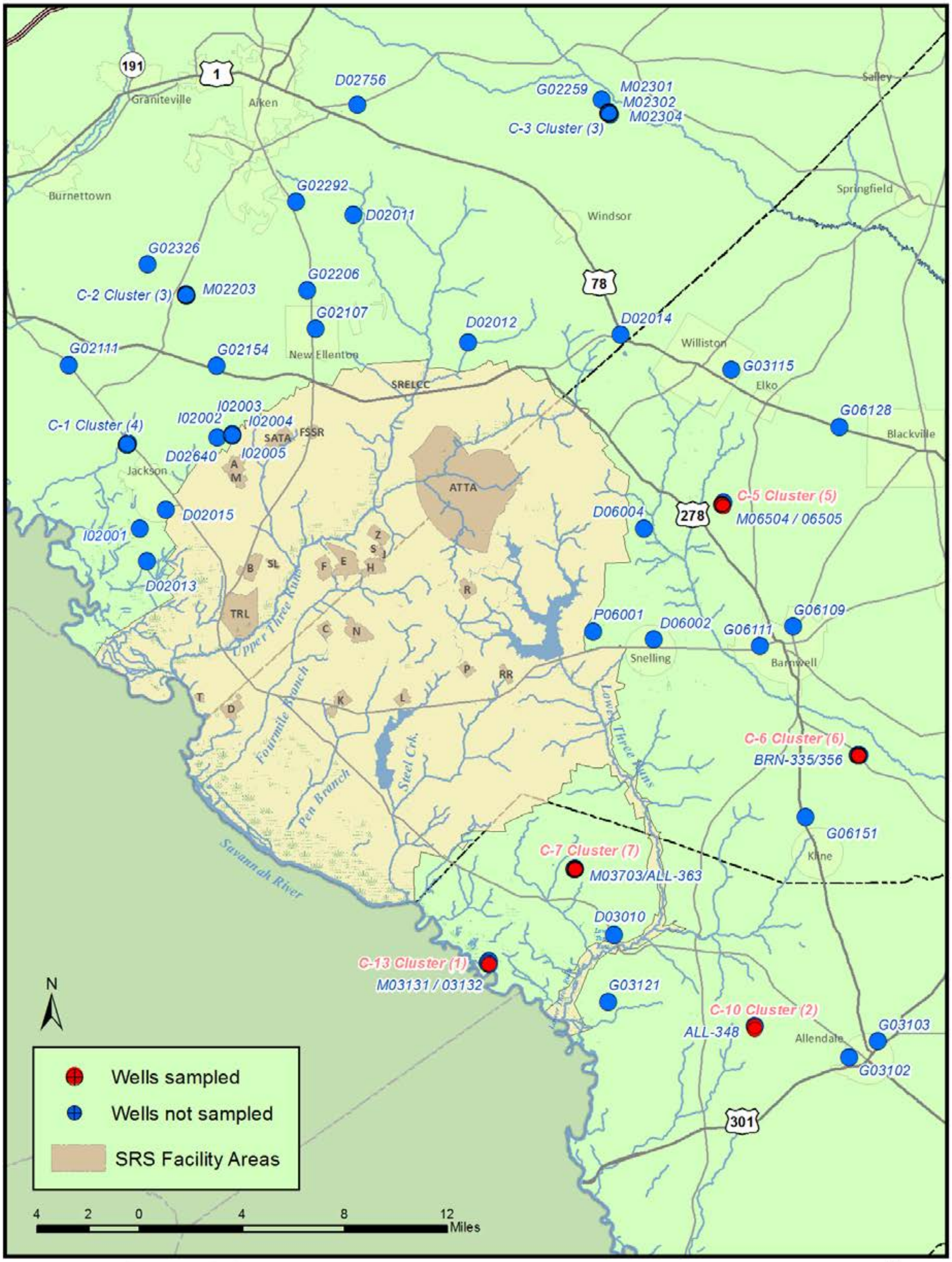
Collecting water to test for radiological material

DOE-SR collects groundwater samples from a separate on-site monitoring well network; therefore, direct DHEC off-site groundwater comparisons could not be made. However, the 2019 SRS report identifies numerous areas of groundwater contamination throughout the SRS property (SRNS, 2020). Various contaminants such as volatile organic compounds (VOCs), tritium, and gross alpha/beta radionuclides have been found in these areas (SRNS, 2020).

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

2.4.0 MAP

2019 Groundwater Sampling Locations



2019 ESOP Groundwater Monitoring Map www.scdhec.gov

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2.5.0 TABLES AND FIGURES

Table 1. DHEC Groundwater Monitoring Wells

Well No.	Well Name	Sample Year	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
G02292	Hunter's Glen	2020	unknown	210	SP
G02206	Oak Hill Subdivision	2020	445	240	SP
G02107	New Ellenton	2020	421	425	CB
G02259	Aiken State Park	2020	262	*	SP
G02154	Talatha Water District	2020	250	185	CB
G02141	Jackson	2020	225	105	SP
G02111	Beech Island Water District	2020	380	360	CB
G02326	Boyd Pond (Former ORA)	2020	300	397	MB
D02013	Cowden Plantation, Well 2	2020	124	*	SP
I02001	Cowden Plantation, Well 1	2020	132	*	CB
D02011	Mettlen Well	2020	400	180	SP
D02756	Montmorenci WD Office Well	2020	504	*	*
D02012	Windsome Plantation, House Well	2020	260	*	SP
G06109	Barnwell, Hwy. 3	2021	230	146	UTR
G06111	Barnwell, Rose St.	2021	220	166	UTR
G06128	Edisto Station	2021	322	360	GOR
G06147	Williston, Halford St.	2021	352	530	CB
D06002	Moore Well	2021	240	*	UTR
P06001	Allied General Nuclear, Well 1	2021	250	*	MB
D03010	Martin Post Office	2022	108	105	UTR
G03102	Allendale, Water St.	2022	201	343	UTR
G03103	Allendale, Googe St.	2022	180	347	UTR
G06151	Chappels Labor Camp	2022	250	260	UTR
G03115	Martin District Fire Department	2022	*	*	*
G03121	Clariant	2022	180	812	CB
I02002	Greene Irrigation 1	2023	381	278	SP
I02003	Greene Irrigation 2	2023	381	280	SP
I02004	Greene Irrigation 3	2023	373	276	SP
I02005	Greene Irrigation 4	2023	373	236	SP
M02101	SCDNR Cluster C-01, AIK-2378	2023	220.3	185	CB
M02102	SCDNR Cluster C-01, AIK-2379	2023	224.2	266	CB
M02103	SCDNR Cluster C-01, AIK-2380	2023	228.9	385	MB
M02104	SCDNR Cluster C-01, AIK-902	2023	231.9	511	MB
M02202	SCDNR Cluster C-02, AIK-825	2023	418.8	231	CB
M02203	SCDNR Cluster C-02, AIK-824	2023	418.6	365	CB
M02204	SCDNR Cluster C-02, AIK-818	2023	418.3	425	MB
M02205	SCDNR Cluster C-02, AIK-817	2023	418.9	535	MB
M02301	SCDNR Cluster C-03, AIK-849	2023	301.6	97	SP
M02302	SCDNR Cluster C-03, AIK-848	2023	299.7	131	CB
M02303	SCDNR Cluster C-03, AIK-847	2023	299	193	CB

M02304	SCDNR Cluster C-03, AIK-846	2023	297.8	255	CB
M02305	SCDNR Cluster C-03, AIK-845	2023	296.9	356	MB
M02306	SCDNR Cluster C-03, AIK-826	2023	294.9	500	MB
M06501	**SCDNR Cluster C-05, BRN-360**	**2019**	**264.3**	**140**	**UTR**
M06502	**SCDNR Cluster C-05, BRN-359**	**2019**	**265.5**	**214**	**GOR**
M06503	**SCDNR Cluster C-05, BRN-367**	**2019**	**263.8**	**285**	**GOR**
M06504**	SCDNR Cluster C-05, BRN-368	2019	265.1	443	CB
M06505**	SCDNR Cluster C-05, BRN-365	2019	263.5	539	CB
M06506	**SCDNR Cluster C-05, BRN-366**	**2019**	**266.7**	**715**	**MB**
M06507	**SCDNR Cluster C-05, BRN-358**	**2019**	**265.6**	**847**	**MB**
M03706	**SCDNR Cluster C-07, ALL-368**	**2019**	**246.6**	**691**	**CB**
M03707	**SCDNR Cluster C-07, ALL-369**	**2019**	**242.1**	**800**	**CB**
M03708	**SCDNR Cluster C-07, ALL-370**	**2019**	**245.1**	**975**	**MB**
M03709	**SCDNR Cluster C-07, ALL-358**	**2019**	**243.1**	**1123**	**MB**
M03701**	SCDNR Cluster C-07, ALL-363	2019	246.1	105	UTR
M03702	**SCDNR Cluster C-07, ALL-364**	**2019**	**245.2**	**225**	**UTR**
M03703**	SCDNR Cluster C-07, ALL-365	2019	244.3	333	GOR
M03704	**SCDNR Cluster C-07, ALL-366**	**2019**	**243.5**	**400**	**GOR**
M03705	**SCDNR Cluster C-07, ALL-367**	**2019**	**245.7**	**566**	**CB**
M06601	**SCDNR Cluster C-06, BRN-351**	**2019**	**207.3**	**95**	**UTR**
M06602	**SCDNR Cluster C-06, BRN-350**	**2019**	**207.4**	**170**	**UTR**
M06603	**SCDNR Cluster C-06, BRN-352**	**2019**	**207.1**	**293**	**GOR**
M06604	**SCDNR Cluster C-06, BRN-354**	**2019**	**207.6**	**411**	**GOR**
M06605	**SCDNR Cluster C-06, BRN-353**	**2019**	**207.7**	**588**	**CB**
M06608	**SCDNR Cluster C-06, BRN-349**	**2019**	**208.6**	**1045**	**MB**
M03101	**SCDNR Cluster C-10, ALL-347**	**2019**	**281.6**	**1423**	**MB**
M03102**	SCDNR Cluster C-10 ALL-372	2019	282	155	UTR
M03103**	SCDNR Cluster C-10 ALL-371	2019	282.2	217	UTR
M03113	**SCDNR Cluster C-13 (Artesian)**	**2019**	**73**	*****	**GOR**
M03132**	SCDNR Cluster C-13 ALL-378	2019	90	1060	MB
M03131**	SCDNR Cluster C-13, Artesian	2019	80	*	GOR
M03104	**SCDNR Cluster C-10, ALL-374**	**2019**	**280.9**	**580**	**GOR**

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
6). UTR is Upper Three Runs
7). GOR is Gordon
8). ** Well was unable to be sampled during the sampling cycle; however, it will remain in the network.

2.6.0 SUMMARY STATISTICS

2019 DHEC Alpha Detects in Groundwater Data in pCi/L

Location Description	2019 Result	Aquifer	2014 Data
M06501	2.46	UTR	NS
M06502	8.86	GOR	NS
M06506	2.60	MB	NS
M06507	2.67	MB	NS
M03705	4.77	CB	ND
M03707	2.46	CB	2.52
M03708	2.13	MB	ND

2019 DHEC Beta Detects in Groundwater Data in pCi/L

Location Description	Result	Aquifer	2014 Data
M06501	3.17	MB	NS
M06503	2.68	GOR	NS
M06506	2.97	MB	NS
M06507	3.83	MB	NS
M06608	11.00	MB	ND
M03704	6.32	GOR	ND
M03706	5.15	CB	ND
M03708	5.39	MB	ND
M03709	8.37	MB	3.14

Note:

1). A total of 21 wells were sampled in 2019, but only those wells that had gross alpha and non-volatile beta detects above the LLD were included in the tables above.

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Chapter 3 Radiological Monitoring of Drinking Water Adjacent to SRS

3.1.0 PROJECT SUMMARY

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.

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 five drinking water systems. Monthly composite samples are taken from three Savannah River-fed systems: one upstream location (North Augusta) and two downstream of SRS (Purrysburg Beaufort/Jasper (B/J) and Chelsea B/J). Additionally, two public drinking water systems that are not primarily served by the Savannah River but draw from surface water sources were sampled each month (Aiken Public Shaw Creek Water Works Treatment Plant and Breezy Hill Water Treatment Plant). 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).

In 2019, 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

In 2019, DHEC and DOE-SR detected tritium above the lower limit of detection (LLD) in some of the Savannah River-fed systems both upstream and downstream of SRS. These activities are well below the EPA established 20,000 pCi/L drinking water limit (EPA, 2019).

Gamma-emitting radionuclides in the List of Analytes, 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.

Gross alpha, tritium and non-volatile beta sample results are presented in the following tables in Section 3.5.0 and can be found in the 2019 DHEC Data File. All results are below their respective EPA MCLs.

3.3.0 CONCLUSIONS AND RECOMMENDATIONS

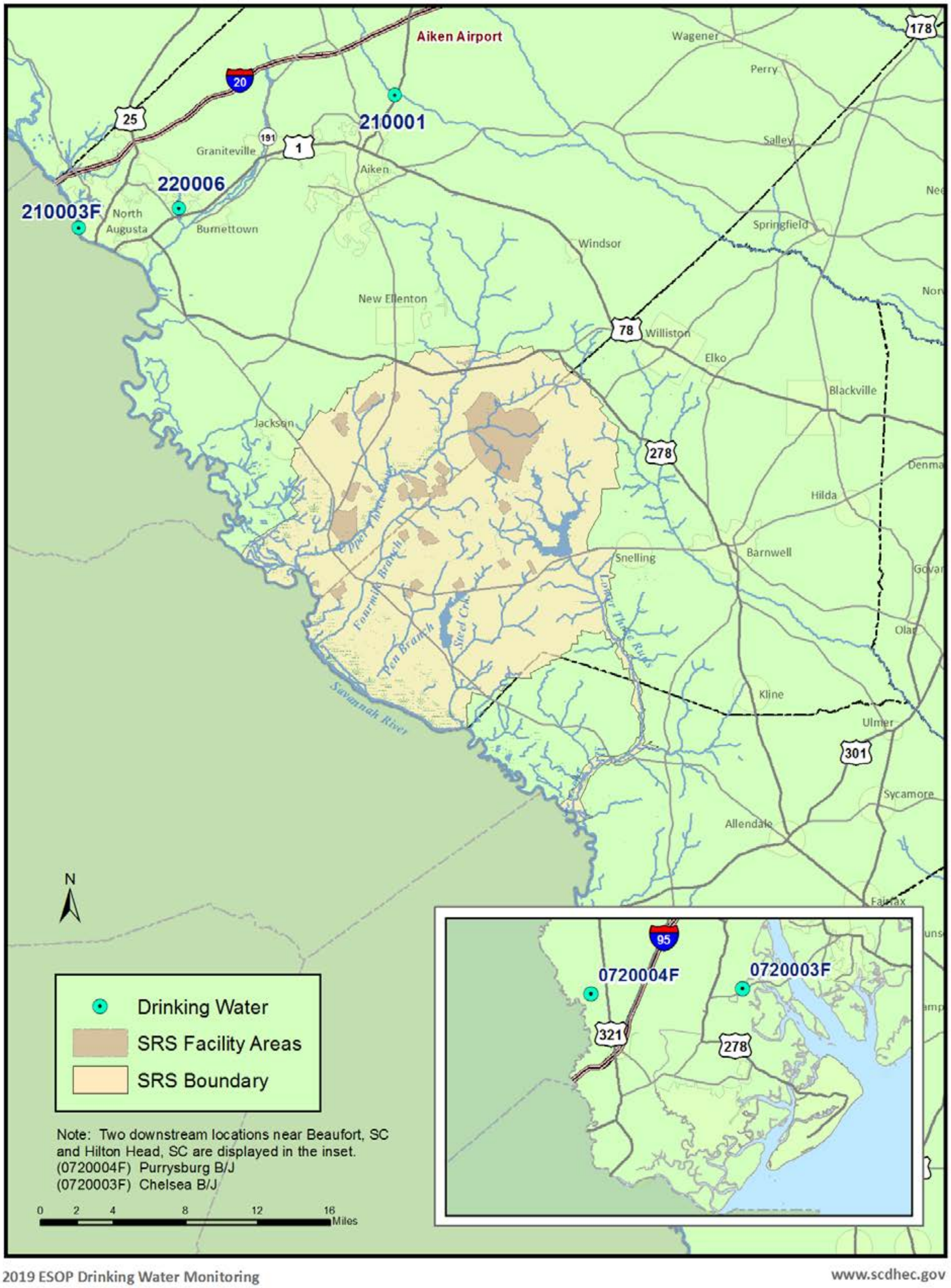
Tritium continues to be the most abundant radionuclide detected in public drinking water supplies potentially impacted by SRS. Observed tritium activities were low when compared to the EPA MCL for tritium in drinking water, which is 20,000 pCi/L. Detections of gross alpha and non-volatile beta were all 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



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
0220006	Breezy Hill Water District	6,871	15,282
0210003F	North Augusta	12,424	27,593
0720003F	Chelsea B/J	55,661	168,036
0720004F	Purrysburg B/J	96	280
	Total		
	Savannah River-fed systems downstream from SRS	55,757	168,316
	Systems not fed from the Savannah River downstream of SRS	38,739	85,161

Notes:
1. Data was obtained from DHEC's Environmental Facility Information System database

Table 2: 2019 DHEC and DOE DW Data for North Augusta (DWO210003F) in pCi/L

Month	DHEC Total Alpha	DHEC Nonvolatile Beta	DHEC Tritium	DOE-SR Total Alpha	DOE-SR Nonvolatile Beta	DOE-SR Tritium
JAN	ND	ND	ND	ND	1.45	ND
FEB	ND	ND	ND	ND	1.74	ND
MAR	ND	ND	ND	ND	1.84	ND
APR	ND	ND	ND	ND	1.85	ND
MAY	ND	ND	ND	ND	1.95	ND
JUN	5.68	ND	ND	ND	1.65	ND
JUL	3.52	ND	ND	ND	1.58	ND
AUG	ND	ND	ND	ND	1.47	ND
SEP	ND	ND	ND	ND	1.67	127
OCT	ND	ND	ND	ND	1.79	ND
NOV	ND	ND	ND	ND	1.79	ND
DEC	ND	ND	ND	ND	2.27	ND

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TABLES AND FIGURES CONT.

Table 3: 2019 DHEC and DOE DW Data for Purrysburg B/J Water Treatment Plant (DW0720004F) in pCi/L

Month	DHEC Total Alpha	DHEC Nonvolatile Beta	DHEC Tritium	DOE-SR Total Alpha	DOE-SR Nonvolatile Beta	DOE-SR Tritium
JAN	ND	ND	ND	ND	2.33	ND
FEB	ND	ND	ND	ND	2.11	ND
MAR	2.07	5.65	452	ND	1.78	ND
APR	ND	ND	398	ND	2.25	248
MAY	ND	ND	292	ND	1.38	ND
JUN	ND	ND	ND	ND	2.18	ND
JUL	ND	ND	309	ND	1.85	257
AUG	ND	ND	309	ND	1.87	410
SEP	ND	ND	257	ND	1.61	177
OCT	ND	ND	ND	ND	1.32	268
NOV	ND	ND	ND	ND	1.57	230
DEC	ND	5.13	ND	ND	1.55	293

Table 4: 2019 DHEC DW Data for Chelsea B/J Water Treatment Plant (DW0720003F) in pCi/L

Month	Total Alpha	Nonvolatile Beta	Tritium
JAN	ND	ND	ND
FEB	11.5	ND	304
MAR	ND	ND	347
APR	ND	ND	415
MAY	ND	ND	289
JUN	ND	ND	ND
JUL	ND	ND	ND
AUG	ND	ND	491
SEP	ND	ND	255
OCT	ND	ND	ND
NOV	ND	ND	ND
DEC	ND	ND	ND

TABLES AND FIGURES CONT.

Table 5: 2019 DHEC DW Data for Aiken Public Shaw Creek Water Works Treatment Plant (DW0210001) in pCi/L

Month	Total Alpha	Nonvolatile Beta	Tritium
JAN	NS	NS	NS
FEB	3.96	ND	377
MAR	2.52	ND	ND
APR	ND	ND	ND
MAY	ND	ND	ND
JUN	ND	ND	ND
JUL	2.09	ND	ND
AUG	ND	ND	ND
SEP	2.25	ND	ND
OCT	ND	ND	259
NOV	ND	ND	ND
DEC	ND	ND	ND

Table 6: 2019 DHEC Raw DW Data for Breezy Hill Water Treatment Plant (DW0220006) in pCi/L

Month	Total Alpha	Nonvolatile Beta	Tritium
JAN	NS	NS	NS
FEB	1.29	ND	ND
MAR	ND	ND	ND
APR	ND	ND	ND
MAY	ND	ND	ND
JUN	ND	ND	ND
JUL	2.03	ND	ND
AUG	ND	ND	ND
SEP	ND	ND	ND
OCT	ND	ND	301
NOV	ND	ND	NS
DEC	ND	ND	ND

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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 that 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 12 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 provide 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 five creek mouths that flow from SRS directly into the Savannah River (Upper Three Runs Creek, Fourmile Branch, Steel Creek Little Hell Boat Landing, 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).

In 2019, the Supplemental Surface Water Monitoring Program was modified from serving as an early detection system for unplanned releases from SRS source term areas to being collected on a monthly basis. Samples from Upper Three Runs, Fourmile Branch, McQueen Branch, and Steel Creek are analyzed for gamma-emitting radionuclides. The McQueen Branch location serves to monitor the Saltstone low-level waste operations and is a monthly composite that is collected by DOE and split with DHEC. Along with the changes DHEC made in 2019, Steel Creek (SV-2052) is now being sampled on a weekly basis and analyzed for tritium.

Example of a Composite Sample

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 at Road C (SV-2044) 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 2019 DHEC Data File.

The data presented in this section concerns DHEC's monitoring of SRS's ambient and on-site streams. Enhanced 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.

Example of a Grab Sample

DHEC data from 2019 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 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.

<u>Tritium</u>

In 2019, 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 (SV-2039) and Pen Branch (SV-2047) have the highest average tritium activity of all SRS streams. The 2019 DHEC and DOE-SR tritium results appear to be consistent with

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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 first quarter in 2019, 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 8593 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 Analytes, Table 1, page ix). DHEC had one location with an average above the minimum detectable activity (MDA) for Cs-137: Fourmile Branch at Road C (SV-2044) with an average of 3.50 pCi/L. All other gamma results were below the MDA. There were two single detections of Am-241 at the DOE-SR collocated sites of Pens Branch and Steel Creek at Road A with an average of 0.010 pCi/L. Pu-238, U-234, U-235, and U-238 were detected in DOE-SR samples but are considered NORM.

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 at Road C (SV-2044) were monitored on a quarterly basis by DHEC. All of the four quarterly I-129 samples had a detection above the MDA with an average of 0.67 pCi/L. All of the quarterly samples had Tc-99 detected with an average of 2.58 pCi/L. DOE-SR reported single detections of I-129 (Tims Branch - 2.65 pCi/L) and Tc-99 (Steel Creek at Road A - 2.29 pCi/L). However, since DHEC and DOE-SR do not have collocated sampling sites for I-129 and Tc-99, these results are not comparable to DHEC's SV-2044 location.

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, 2019).

Alpha

In 2019, alpha-emitting radionuclides were detected at six 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's Pen Branch sample exhibited the highest alpha activity of the collocated locations with an average of 9.83 pCi/L, whereas DOE-SR's sample at Tim Branch had the highest alpha activity with an average of 8.20 pCi/L (Section 4.5.0, Table 3, SRNS, 2020).

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

Historically, Upper Three Runs Creek at SC 125 (SV-325) yields detections for alpha activity (DHEC, 2016-2019). Isotopic analysis performed by DOE-SR revealed the source to be natural uranium (SRNS, 2013). This may contribute to the common occurrence of alpha detections at this location. The 2019 average alpha activity of 3.01 pCi/L at DHEC's SV-325 was below the EPA MCL for drinking water of 15 pCi/L (EPA, 2019). 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 reduced by salts and solids dried onto a sampling planchet (Floeckher, 2000). Pump tubing is evaluated during each sample collection at all locations to ensure no blockage of sediment has occurred.

<u>Beta</u>

Beta-emitting radionuclide activity was detected in six of nine locations where monthly composite samples were collected. DHEC detected gross beta activity at five of the seven collocated sampling locations while DOE-SR detected activity at all of the collocated locations (Section 4.5.0, Table 4). The samples exhibiting the highest average gross beta activity were Fourmile Branch at Rd. 12.2 (SV-2039) with an average of 5.56 pCi/L (DHEC) and Tims Branch with an average of 4.52 pCi/L (DOE-SR) (SRNS, 2020). DOE-SR also reported a single detection of Sr-89/90 at Fourmile Branch Rd. 12.2 (1.06 pCi/L) and River Mile 141.5 - Steel Creek Mouth (0.57 pCi/L) (SRNS, 2020).

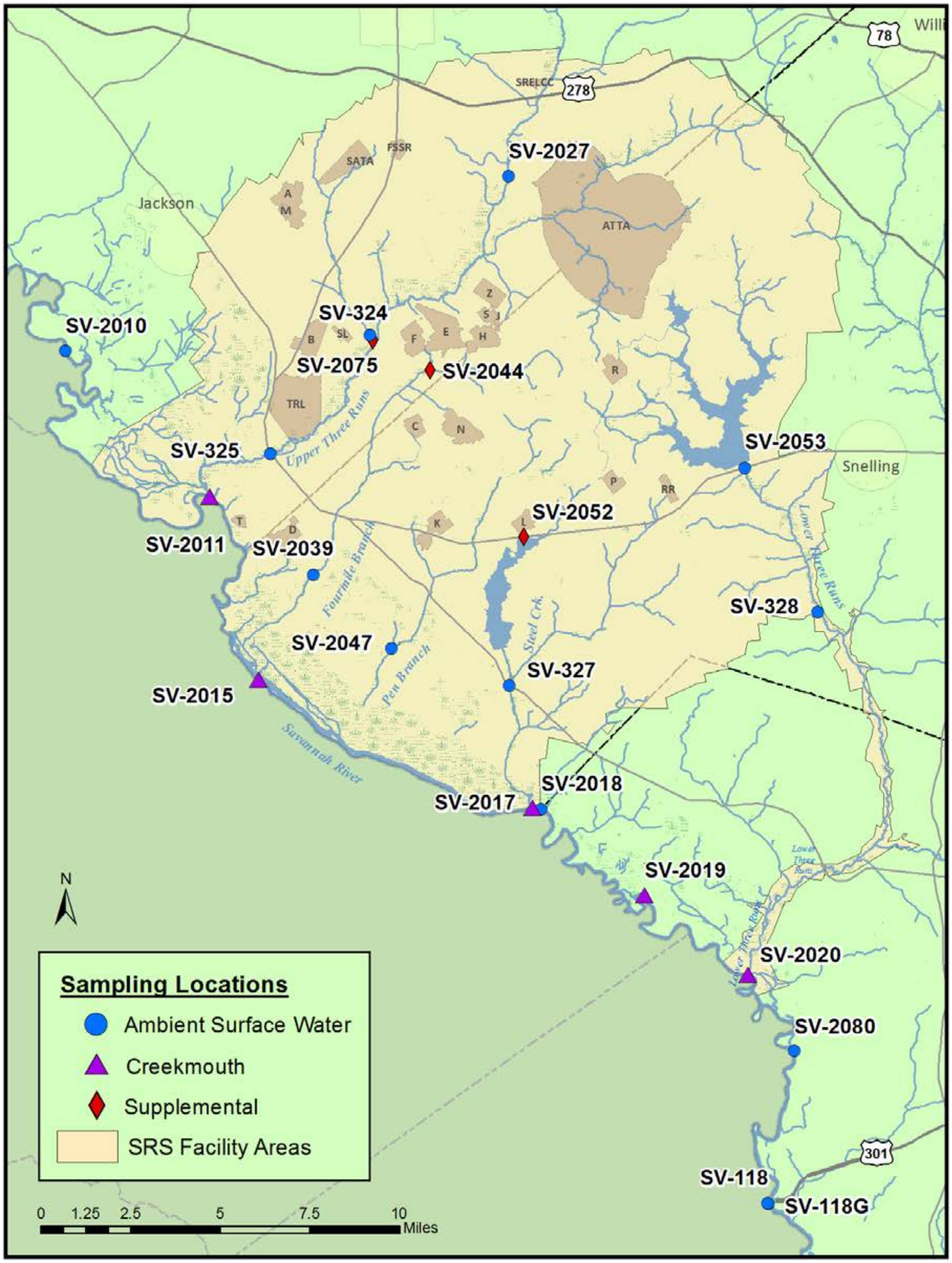
EPA has established a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The EPA screening MCL for gross beta-emitting particles for drinking water systems is 50 pCi/L minus natural potassium-40 (K-40) (EPA, 2019). All averages were below this limit.

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 changed 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



2019 ESOP Radiological Surface Water Monitoring www.scdhec.gov

4.5.0 TABLES AND FIGURES

Table 1. 2019 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 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-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

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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-2019[a]	Savannah River at RM 134.5 (Little Hell Boat Landing)	Accessible to the public; Downstream of SRS operations and tributaries; River 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	Monthly gamma composite
SV-2044*	Fourmile Branch at Road C	Downstream from F-and H-Areas HLW I Tanks	Monthly gamma composite
SV-2052*	Steel Creek at the top of L-Lake	Downstream from P- and L- Areas	Weekly tritium, Monthly 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
6. * Indicates a location that is collocated with DOE sampling
7. [a] Indicates that SV-2019 is not a creek mouth; however, it is included in this chart as it is a boat landing that has water collected and analyzed for tritium on a quarterly basis.

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Table 2. 2019 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	368	81	365	232	556	42	51
	TB-5	368	NA	368	368	368	1	11
Upper Three Runs Creek at Road A	SV-325	773	356	681	317	1977	52	52
	U3R-4	593	159	621	365	889	10	12
Fourmile Branch at Road 12.2	SV-2039	27475	3744	27686	18106	35231	51	52
	FM-6	24083	2234	24200	20600	26600	12	12
Pen Branch at Road A-13.2	SV-2047	12683	4171	12731	5357	24396	51	52
	PB-3	10520	3101	10480	5890	15200	12	12
Steel Creek at Road A	SV-327	1950	384	1930	1205	2787	52	52
	SC-4	1653	295	1685	1200	2000	12	12
Highway 301 Bridge at RM 118.8	SV-118	1950	384	1930	1205	2787	52	52
	RM 118	264	118	222	123	605	47	52
Lower Three Runs Creek at Road B	SV-2053	344	192	284	226	949	19	52
	L3R-1A	408	NA	408	408	408	1	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 2019 (SRNS, 2020)
3. ND is Not Detected
4. NA is Not Applicable

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TABLES AND FIGURES

Table 3. 2019 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	3.33	1.70	2.97	2.12	7.03	7	11
	TB-5	8.20	8.16	5.43	1.54	28.10	11	12
Upper Three Runs Creek at Road A	SV-325	3.01	1.25	2.87	1.51	4.70	7	12
	U3R-4	4.06	2.52	3.34	0.53	9.14	12	12
Fourmile Branch at Road 12.2	SV-2039	ND	NA	NA	<LLD	<LLD	0	12
	FM-6	1.07	1.32	0.49	0.26	4.76	12	12
Pen Branch at Road A-13.2	SV-2047	9.83	3.64	9.83	7.25	12.40	2	12
	PB-3	1.79	1.00	1.99	0.37	3.22	9	12
Steel Creek at Road A	SV-327	ND	NA	NA	<LLD	<LLD	0	12
	SC-4	0.85	0.71	0.48	0.28	2.18	10	12
Highway 301 Bridge at RM 118.8	SV-118	2.01	NA	2.01	2.01	2.01	1	12
	RM 118	0.39	0.17	0.34	0.21	0.71	10	52
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	<LLD	<LLD	0	12
	L3R-1A	1.32	1.93	0.56	0.31	4.76	5	11

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 2019 (SRNS, 2020)
3). ND is Not Detected
4). NA is Not Applicable

TABLES AND FIGURES

Table 4. 2019 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	3.46	NA	3.46	3.46	3.46	1	11
	TB-5	4.52	3.85	3.24	1.18	13.70	11	11
Upper Three Runs Creek at Road A	SV-325	3.88	NA	3.88	3.88	3.88	1	12
	U3R-4	2.62	1.44	2.50	0.90	5.22	12	12
Fourmile Branch at Road 12.2	SV-2039	5.56	1.41	5.58	3.81	7.27	4	12
	FM-6	3.93	1.54	3.39	2.65	8.05	12	12
Pen Branch at Road A-13.2	SV-2047	ND	NA	NA	<LLD	<LLD	0	12
	PB-3	1.66	0.97	1.85	0.59	3.14	11	12
Steel Creek at Road A	SV-327	5.07	3.01	5.07	2.94	7.19	2	12
	SC-4	1.53	0.76	1.28	0.74	3.49	12	12
Highway 301 Bridge at RM 118.8	SV-118	4.21	1.39	4.04	2.74	4.42	4	12
	RM 118	1.86	0.33	1.85	1.21	2.58	52	52
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	<LLD	<LLD	0	12
	L3R-1A	1.54	1.23	1.04	0.76	5.14	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 2019 (SRNS, 2020)
3). ND is Not Detected
4). NA is Not Applicable

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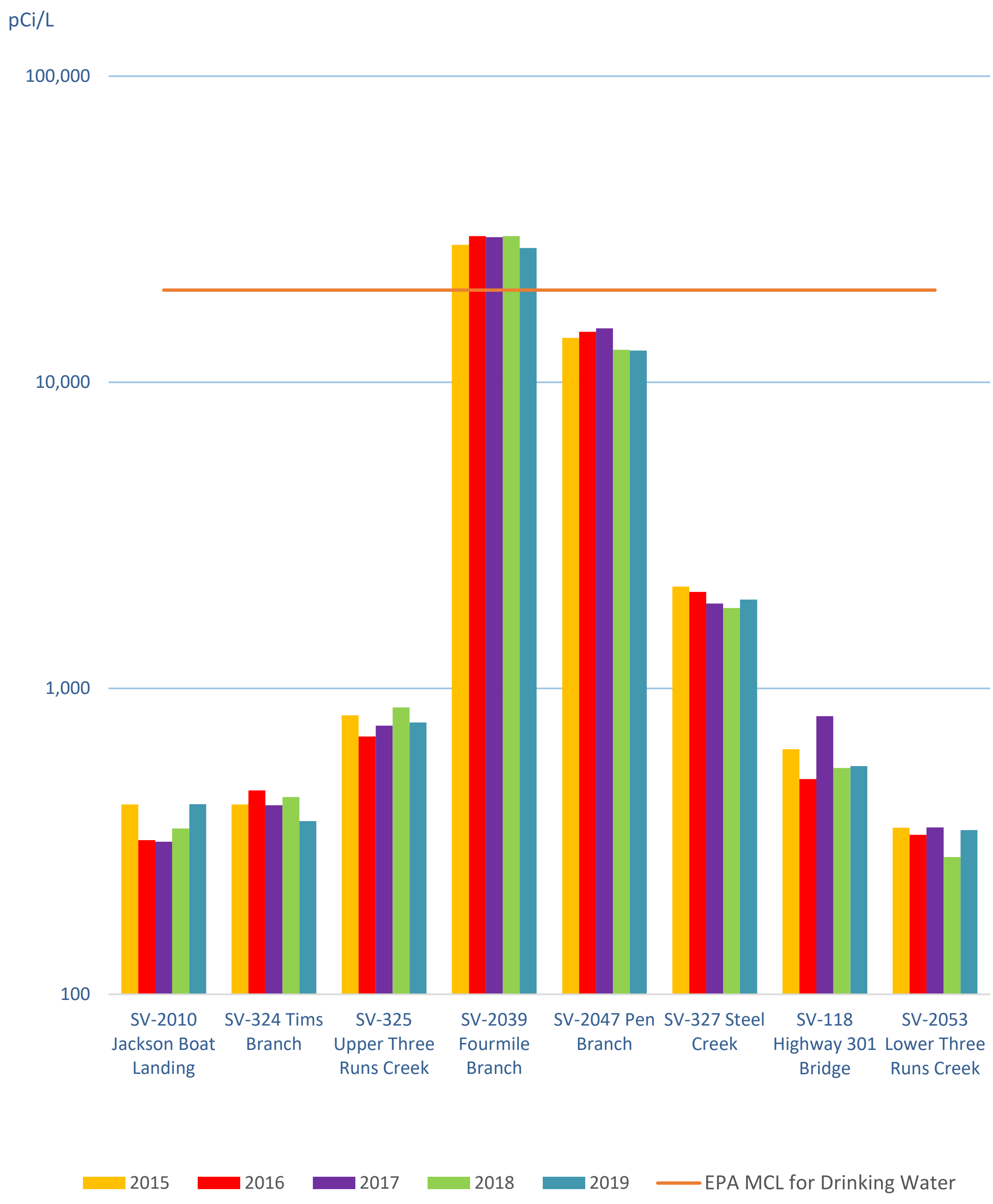
TABLES AND FIGURES

Figure 1. DHEC Average Tritium Data Trends for 2015-2019 (DHEC, 2016-2019)



TABLES AND FIGURES

Figure 2. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for Upper Three Runs Creek at S.C. Highway 125 (SRNS, 2016a-2020; DHEC, 2016-2019)

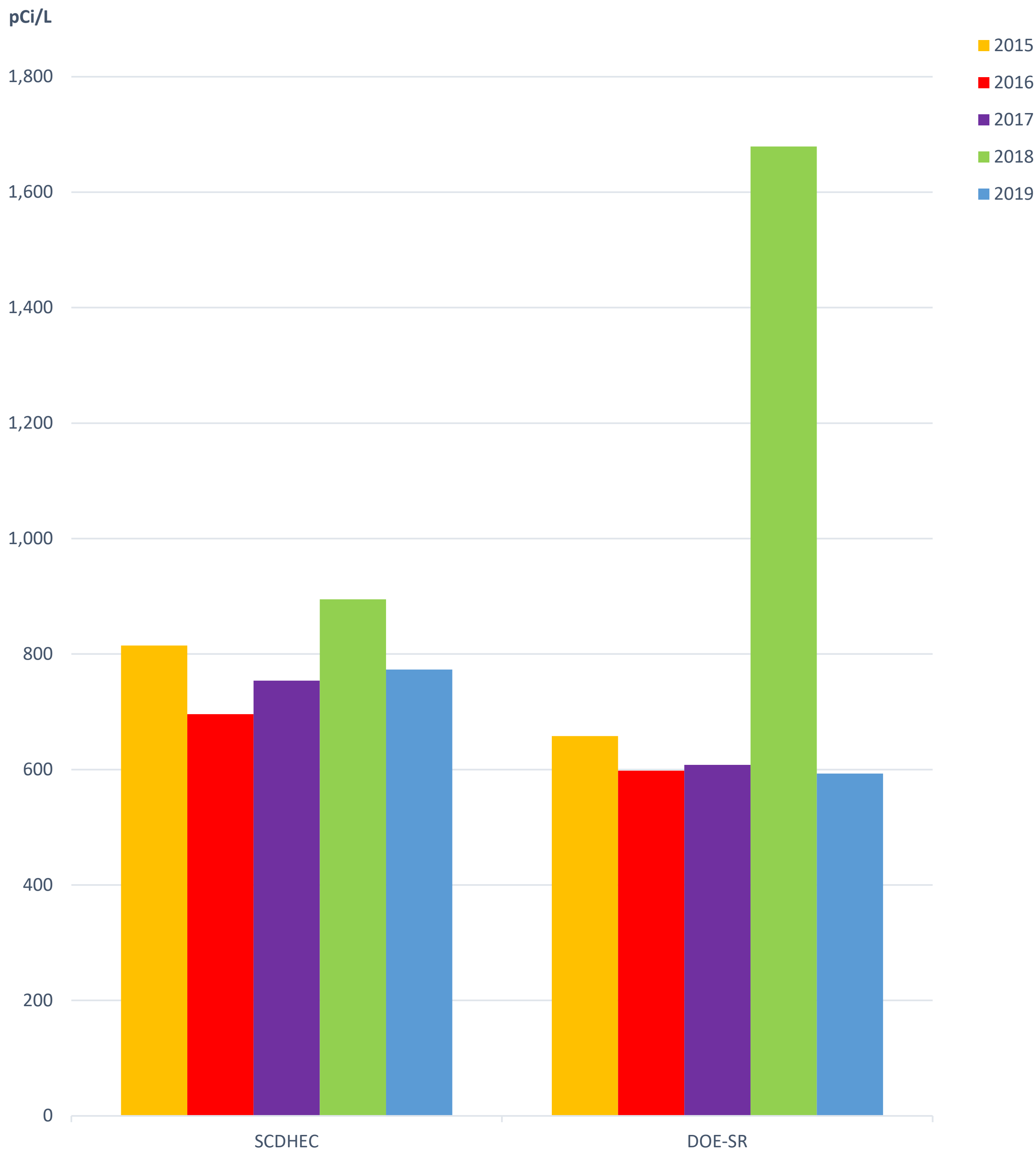


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Figure 3. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for Fourmile Branch at Road 12.2 (SRNS, 2016a-2020; DHEC, 2016-2019)

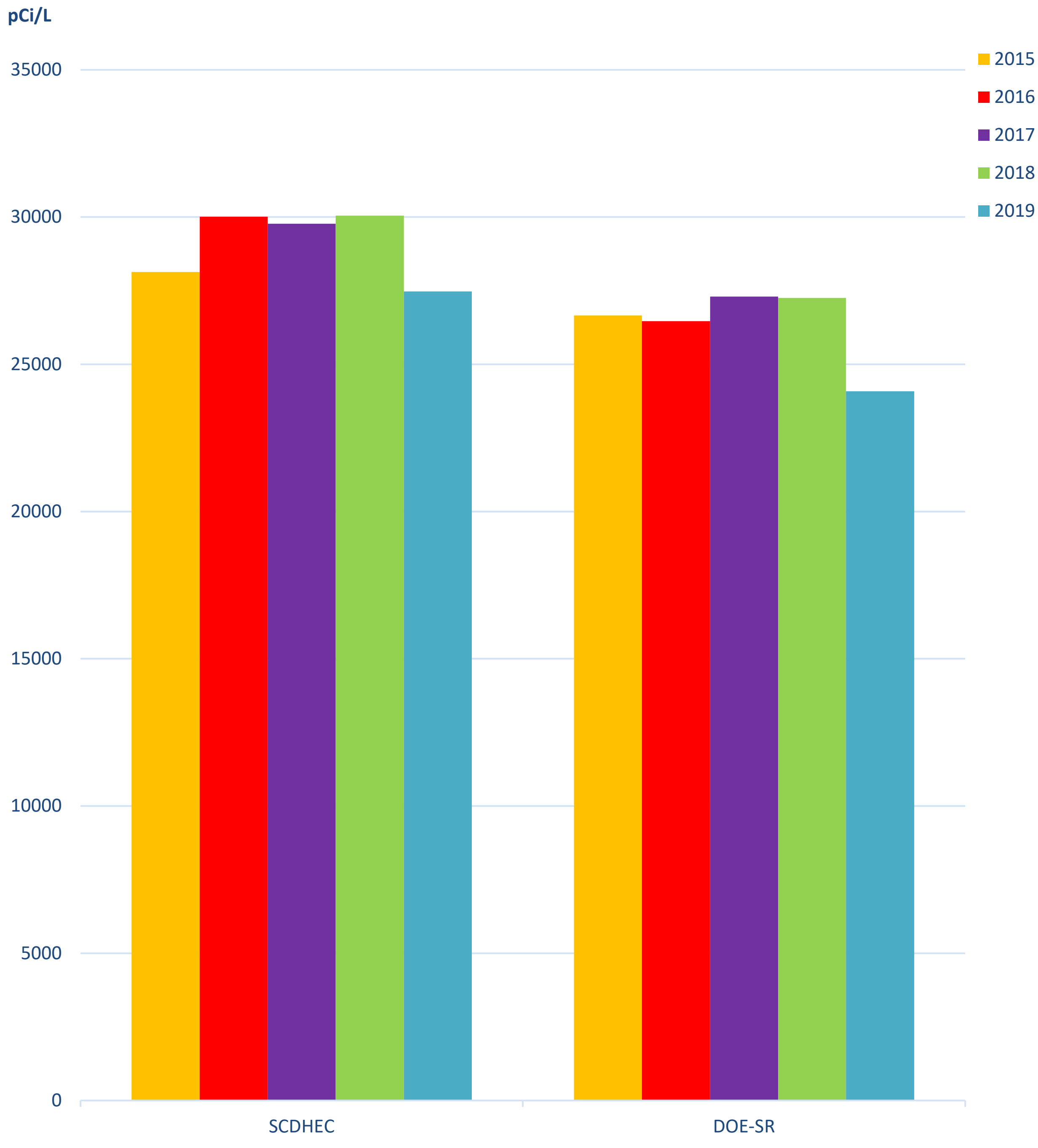

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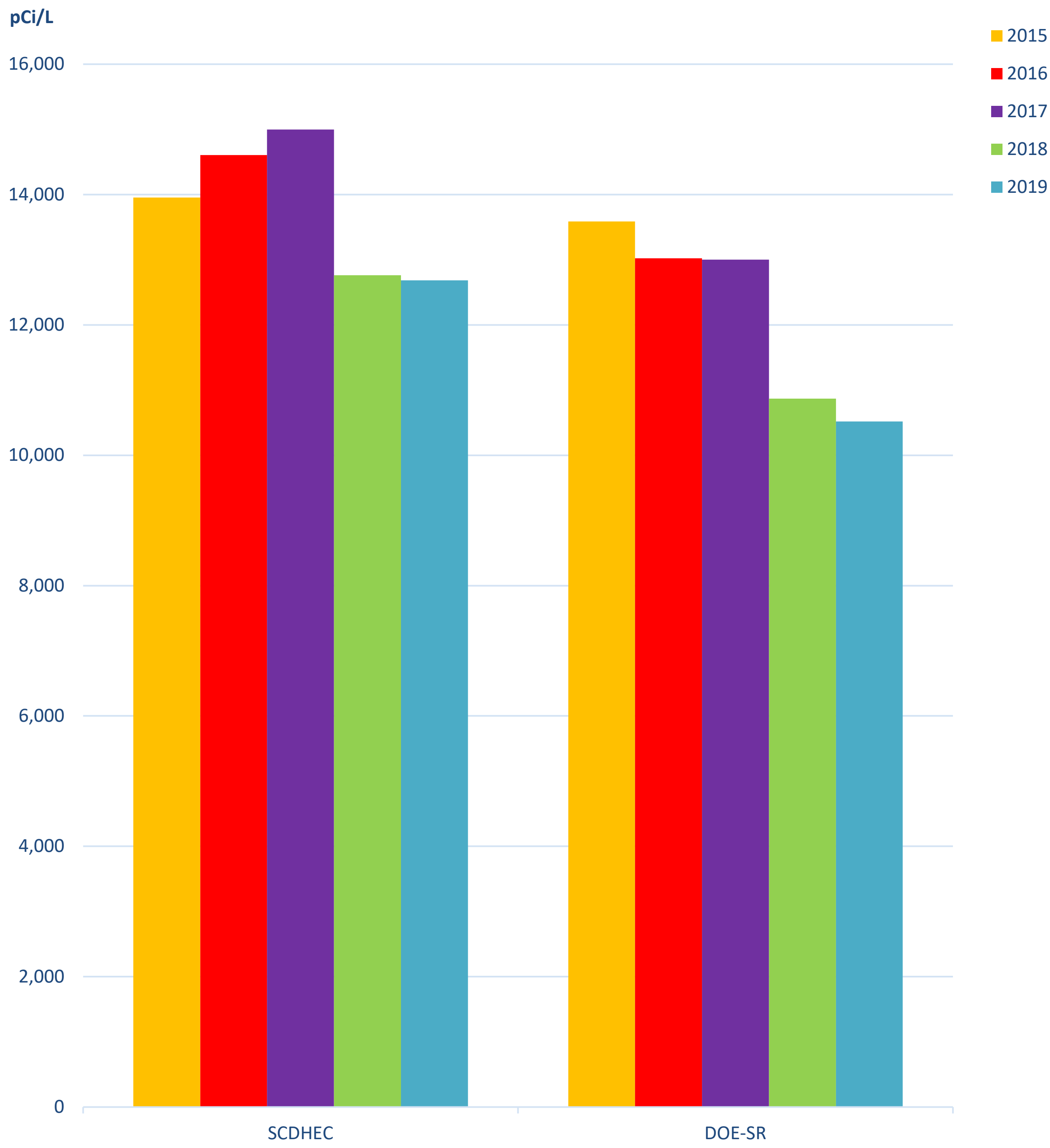
Figure 4. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for Pen Branch at Road A-13.2 (SRNS, 2016a-2020; DHEC, 2016-2019)



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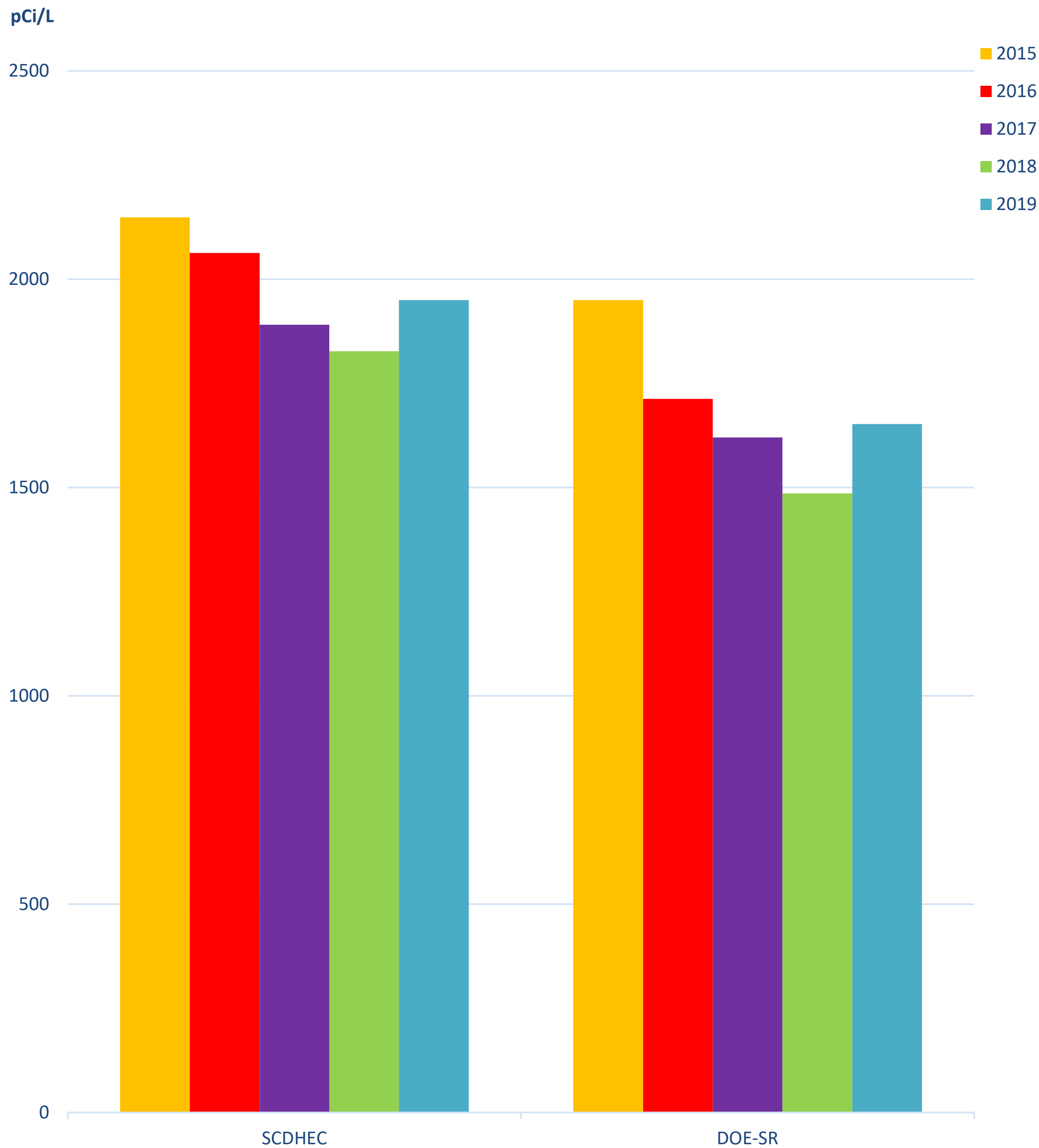
TABLES AND FIGURES

Figure 5. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for Steel Creek at S.C. Highway 125 (SRNS, 2016a-2020; DHEC, 2016-2019)



TABLES AND FIGURES

Figure 6. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for Lower Three Runs Creek at SRS Road B (SRNS, 2016a-2020; DHEC, 2016-2019)

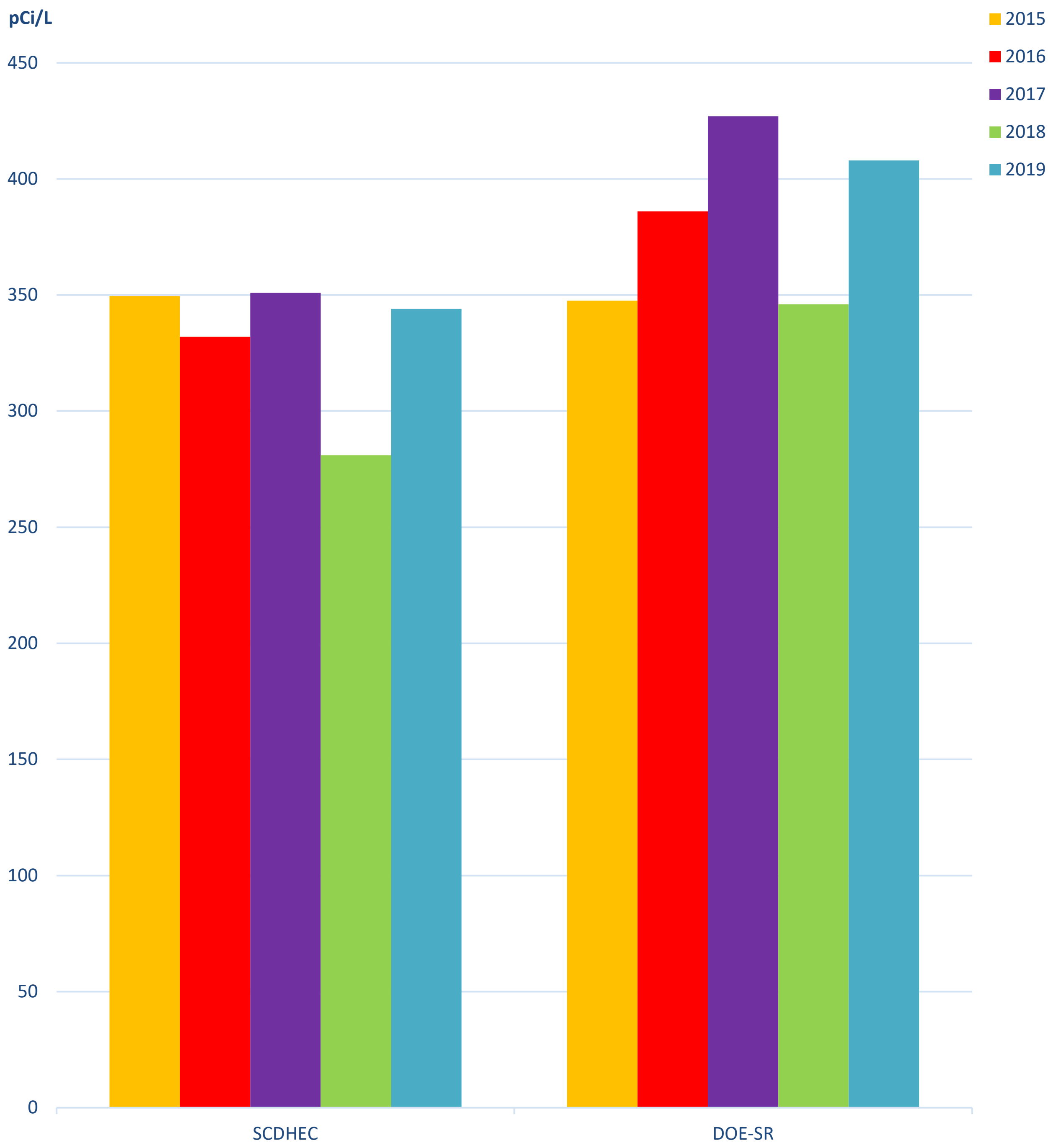


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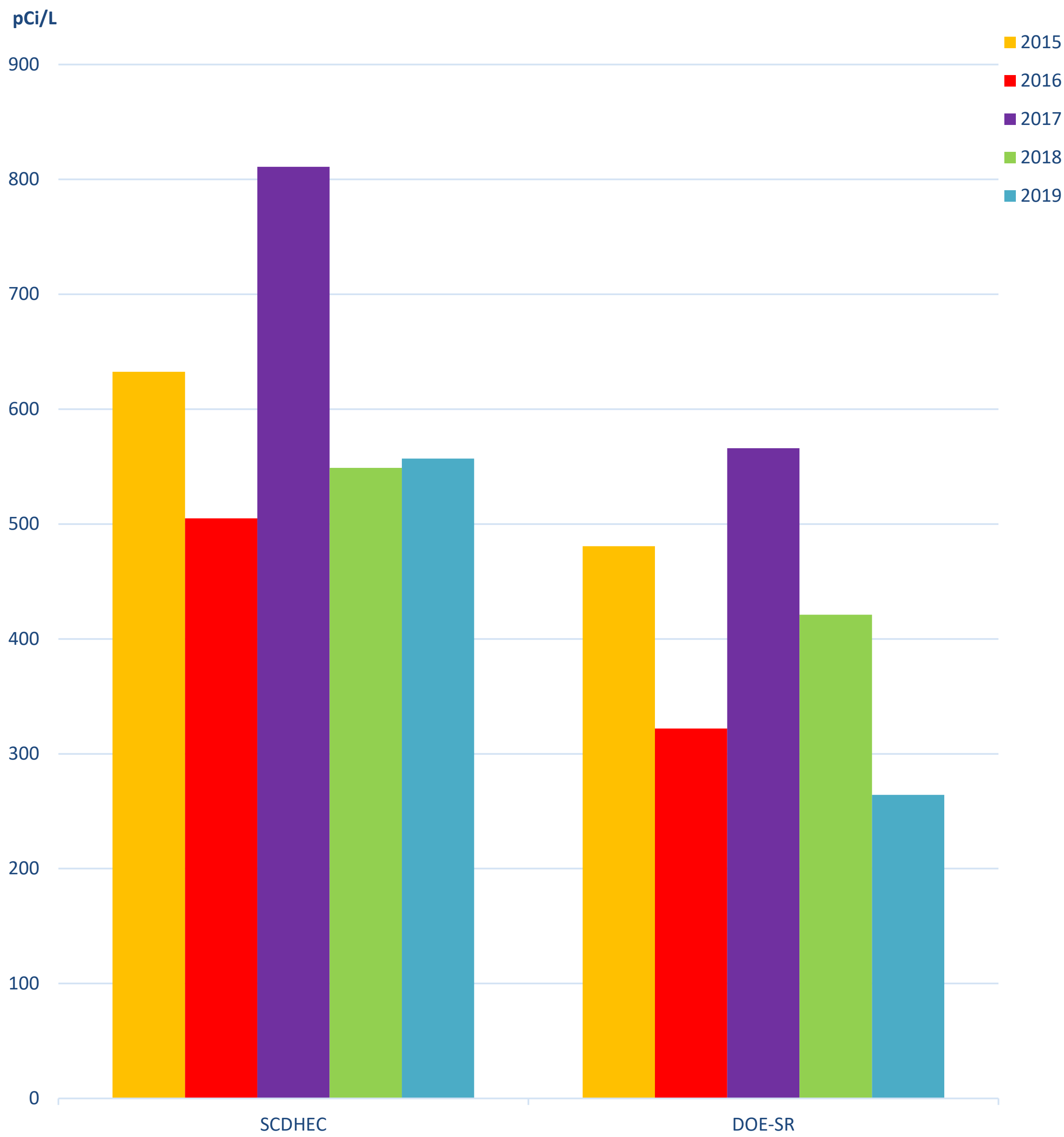
Figure 7. 2015-2019 Average Tritium Data Trends for DHEC and DOE-SR for the Savannah River at US Highway 301 Bridge (SRNS, 2016a-2020; DHEC, 2016-2019)



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4.6.0 SUMMARY STATISTICS

2019 DHEC Ambient Monitoring Data-Tritium in pCi/L

Sample Location	Average Concentration	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detections	Number of Samples
Jackson Boat Landing (SV-2010)	418	288	259	139	1040	11	52
Tims Branch (SV-324)*	368	81	365	232	556	42	51
Upper Three Runs Creek at SC 125 (SV-325)*	773	356	681	317	1977	52	52
Fourmile Branch (SV-2039)*	27475	3744	27686	18106	35231	51	52
Pen Branch (SV-2047)*	12683	4171	12731	5357	24396	51	52
Steel Creek (SV-327)*	1950	384	1930	1205	2787	52	52
Steel Creek Boat Landing (SV-2018)	1346	1548	484	235	5852	37	52
Highway 301 Bridge (SV-118)*	557	579	375	251	3494	32	52
Lower Three Runs Creek at Patterson Mill Rd. (SV-328)	1530	611	1424	273	3162	51	52
L-Lake Spill Way (SV-2052)*	261	24	256	226	308	19	52
Lower Three Runs Creek at Road B (SV-2053)*	344	192	284	226	949	19	52
Upper Three Runs Creek at SRS Road 2-1 (SV-2027)	283	42	282	243	325	4	52
Creek Mouths	**Average Concentration**	**Standard Deviation**	**Median**	**Minimum Detect**	**Maximum Detect**	**Number of Detects**	**Number of Samples**
Upper Three Runs Mouth @ RM 157.4 (SV-2011)	499	147	478	364	656	3	3
Four Mile Creek @ RM 150.6 (SV-2015)	8593	NA	8593	8593	8593	1	3
Steel Creek Mouth @ RM 141.5 (SV-2017)	1295	1043	1295	558	2033	2	3
Lower Three Runs Mouth @ RM 129.1 (SV-2020)	685	541	685	303	1068	2	3
Little Hell Boat Landing (SV-2019)	404	87	404	343	466	2	4

Note: In 2019, due to flooded rivers and safety concerns a fourth sample was not able to be taken for creek mouths. However, as SV-2019 was being transitioned from an ambient to creek mouth location in 2019, it had an additional sample collected as a grab in January which caused it to be the exception with four samples. Also, * indicates locations that are collocated with DOE-SR sampling sites.

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SUMMARY STATISTICS

2019 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)	3.22	NA	3.22	3.22	3.22	1	12
Tims Branch (SV-324)	3.33	1.70	2.97	2.12	7.03	7	11
Upper Three Runs Creek at S.C. 125 (SV-325)	3.01	1.25	2.87	1.51	4.70	7	12
Fourmile Branch (SV-2039)	ND	NA	NA	<LLD	<LLD	0	12
Pen Branch (SV-2047)	9.83	3.64	9.83	7.25	12.40	2	12
Steel Creek (SV-327)	ND	NA	NA	<LLD	<LLD	0	12
Steel Creek Boat Landing (SV-2018)	3.87	NA	3.87	3.87	3.87	1	12
Highway 301 Bridge (SV-118)	2.01	NA	2.01	2.01	2.01	1	12
Lower Three Runs Creek at Road B (SV-2053)	ND	NA	NA	<LLD	<LLD	0	12

2019 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	<LLD	<LLD	0	12
Tims Branch (SV-324)	3.46	NA	3.46	3.46	3.46	1	11
Upper Three Runs Creek at S.C. 125 (SV-325)	3.88	NA	3.88	3.88	3.88	1	12
Fourmile Branch (SV-2039)	5.56	1.41	5.58	3.81	7.27	4	12
Pen Branch (SV-2047)	ND	NA	NA	<LLD	<LLD	0	12
Steel Creek (SV-327)	5.07	3.01	5.07	2.94	7.19	2	12
Steel Creek Boat Landing (SV-2018)	5.70	NA	5.70	5.70	5.70	1	12
Highway 301 Bridge (SV-118)	4.21	1.39	4.04	2.74	4.42	4	12
Lower Three Runs Creek at Road B (SV-2053)	ND	NA	NA	<LLD	<LLD	0	12

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Chapter 5 Non-radiological Monitoring of Surface Water on SRS

5.1.0 PROJECT SUMMARY

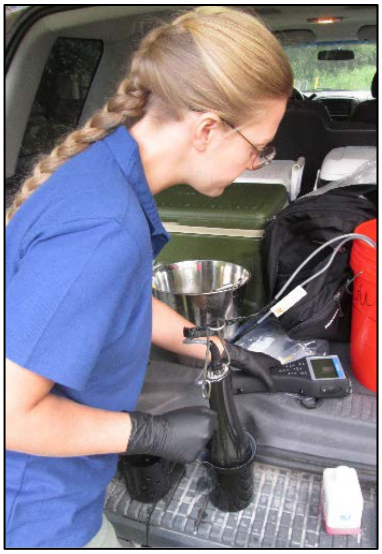
The streams located on SRS receive a wide variety of permitted point source discharges and non-point source run-off from on-site facilities and operations. These discharges specifically include, but are not limited to, industrial storm water, utility water, treated industrial and sanitary wastewater, 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 2019 at SRS by sampling the on-site streams for inorganic and organic constituents. 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 2019 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 blackwater. A blackwater 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 blackwater 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 5.82, Upper Three Runs at Road A (NWSV-325) with a pH average of 5.84, and Upper Three Runs at Road 2-1 (NWSV-2027) with an average pH of 5.55. All of these streams are blackwater 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, 2020).

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 2019. A DO comparison of DHEC and DOE-SR data for collocated samples can be found in Section 5.5.0, Figure 2 (SRNS, 2020). There are no numeric criteria in the South Carolina freshwater standards for a maximum BOD level; however, in 2019, DHEC samples had no detections above the LLD of 2.0 mg/L except for SV-325 which had one sample at 4.40 mg/L. DOE-SR did not collect BOD samples in 2019, 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 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 and did not exceed the maximum of 32.2°C.

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).

Drawing up creek water for testing

In 2019, some of 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 2019; therefore, no comparison can be made.

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 2019. DOE-SR did not sample for turbidity in 2019, 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, 2020).

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 (DHEC, 2014b). Two locations had a yearly average above the standard (SV-2047 with 349.7 MPN/100 mL and SV-2055 with 429.6 MPN/100 mL). DOE-SR did not collect samples for *E. coli* in 2019, 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 2019, 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 total phosphorus, TKN, or ammonia.

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 (DHEC, 2014b). 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 2019; 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 2019, DHEC personnel collected samples for the following metals: beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, thallium, 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, magnesium, and manganese, have numeric criteria for the protection of human health and aquatic life in the South Carolina freshwater quality standards.

DHEC and DOE-SR detected iron and manganese in all the collocated sample locations. See Section 5.5.0, Figure 6 for an iron and Figure 7 for a manganese comparison of DHEC and DOE-SR data for collocated samples (SRNS, 2020). DHEC did have detections of iron above 1 mg/L at Tims Branch with a yearly average of 2.4 mg/L. Tims Branch has several groundwater seeps that contribute to relatively low flow, and naturally occurring processes that could cause elevated iron levels at this location. All DHEC manganese sample results were within the levels seen in the Savannah River Basin (DHEC, 2013b). DHEC had detects of magnesium; however, DOE-SR does not test samples for magnesium, so comparisons were not made.

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. DOE-SR detected cadmium above the standard at one of the collocated sample locations in 2019 (SRNS, 2020).

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). DHEC did not detect chromium or nickel in 2019. Due to copper's standard of 0.0029 mg/L being lower than the DHEC laboratory's limit of detection of <0.010 mg/L, all samples were found to be <0.010 mg/L and were considered to be non-detects. DOE-SR detected chromium, copper, and nickel in their collocated sample locations, but the averages did not exceed the standards (SRNS, 2020).

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 locations with average lead detections above the standard in 2019 in the collocated samples; however, individual samples for Tims Branch, Steel Creek, Lower Three Runs, and Pen Branch had detects above the standard (SRNS, 2020).

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 2019. DOE-SR detected mercury at two of the collocated sampling locations, but not in exceedance of the standard (SRNS, 2020).

The freshwater quality standard for zinc in South Carolina streams is not to exceed 0.037 mg/L (DHEC, 2014b). All of DHEC's locations had samples over the standard in 2019, while DOE-SR had all locations' averages below the zinc standard (Lower Three Runs had two individual samples above the standard at 0.046 mg/L and 0.044 mg/L) (SRNS, 2020). A zinc comparison of DHEC and DOE-SR yearly averages for collocated samples can be found in Section 5.5.0, Figure 8.

Samples were also analyzed for beryllium and thallium whose freshwater quality standards are <0.004 mg/L and <0.00024 mg/L, respectively. DHEC had no detects of either of these metals in 2019. DOE-SR had detects above the standard for thallium in four collocated samples and had two detects of beryllium that were not above the standard (SRNS, 2020).

Due to multiple years of having no detects of VOC, PCB, or pesticide contaminants, DHEC discontinued performing analyses for these parameters in 2019.

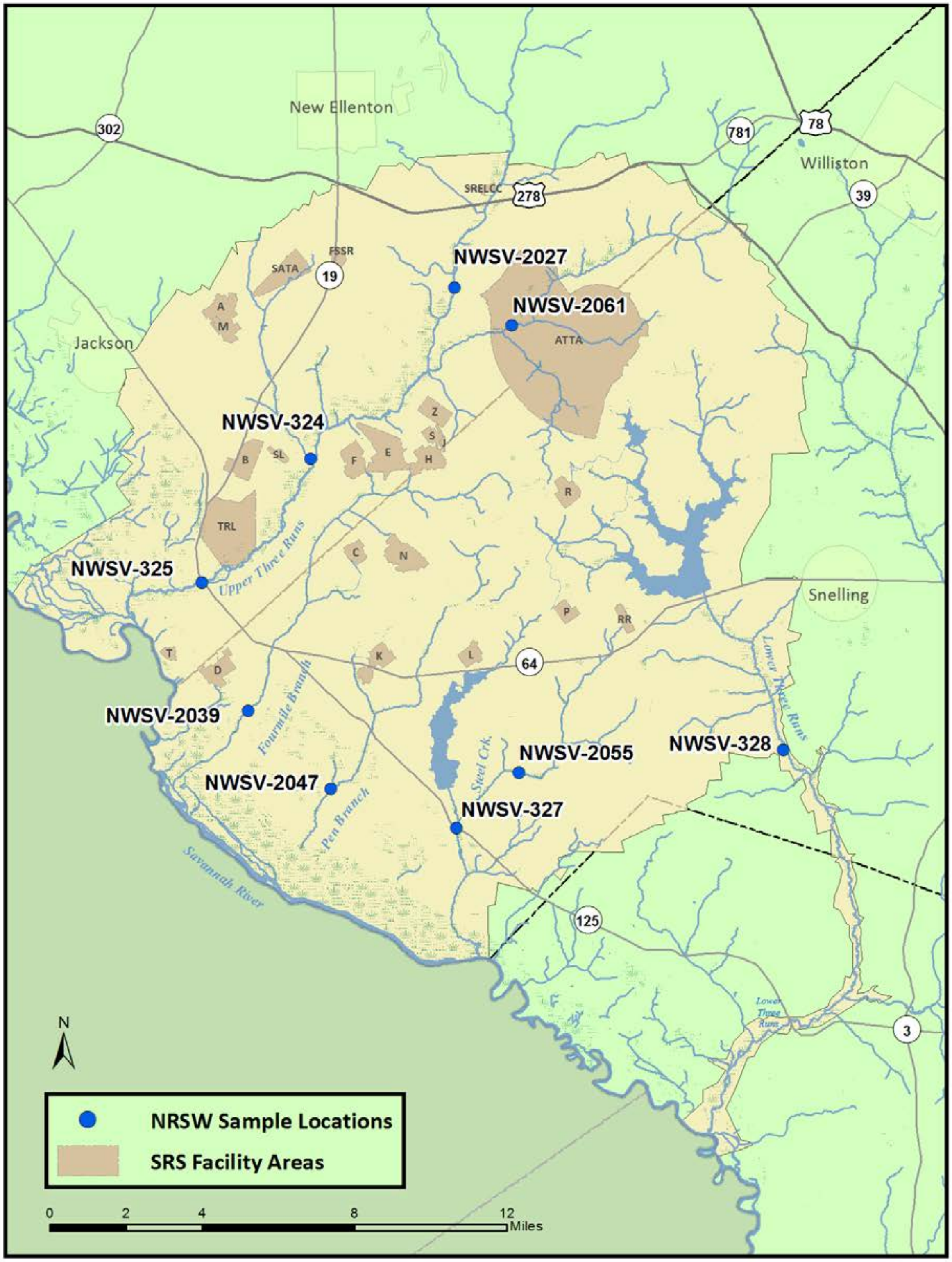
Small discrepancies in data between DOE-SR and DHEC may be attributed to differences in sample collection date and time, sample preservation, and lab analysis. Variances in statistical calculations, such as the yearly averages, may also attribute to dissimilarities. All data less than the LLD were left 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 2019 compared favorably with the South Carolina Freshwaters Standard or other recommendations for the parameters and monitored locations. The 2019 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



2019 ESOP Non-Radiological Surface Water Monitoring

www.scdhec.gov

5.5.0 TABLES AND FIGURES

Table 1. 2019 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 12.2	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. 2019 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

TABLES AND FIGURES

Figure 1. pH 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)

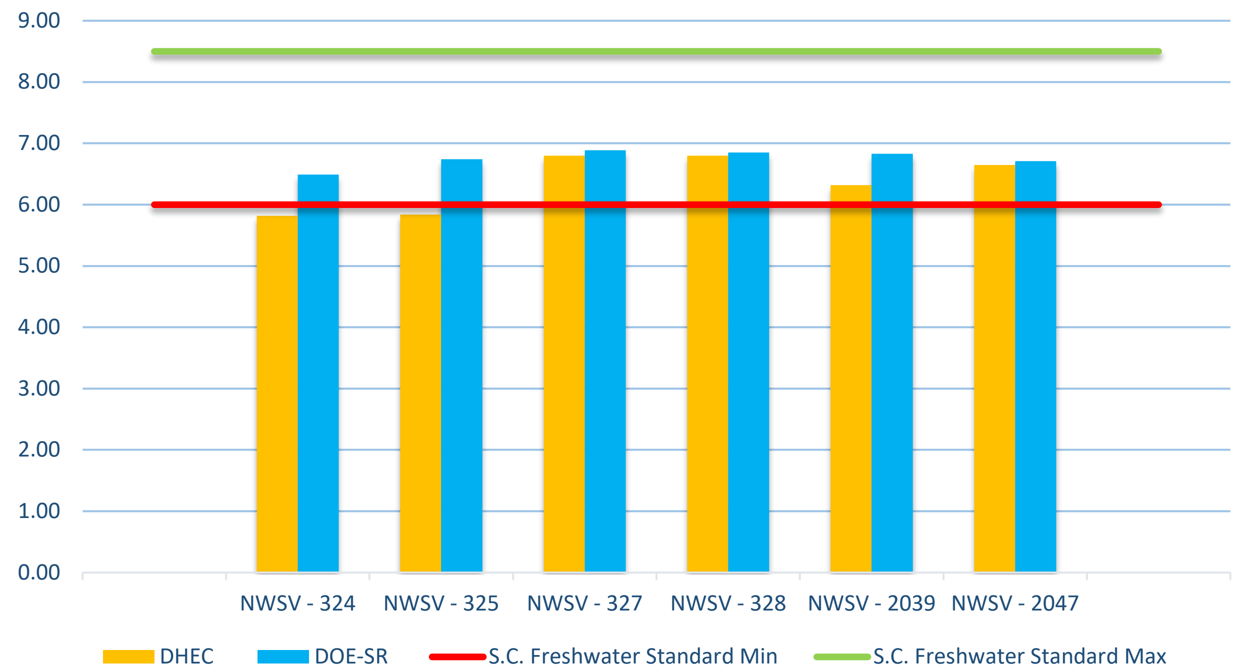
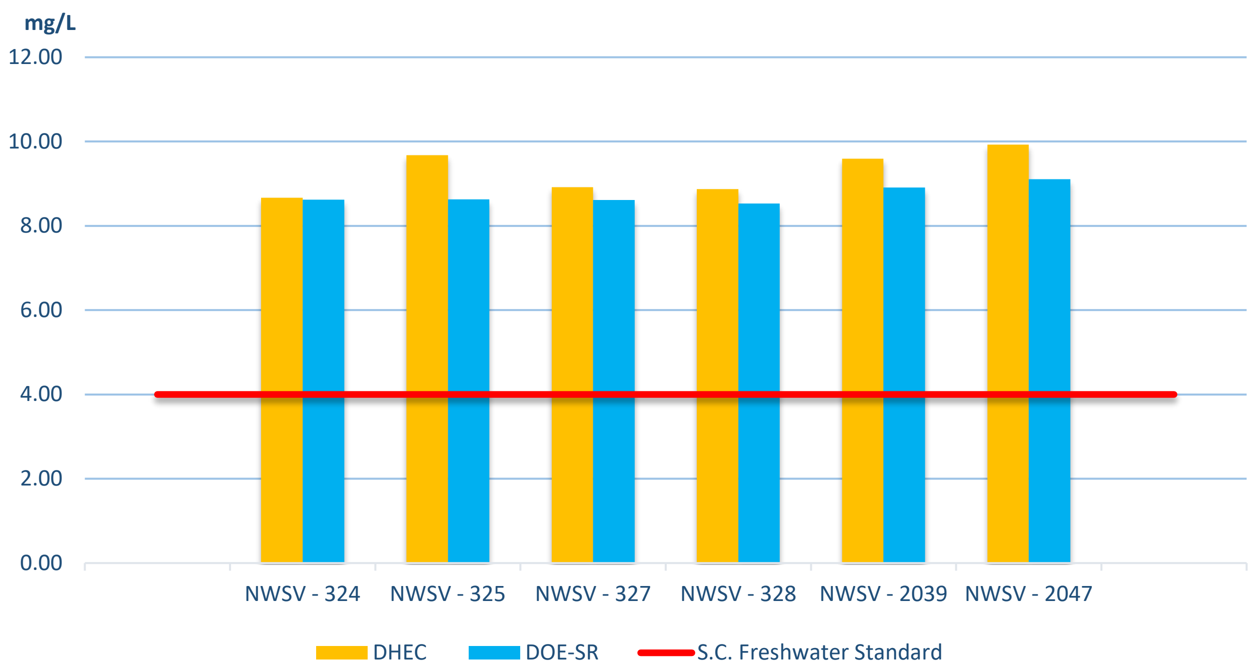


Figure 2. DO 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)



TABLES AND FIGURES

Figure 3. TSS 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)

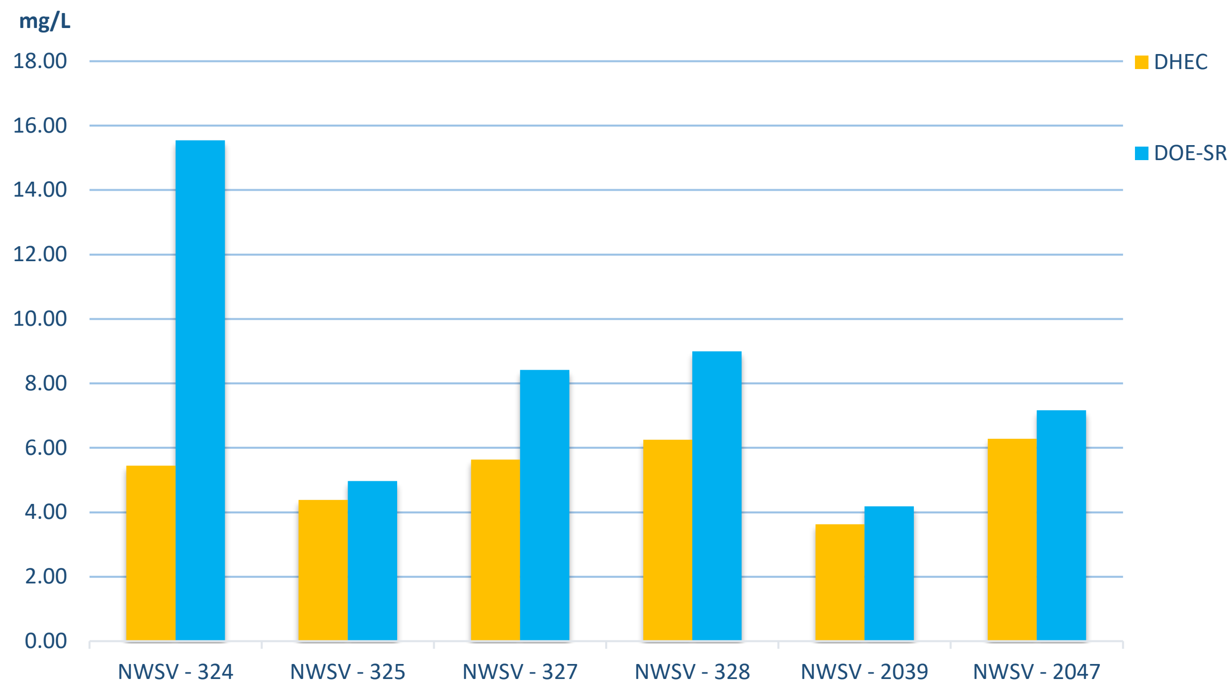
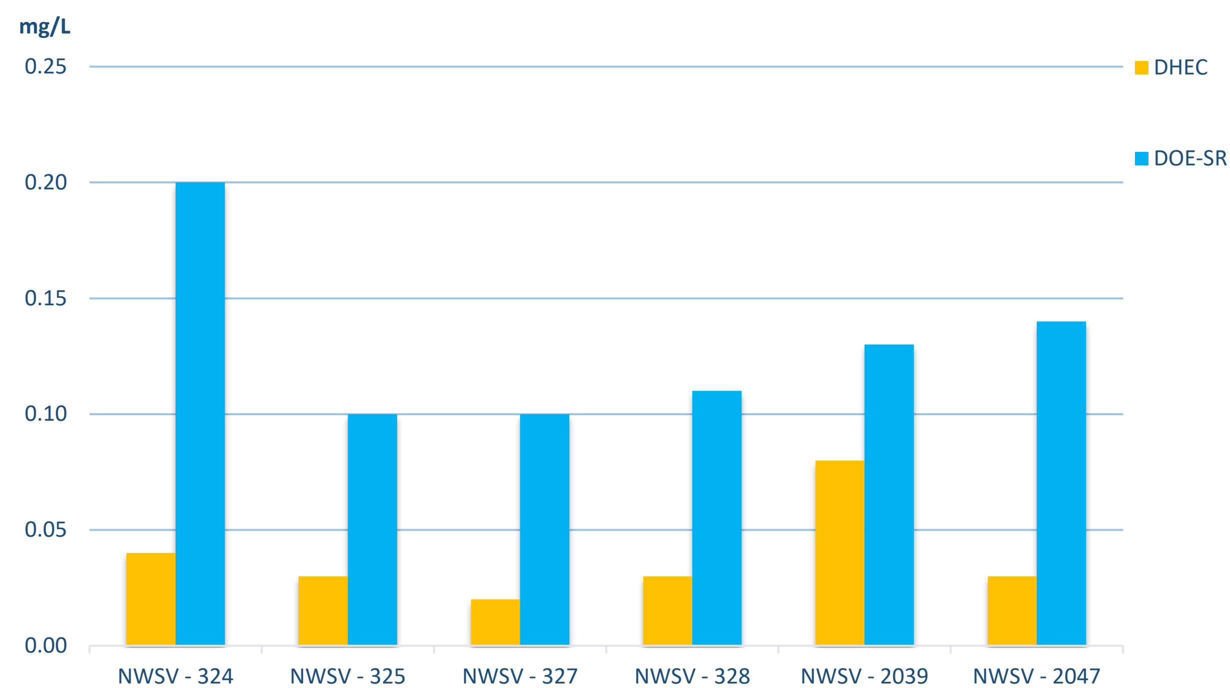
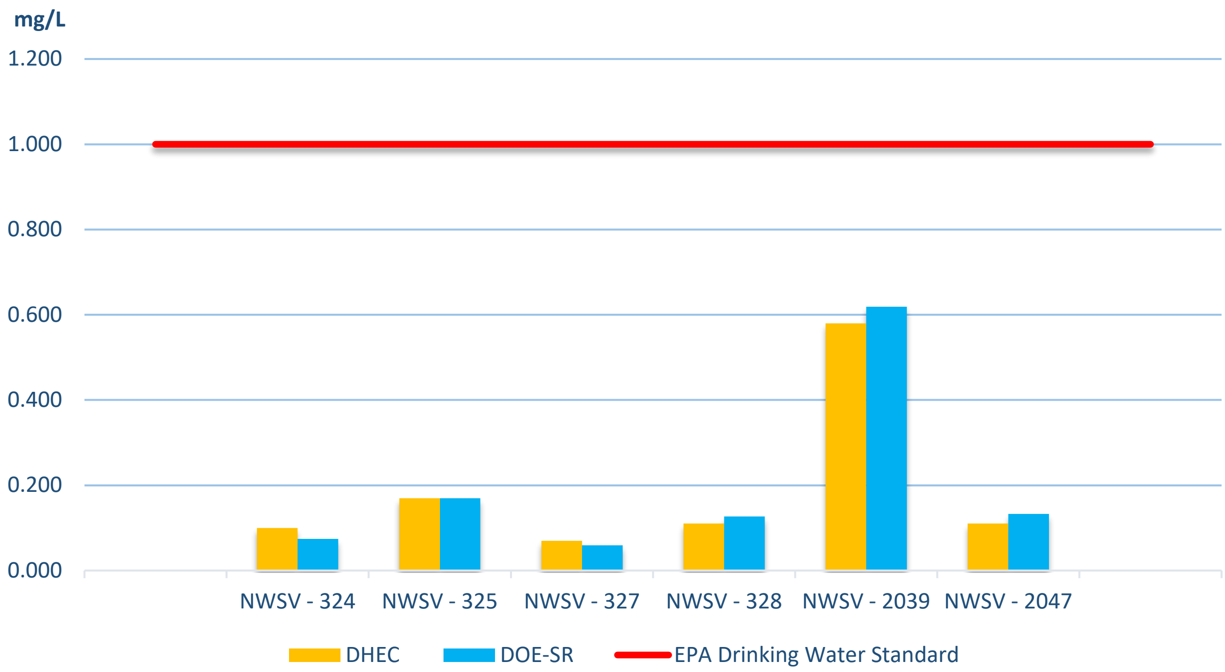


Figure 4. Total Phosphorous 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)



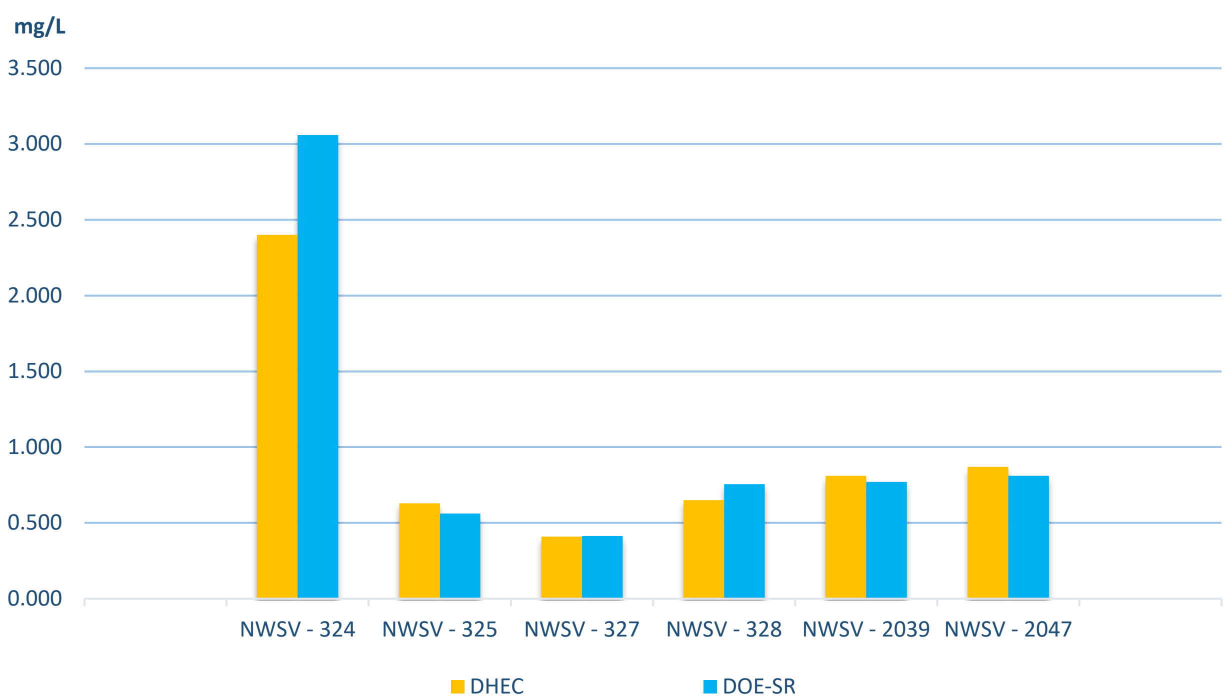
TABLES AND FIGURES

Figure 5. Nitrate/Nitrite 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)



Note: DOE-SR collects nitrate and nitrite as separate parameters. In this graph, DOE-SR's nitrate and nitrite were added together and then an average of the sum was taken to produce one number representing both nitrate and nitrite at each location in order to have comparable data to DHEC.

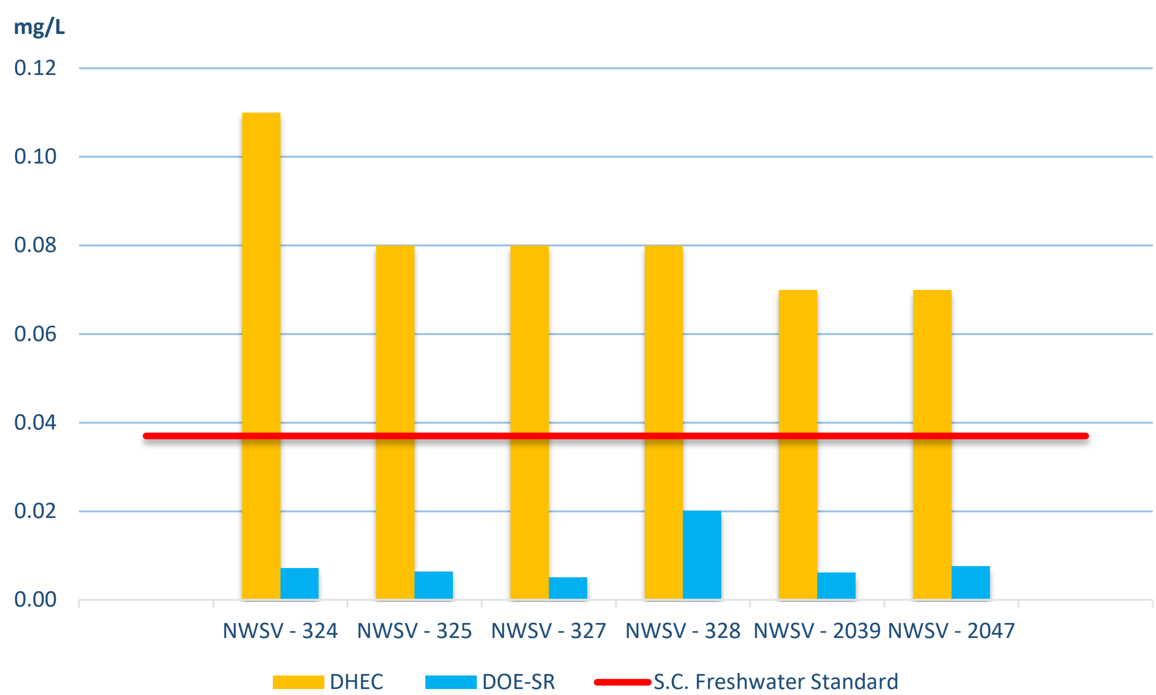
Figure 6. Iron 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)



TABLES AND FIGURES

Figure 7. Manganese 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)

Figure 8. Zinc 2019 Yearly Average DHEC and DOE-SR Comparison (SRNS, 2020)



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

Return to TOC

5.6.0 2019 SUMMARY STATISTICS

NWSV–324 Tims Branch at Road C

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	5.82	0.27	5.85	5.26	6.24	10
	DO (mg/L)	8.67	1.75	8.66	6.46	12.58	11
	Water Temp (°C)	18.78	4.78	18.98	13.00	24.95	11
	Conductivity (mS/cm)	0.02	0.001	0.02	0.02	0.02	11
Laboratory	Alkalinity (mg/L)	5.31	1.45	5.50	3.10	7.30	11
	Turbidity (NTU)	5.58	2.37	5.40	2.50	10.00	11
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	5.45	2.23	5.20	1.80	10.00	11
	E. Coli (MPN/100mL)	114.34	58.00	84.20	47.10	214.30	11
	TKN (mg/L)	0.31	0.16	0.25	0.17	0.67	9
	Ammonia (mg/L)	0.08	NA	0.08	0.08	0.08	1
	Nitrate/Nitrite (mg/L)	0.10	0.14	0.06	0.02	0.43	8
	Total Phosphorus (mg/L)	0.04	0.02	0.04	0.02	0.08	11
	Calcium (mg/L)	1.07	0.27	1.00	0.68	1.40	11
	Iron (mg/L)	2.40	0.73	2.40	1.50	3.70	11
	Magnesium (mg/L)	0.45	0.08	0.46	0.32	0.56	11
	Manganese (mg/L)	0.08	0.03	0.06	0.05	0.14	11
	Zinc (mg/L)	0.11	0.06	0.10	0.04	0.21	8
	Hardness(mg/L)	4.52	0.98	4.60	3.10	5.80	11
	Aluminum(mg/L)	0.13	0.05	0.11	0.07	0.24	11

Notes for the 5.6.0 Summary Statistic Tables on pages 62-66:
1). ND is Not Detected
2). NA is Not Applicable
3). Beryllium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, and Thallium were not included in the charts as all locations had averages that were non-detects
4). NWSV-324 was not sampled in November 2019
5). pH was not able to be sampled at NRSW- 324, 325, 327, 2039, and 2047 in January 2019 due to equipment failure

NWSV-325 Upper Three Runs at Road A

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	5.84	0.60	5.94	4.48	6.70	11
	DO (mg/L)	9.68	1.76	9.47	8.01	13.51	12
	Water Temp (°C)	19.05	4.66	19.85	13.21	25.25	12
	Conductivity (mS/cm)	0.025	0.007	0.023	0.021	0.045	12
Laboratory	Alkalinity (mg/L)	3.65	1.45	4.10	1.20	5.50	11
	Turbidity (NTU)	3.46	1.31	3.30	1.70	5.90	12
	BOD (mg/L)	4.40	NA	4.40	4.40	4.40	1
	TSS (mg/L)	4.38	1.60	4.35	2.00	7.10	12
	E. Coli (MPN/100mL)	215.17	109.77	195.45	75.90	461.10	12
	TKN (mg/L)	0.33	0.23	0.25	0.12	0.86	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.17	0.09	0.14	0.02	0.36	12
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.02	0.05	12
	Calcium (mg/L)	2.16	0.21	2.20	1.90	2.60	12
	Iron (mg/L)	0.63	0.25	0.59	0.34	1.10	12
	Magnesium (mg/L)	0.44	0.07	0.42	0.36	0.58	12
	Manganese (mg/L)	0.02	0.02	0.02	0.01	0.09	12
	Zinc (mg/L)	0.08	0.04	0.09	0.01	0.14	10
	Hardness(mg/L)	7.22	0.73	7.20	6.20	8.90	12
	Aluminum(mg/L)	0.20	0.09	0.21	0.10	0.36	12

NWSV-327 Steel Creek at Road A

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.80	0.24	6.82	6.38	7.21	11
	DO (mg/L)	8.92	1.34	9.18	7.01	10.91	12
	Water Temp (°C)	20.31	5.59	20.22	13.36	28.30	12
	Conductivity (mS/cm)	0.059	0.005	0.060	0.050	0.065	12
Laboratory	Alkalinity (mg/L)	21.33	2.61	21.50	17.00	24.00	12
	Turbidity (NTU)	3.67	1.71	3.20	1.90	7.80	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	5.64	3.58	5.20	1.80	15.00	11
	E. Coli (MPN/100mL)	147.19	98.08	115.70	41.00	365.40	12
	TKN (mg/L)	0.27	0.12	0.22	0.13	0.45	9
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.07	0.08	0.05	0.02	0.32	11
	Total Phosphorus (mg/L)	0.02	0.004	0.02	0.02	0.03	6
	Calcium (mg/L)	6.47	0.58	6.75	5.30	7.00	12
	Iron (mg/L)	0.41	0.17	0.38	0.20	0.67	12
	Magnesium (mg/L)	0.80	0.12	0.81	0.60	0.98	12
	Manganese (mg/L)	0.03	0.01	0.02	0.02	0.06	12
	Zinc (mg/L)	0.08	0.04	0.07	0.04	0.16	9
	Hardness(mg/L)	19.50	1.45	20.00	17.00	21.00	12
	Aluminum(mg/L)	0.14	0.08	0.12	0.05	0.31	10

NWSV-328 Lower Three Runs at Patterson Mill Road

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.80	0.64	6.65	6.02	8.71	12
	DO (mg/L)	8.87	1.45	9.42	6.80	10.81	12
	Water Temp (°C)	18.59	5.58	19.41	10.16	26.18	12
	Conductivity (mS/cm)	0.07	0.02	0.07	0.05	0.10	12
Laboratory	Alkalinity (mg/L)	35.33	9.71	31.50	24.00	48.00	12
	Turbidity (NTU)	3.39	1.30	3.40	1.90	5.70	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	6.25	3.86	5.60	1.10	12.00	11
	E. Coli (MPN/100mL)	211.32	181.16	128.95	64.40	613.10	12
	TKN (mg/L)	0.31	0.24	0.23	0.10	0.93	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.11	0.18	0.07	0.02	0.61	10
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.02	0.04	10
	Calcium (mg/L)	13.48	3.54	12.50	8.80	18.00	12
	Iron (mg/L)	0.65	0.32	0.58	0.32	1.30	12
	Magnesium (mg/L)	0.61	0.09	0.60	0.49	0.80	12
	Manganese (mg/L)	0.05	0.01	0.05	0.03	0.07	12
	Zinc (mg/L)	0.08	0.03	0.08	0.03	0.14	10
	Hardness(mg/L)	36.08	9.08	34.00	24.00	48.00	12
	Aluminum(mg/L)	0.16	0.07	0.17	0.06	0.27	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)	5.55	0.45	5.45	4.69	6.43	12
	DO (mg/L)	8.80	1.25	8.73	7.05	10.41	12
	Water Temp (°C)	18.21	3.83	18.43	11.79	23.01	12
	Conductivity (mS/cm)	0.02	0.002	0.02	0.01	0.02	12
Laboratory	Alkalinity (mg/L)	2.83	1.05	3.00	1.00	4.50	11
	Turbidity (NTU)	2.41	1.12	2.35	1.20	5.60	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	3.77	1.40	3.60	1.80	6.20	12
	E. Coli (MPN/100mL)	205.80	176.10	156.20	66.30	613.10	12
	TKN (mg/L)	0.25	0.21	0.18	0.10	0.72	8
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.44	0.31	0.33	0.23	1.30	12
	Total Phosphorus (mg/L)	0.02	0.003	0.02	0.02	0.03	4
	Calcium (mg/L)	0.85	0.17	0.85	0.54	1.10	12
	Iron (mg/L)	0.42	0.13	0.40	0.21	0.64	12
	Magnesium (mg/L)	0.46	0.05	0.48	0.37	0.51	12
	Manganese (mg/L)	0.02	0.01	0.01	0.01	0.02	3
	Zinc (mg/L)	0.09	0.04	0.09	0.03	0.19	10
	Hardness(mg/L)	3.99	0.53	4.00	2.90	4.80	12
	Aluminum(mg/L)	0.14	0.10	0.12	0.06	0.38	12

NWSV-2039 Fourmile Branch at Road 12.2

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.32	0.30	6.29	5.9	6.89	11
	DO (mg/L)	9.59	2.26	8.90	6.90	15.32	12
	Water Temp (°C)	18.67	4.97	19.38	12.31	25.35	12
	Conductivity (mS/cm)	0.05	0.01	0.05	0.04	0.06	12
Laboratory	Alkalinity (mg/L)	12.48	3.58	12.50	7.60	17.00	12
	Turbidity (NTU)	3.62	1.44	3.45	1.90	6.80	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	3.63	1.89	3.00	2.10	8.20	12
	E. Coli (MPN/100mL)	93.71	39.39	80.70	52.10	191.80	12
	TKN (mg/L)	0.25	0.11	0.24	0.10	0.45	9
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.58	0.48	0.44	0.20	2.00	12
	Total Phosphorus (mg/L)	0.08	0.03	0.08	0.02	0.11	12
	Calcium (mg/L)	3.49	0.44	3.50	2.80	4.30	12
	Iron (mg/L)	0.81	0.30	0.82	0.44	1.30	12
	Magnesium (mg/L)	0.56	0.06	0.58	0.44	0.67	12
	Manganese (mg/L)	0.04	0.01	0.03	0.02	0.06	12
	Zinc (mg/L)	0.07	0.03	0.07	0.04	0.12	9
	Hardness(mg/L)	11.07	1.23	11.00	9.10	13.00	11
	Aluminum(mg/L)	0.14	0.06	0.15	0.06	0.24	10

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	0.37	6.83	6.09	7.22	11
	DO (mg/L)	9.93	2.37	9.35	7.39	16.89	12
	Water Temp (°C)	18.64	4.79	18.63	13.39	25.67	12
	Conductivity (mS/cm)	0.05	0.01	0.05	0.04	0.07	12
Laboratory	Alkalinity (mg/L)	18.33	5.96	16.50	11.00	26.00	12
	Turbidity (NTU)	5.43	2.82	4.50	1.70	11.00	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	6.28	4.94	4.05	2.40	18.00	12
	E. Coli (MPN/100mL)	349.70	444.09	242.65	108.10	1732.90	12
	TKN (mg/L)	0.28	0.10	0.25	0.18	0.51	9
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.11	0.05	0.13	0.03	0.19	12
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.02	0.07	10
	Calcium (mg/L)	7.27	1.28	7.30	5.40	8.90	12
	Iron (mg/L)	0.87	0.37	0.80	0.45	1.50	12
	Magnesium (mg/L)	0.54	0.07	0.56	0.43	0.70	12
	Manganese (mg/L)	0.04	0.02	0.04	0.02	0.08	12
	Zinc (mg/L)	0.07	0.03	0.08	0.03	0.13	9
	Hardness(mg/L)	20.42	3.34	20.50	15.00	25.00	12
	Aluminum(mg/L)	0.22	0.17	0.18	0.05	0.56	12

NWSV-2055 Meyers Branch at Road 9

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.52	0.49	6.47	6	7.73	12
	DO (mg/L)	9.81	1.49	9.62	7.97	11.84	12
	Water Temp (°C)	17.68	4.99	17.07	10.00	24.11	12
	Conductivity (mS/cm)	0.04	0.01	0.04	0.04	0.05	12
Laboratory	Alkalinity (mg/L)	16.18	4.90	15.50	8.90	22.00	12
	Turbidity (NTU)	4.26	2.56	3.40	1.90	11.00	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	7.36	5.62	5.85	1.60	23.00	12
	E. Coli (MPN/100mL)	429.59	346.35	280.70	124.60	1299.70	12
	TKN (mg/L)	0.31	0.30	0.22	0.10	1.10	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.18	0.29	0.10	0.05	1.10	12
	Total Phosphorus (mg/L)	0.03	0.002	0.03	0.02	0.03	3
	Calcium (mg/L)	6.36	1.44	6.20	4.10	8.20	12
	Iron (mg/L)	0.59	0.27	0.58	0.23	1.20	12
	Magnesium (mg/L)	0.48	0.07	0.48	0.40	0.61	12
	Manganese (mg/L)	0.04	0.02	0.04	0.02	0.07	12
	Zinc (mg/L)	0.08	0.03	0.08	0.02	0.12	10
	Hardness(mg/L)	17.83	3.59	18.00	12.00	22.00	12
	Aluminum(mg/L)	0.26	0.16	0.27	0.06	0.52	10

NWSV-2061 Upper Three Runs at Road 2-1

Parameters		Average	Standard Deviation	Median	Minimum Detect	Maximum Detect	Number of Detects
Field	pH (SU)	6.07	0.67	5.99	4.7	7.15	12
	DO (mg/L)	9.28	2.02	9.15	6.99	13.08	12
	Water Temp (°C)	18.48	5.48	18.74	9.82	25.64	12
	Conductivity (mS/cm)	0.02	0.01	0.03	0.001	0.03	12
Laboratory	Alkalinity (mg/L)	5.62	1.63	5.60	2.70	8.00	11
	Turbidity (NTU)	2.98	0.85	2.85	1.90	4.60	12
	BOD (mg/L)	ND	NA	NA	ND	ND	0
	TSS (mg/L)	5.41	2.49	4.90	2.10	10.00	12
	E. Coli (MPN/100mL)	214.96	217.20	93.40	37.30	648.80	12
	TKN (mg/L)	0.34	0.20	0.29	0.10	0.71	10
	Ammonia (mg/L)	ND	NA	NA	ND	ND	0
	Nitrate/Nitrite (mg/L)	0.15	0.16	0.06	0.03	0.50	11
	Total Phosphorus (mg/L)	0.05	0.01	0.06	0.04	0.08	12
	Calcium (mg/L)	3.03	0.48	3.05	2.30	3.80	12
	Iron (mg/L)	0.49	0.13	0.49	0.29	0.66	12
	Magnesium (mg/L)	0.41	0.07	0.43	0.30	0.52	12
	Manganese (mg/L)	0.02	0.01	0.02	0.02	0.06	12
	Zinc (mg/L)	0.08	0.03	0.07	0.05	0.14	10
	Hardness (mg/L)	9.21	1.47	9.20	7.00	12.00	12
	Aluminum (mg/L)	0.23	0.10	0.19	0.12	0.49	12

Chapter 6 Monitoring of Sediments on and Adjacent to SRS

6.1.0 PROJECT SUMMARY

Collecting sediment samples from the riverbank

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).

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 Analytes, Table 1 and Table 2 on page ix. DHEC sediment sampling locations are illustrated in Section 6.4.0, Map. DHEC and DOE-SR split samples were collected from seven 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 2019 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 in 2019.

DHEC had sporadic gross alpha and gross non-volatile beta activity detections in 2019. 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 2019 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 2019 DHEC and DOE-SR collocated sediment samples occurred at Steel Creek Mouth (1.84 pCi/g for DHEC and 1.33 pCi/g for DOE-SR) and Four Mile Creek (5.69 pCi/g for DHEC and 4.25 pCi/g for DOE-SR) (SRNS, 2020). Cesium-137 contamination in Steel Creek mouth 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, 2014).

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 2015-2019 (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 2019 DHEC samples had averages below the Ecological Screening Values (ESVs) for beryllium, copper, lead, nickel, and zinc (EPA, 2018a). DHEC had no chemicals with detection concentrations above the ESV for the background location in 2019 except for Barium. DOE-SR had sample averages that were above the ESVs for Barium and Manganese, as well as individual samples that had detects over the ESVs for Chromium, Copper, and Mercury.

Comparisons were made to the ESVs for sediment, which do not represent remediation goals or cleanup levels but are used to identify constituents of potential concern (EPA, 2018a).

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

Barium was detected above the ESV of 20 mg/kg by DHEC in all creek mouths, storm-water basins, and on-site streams, in four of the boat landings (SMSVC19, SMJBL19, SMBFL19, and SMSC19), and in the background location. DOE-SR detected barium above the ESV in all creek mouths and storm-water basins and in six on-site streams (PB @ Rd A, FMC @ Rd A, TC-1, McQB at MO, U3R-3, and U3R-4).

Beryllium does not have an established ESV for sediment, so in lieu of a sediment value, the ESV for soil was used. DHEC had one on-site stream sample (SMSV-2069) with a detection above the ESV of 2.5 mg/kg. DOE-SR did not test for beryllium in 2019.

Cadmium was detected above the ESV of 1 mg/kg by DHEC in three of the on-site streams (SMSV-2048, SMSV-2049, and SMSV-2069), three of the creek mouths (SMSV-2011, SMSV-2017, and SMSV-2020), all three of the storm-water basins, and four of the public boat landings (SMSVC19, SMJBL19, SMBFL19, and SMSC19). DOE-SR did not detected cadmium above the ESV in any location in 2019.

Chromium was detected by both DHEC and DOE-SR above the ESV of 43.4 mg/kg at one of the storm-water basins (SME-004).

DHEC did not detect copper above the ESV of 31.6 mg/kg, whereas DOE had one on-site stream (McQB at MO) over the ESV.

DHEC detected manganese above the ESV of 460 mg/kg in one on-site location (SMSV-2049), four creek mouths (SMSV-2013, SMSV-2015, SMSV-2017, and SMSV-2020), and three boat landings (SMSVC19, SMJBL19, and SMSC19). DOE-SR had three creek mouths (BDC RM, SC RM, and RM 129) with results above the ESV.

Mercury was detected above the ESV of 0.18 mg/kg in two on-site streams (SMSV-2053 and SMSV-2069) for DHEC. DOE-SR had on-site stream sample (SMSV-2053) with a result above the ESV of mercury. DOE-SR had two on-site stream samples (L3R-1A and PB @ Rd A) with a result above the ESV of mercury.

DHEC and DOE-SR did not have detections above the ESVs for lead (35.8 mg/kg), nickel (22.7 mg/kg), or zinc (121 mg/kg) in 2019.

DHEC non-radiological sediment data can be found in the 2019 DHEC Data File and non-radiological summary statistics can be found in Section 6.6.0.

6.3.0 CONCLUSIONS AND RECOMMENDATIONS

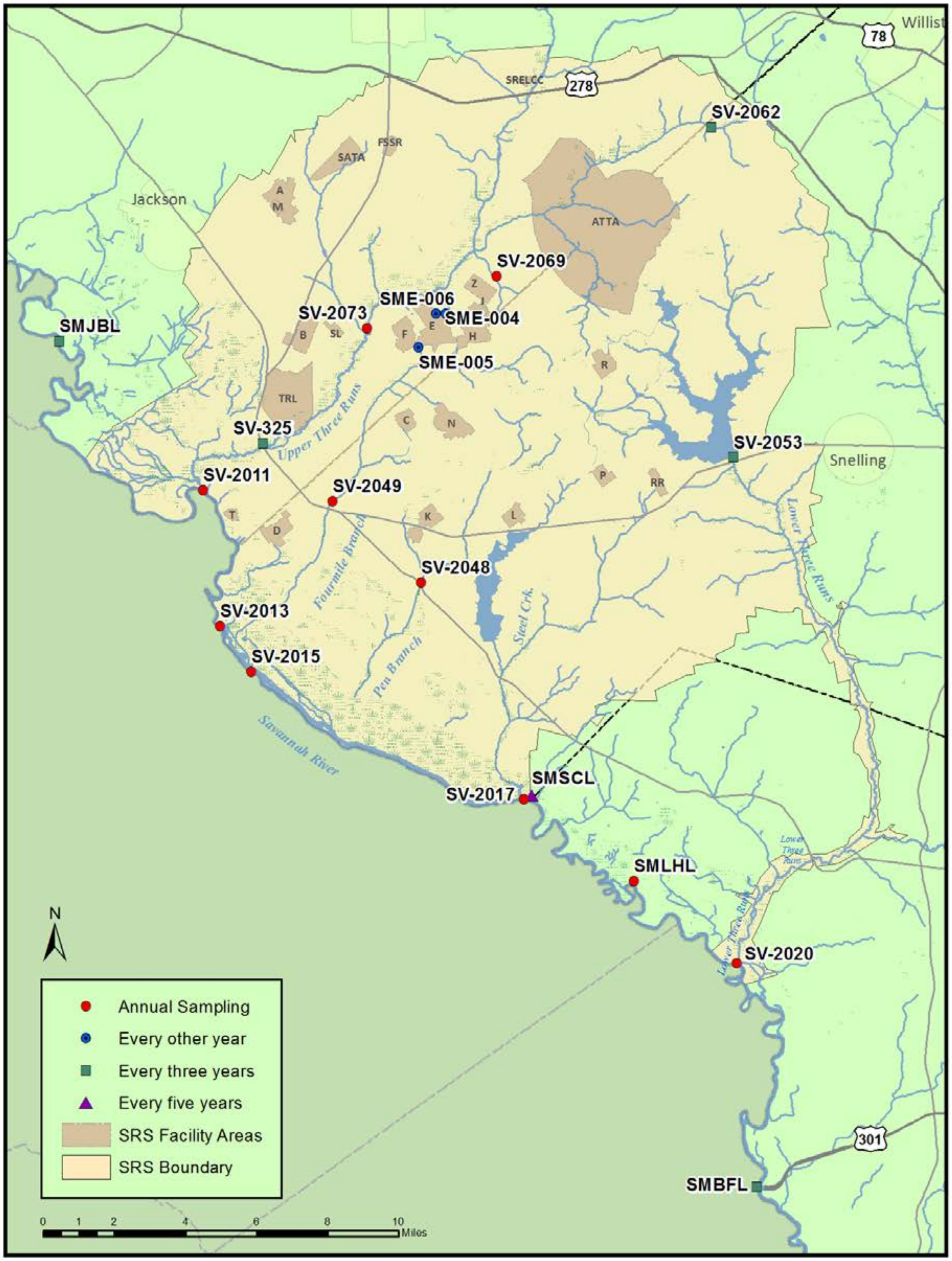
SRS sediments should continue to be monitored due to current releases of contaminants and the potential for future discharges from SRS operations, legacy wastes, and clean-up activities. Year-to-year data comparisons are difficult to interpret due to the nature of sediment accumulation. Differences among 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 independent monitoring of 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



2019 ESOP Sediment Monitoring Map

www.scdhec.gov/srs

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6.5.0 TABLES AND FIGURES

Table 1. 2019 DHEC Sediment Sample Locations

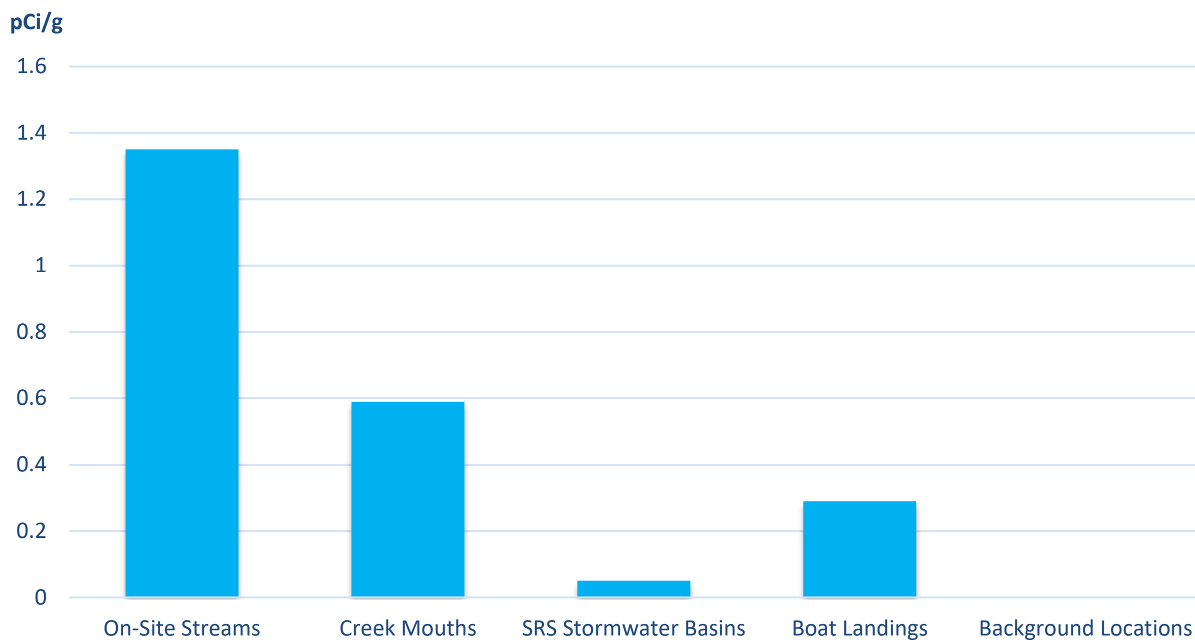
DHEC Sample Location ID	DOE Sample Location ID	Location Description
Storm-water Basins		
SME-004	E-004	E-004 E Area Storm-water Basin
SME-005	E-05	E-005 E Area Storm-water Basin
SME-006	E-06	E-006 E Area Storm-water Basin
Creek Mouths		
SMSV-2011	RM 157.2	Upper Three Runs Mouth @ RM 157.4
SMSV-2013	BDC RM	Beaver Dam Creek @ RM 152.3
SMSV-2015	RM 150.2	Fourmile Branch Creek Mouth @RM 150.6
SMSV-2017	SC RM	Steel Creek Mouth @ RM 141.5
SMSV-2020	RM 129	Lower Three Runs Mouth @RM 129.1
On-site Streams		
SMSV-2073	U3R-3	Upper Three Runs @ Rd C
SMSV-2069	McQB at MO	McQueen Branch @ Monroe Owens Rd
SMSV-2062	TC-1	Tinker Creek @ Kennedy Pond Road
SMSV-325	U3R-4	Upper Three Runs@ SC 125
SMSV-2048	PB @ Rd A	Pen Branch @ Rd 125
SMSV-2049	FMC @ Rd A	Four Mile Creek @ Rd 125
SMSV-2053	L3R-1A	Lower Three Runs-1A
Upstream of SRS		
SMRVP19	NA	North Augusta Riverview Park Boat Landing
SMSVC19	NA	Steven’s Creek Boat Landing
SMJBL19	NA	Jackson Boat Landing
Downstream of SRS		
SMSC19	NA	Steel Creek Landing
SMLHL19	NA	Little Hell Landing
SMBFL19	NA	Burton's Ferry Landing

DHEC Sample Location ID	DOE Sample Location ID	Location Description
SMPKY19	NA	Pinckney Island National Wildlife Refuge

Table 2. Soil Ingestion Preliminary Remediation Goals of Select Anthropogenic Radionuclides (EPA, 2014)

Radionuclide	PRG (pCi/g)
Americium-241	4.9
Cesium-137	28
Cobalt – 60	83
Iodine-131	6000
Plutonium-238	4.4
Plutonium-239/240	3.9

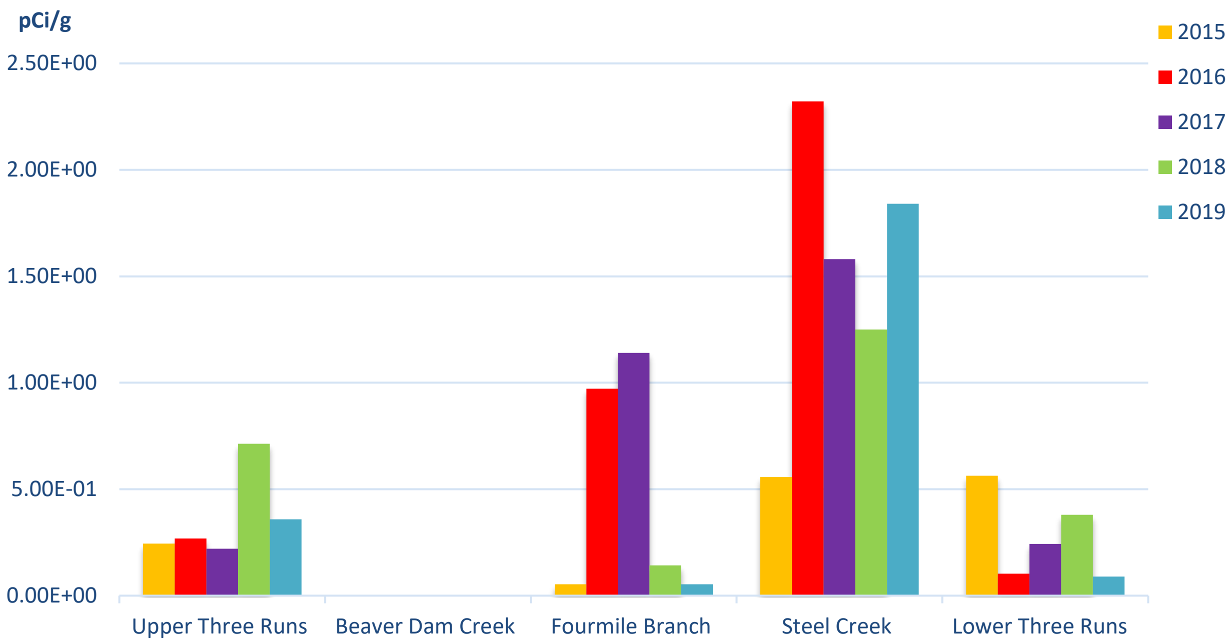
Figure 1. 2019 Comparisons of Cs-137 Average Activity Among Sample Location Type



Note: No bar denotes no detection.

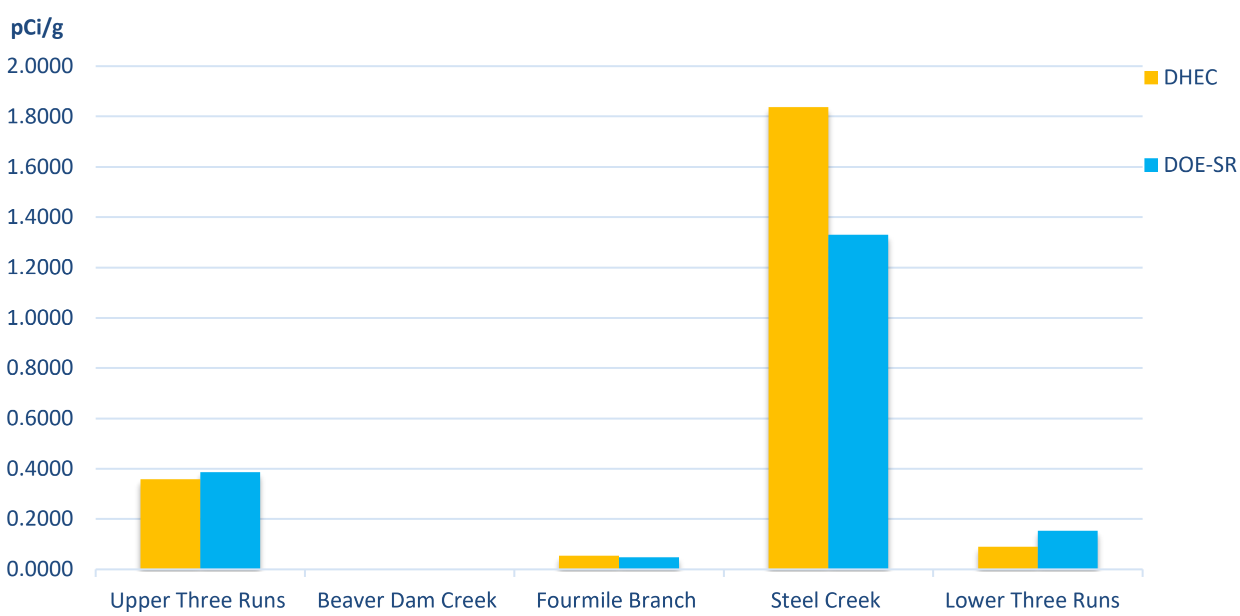
TABLES AND FIGURES

Figure 2. 2015-2019 Trending Data for Cs-137 in SRS Creek Mouth Samples (DHEC, 2016-2019)



Note: No bar denotes no detection for that year.

Figure 3. 2019 Cesium-137 in Savannah River Creek Mouths–DHEC Comparison to DOE-SR Data (SRNS, 2020)



Note: Beaver Dam Creek had no detection from DHEC or DOE-SR**.** Beaver Dam Creek is a manmade stream for operations at D-Area, but it stopped flowing when operations in D-Area ceased in 2012.

6.6.0 SUMMARY STATISTICS

2019 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	1.35	2.43	0.43	0.09	5.69	5	7
Gross Alpha	17.98	9.54	18.00	8.66	27.40	6	7
Gross Beta	16.06	7.96	11.10	7.10	26.60	7	7

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	0.59	0.85	0.22	0.05	1.84	4	5
Gross Alpha	16.88	16.72	16.88	5.06	28.70	2	5
Gross Beta	23.04	5.60	23.60	17.40	31.00	5	5

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	0.05	NA	0.05	0.05	0.05	1	3
Gross Alpha	9.53	3.29	8.53	6.86	13.20	3	3
Gross Beta	14.91	7.99	11.7	9.02	24.00	3	3

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	0.29	0.34	0.29	0.05	0.53	2	6
Gross Alpha	10.35	3.04	10.35	8.20	12.50	2	6
Gross Beta	19.60	5.43	18.40	14.60	27	4	6

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	ND	NA	NA	<LLD	<LLD	0	1
Gross Alpha	ND	NA	NA	<LLD	<LLD	0	1
Gross Beta	13.8	NA	13.8	13.8	13.8	1	1

Note: ND is Not Detected, NA is Not Applicable

SUMMARY STATISTICS

2019 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	76.29	56.91	46.00	24.00	170.00	7	7	20
Beryllium	1.26	0.98	0.81	0.30	2.80	5	7	2.5*
Cadmium	2.23	0.64	2.60	1.50	2.60	3	7	1
Chromium	14.29	13.84	6.50	2.50	38.00	7	7	43.4
Copper	8.40	10.07	4.55	1.10	27.00	6	7	31.6
Lead	10.78	4.85	10.45	5.20	17.00	4	7	35.8
Manganese	203.43	253.97	48.00	10.00	710.00	7	7	460
Mercury	0.29	0.21	0.21	0.13	0.52	3	7	0.18
Nickel	8.20	5.87	7.85	2.10	17.00	6	7	22.7
Zinc	43.87	46.16	20.00	6.10	120.00	7	7	121

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	110.00	52.92	100.00	40.00	180.00	5	5	20
Beryllium	2.00	NA	2.00	2.00	2.00	1	5	2.5*
Cadmium	2.10	0.70	2.40	1.30	2.60	3	5	1
Chromium	20.20	13.11	17.00	8.60	40.00	5	5	43.4
Copper	7.52	7.79	4.50	1.10	20.00	5	5	31.6
Lead	11.17	6.09	9.20	6.30	18.00	3	5	35.8
Manganese	762.00	318.31	840.00	350.00	1100.00	5	5	460
Mercury	0.12	NA	0.12	0.12	0.12	1	5	0.18
Nickel	9.24	6.22	7.70	2.80	19.00	5	5	22.7
Zinc	40.20	26.26	37.00	12.00	79.00	5	5	121

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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	55.33	20.31	65.00	32.00	69.00	3	3	20
Beryllium	0.91	0.06	0.91	0.86	0.95	2	3	2.5*
Cadmium	2.67	0.67	3.00	1.90	3.10	3	3	1
Chromium	37.33	7.09	36.00	31.00	45.00	3	3	43.4
Copper	9.13	3.42	7.90	6.50	13.00	3	3	31.6
Lead	24.50	4.95	24.50	21.00	28.00	2	3	35.8
Manganese	106.33	68.63	130.00	29.00	160.00	3	3	460
Mercury	0.12	NA	0.12	0.12	0.12	1	3	0.18
Nickel	10.53	2.73	11.00	7.60	13.00	3	3	22.7
Zinc	34.67	24.58	22.00	19.00	63.00	3	3	121

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	73.42	70.13	54.50	6.50	190.00	6	6	20
Beryllium	0.50	0.11	0.50	0.42	0.57	2	6	2.5*
Cadmium	2.48	1.42	2.20	1.20	4.30	4	6	1
Chromium	13.07	9.56	10.95	1.50	25.00	6	6	43.4
Copper	8.94	6.80	5.00	3.80	20.00	5	6	31.6
Lead	10.85	4.45	10.85	7.70	14.00	2	6	35.8
Manganese	559.17	498.44	470.00	15.00	1200.00	6	6	460
Mercury	ND	NA	NA	<LLD	<LLD	0	0	0.18
Nickel	8.55	4.73	7.95	4.30	14.00	4	6	22.7
Zinc	32.45	24.94	22.50	4.70	72.00	6	6	121

Background Sample

Analyte	Concentration (mg/kg)	Number of Detections	Number of Samples	ESV
Barium	22.00	1	1	20
Beryllium	ND	0	1	2.5*
Cadmium	ND	0	1	1
Chromium	10.00	1	1	43.4
Copper	1.80	1	1	31.6
Lead	ND	0	1	35.8
Manganese	43.00	1	1	460
Mercury	ND	0	1	0.18
Nickel	2.50	1	1	22.7
Zinc	9.00	1	1	121

Note:

1. ND is Not Detected
2. NA is Not Applicable
3. ESVs come from EPA, 2018a
4. There is not an ESV established for beryllium in sediment, so the ESV for beryllium in soil is used in lieu of the sediment value. This is denoted by an *.

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 area from the center of SRS was chosen for the comparison of DHEC and DOE-SR SRS perimeter radiological data averages. DOE-SR does not collect metals for surface soil; therefore, no direct data comparisons can be made.

DHEC collected samples from nine SRS perimeter locations and one background location in 2019 (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 2019 DHEC Data File.

Samples being prepped for the oven

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 (SRNS, 2020). An assessment of Cs-137 activity in 2019 is comparable to levels detected by DHEC in the past. There were no surface soil samples collected in 2019 that were above the EPA Preliminary Remediation Goals (PRGs), which can be found in Section 7.5.0, Table 2 (EPA, 2014).

DHEC had Cs-137 detections in eight of nine SRS perimeter samples and in one background sample in 2019 (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 a perimeter average Cs-137 concentration of 0.13 pCi/g, which was slightly lower than DOE-SR’s findings of 0.17 pCi/g. The PRG for C-137 is 28 pCi/g and all sample results were well below that level. 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 (2019 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 2019 (EPA, 2018b). 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 and background 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 2019.

Cadmium enters the atmosphere through fuel and coal combustion (Till et al. 2001). None of the perimeter and background 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 amounts of chromium (Alloway, 1995). Chromium was detected in all nine of the SRS perimeter samples and in the background location.

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 eight 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 three 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 nine of the SRS perimeter samples and in the background location.

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 four 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 nine SRS perimeter samples and in the background location.

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 2019.

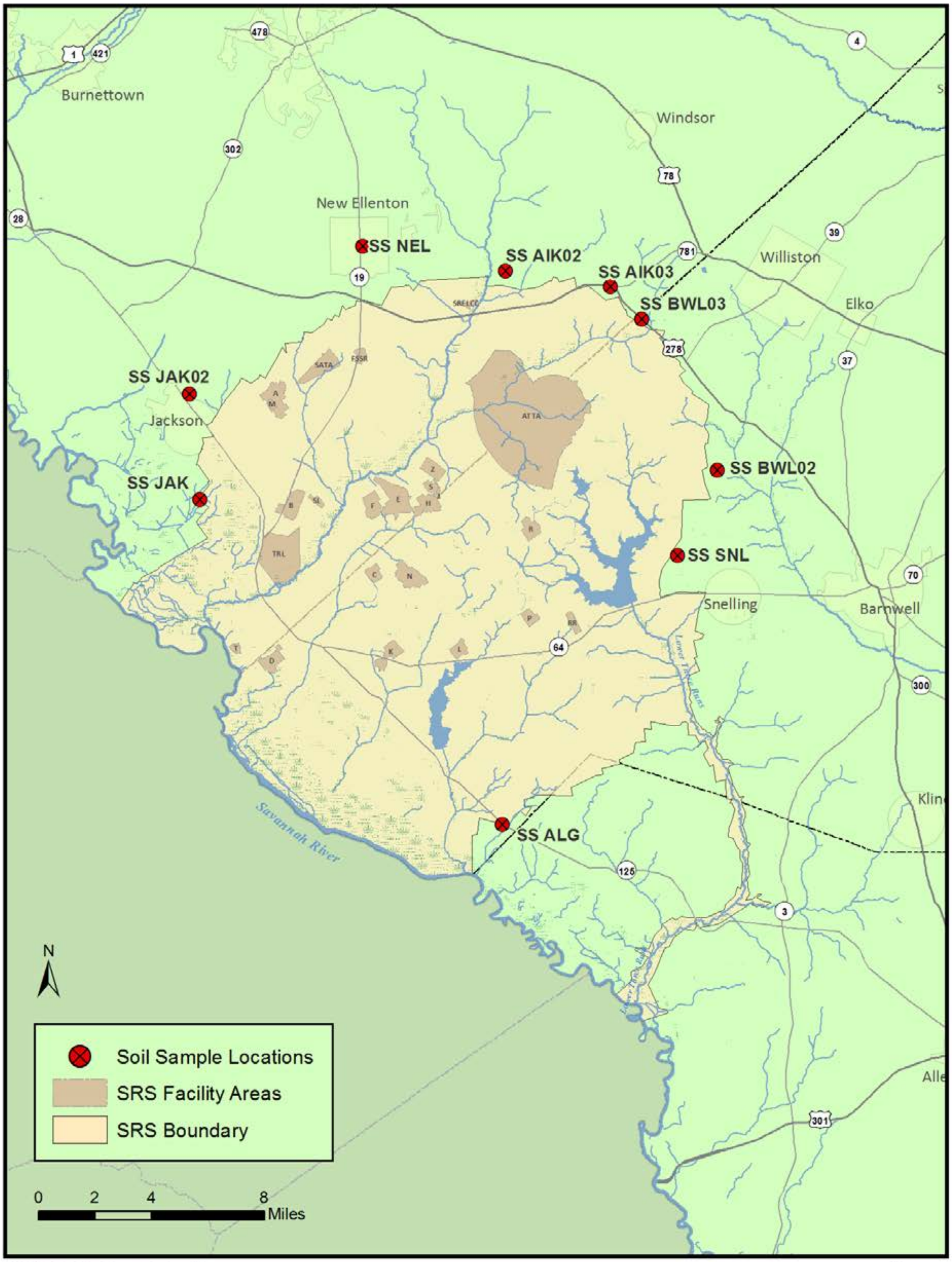
7.3.0 CONCLUSIONS AND RECOMMENDATIONS

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 monitor independently the 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



2019 ESOP Soil Monitoring Map www.scdhec.gov

7.5.0 TABLES AND FIGURES

Table 1. Soil Sample Locations for in 2019

Perimeter Soil Samples		
Sample ID	**Location**	**County**
SS AIK02 19	Boggy Gut Rd	Aiken
SS AIK03 19	Dunlap Circle, across 278 from Jaywood Rd	Aiken
SS ALG 19	Cemetery at Steel Creek	Barnwell
SS BWL02 19	Seven Pines Rd	Allendale
SS BWL03 19	Hwy 278 and Grandy's Mill Rd	Allendale
SS JAK 19	Near SRS air station at Green Pond	Allendale
SS JAK02 19	Crackerneck Gate	Barnwell
SS NEL 19	New Ellenton Fire Department	Barnwell
SS SNL 19	Technology Rd in Snelling	Barnwell
Background Soil Samples		
Sample ID	**Location**	**County**
SS BKG 19	Pinckney Island National Refuge	Beaufort

Note: * The location named BKG 19 can be found in other media under the name PKG

TABLES AND FIGURES

Table 2. Soil Ingestion Preliminary Remediation Goals of Select Anthropogenic Radionuclides (EPA, 2014)

Radionuclide	PRG (pCi/g)
Americium-241	4.9
Cesium-137	28
Cobalt – 60	83
Iodine-131	6000
Plutonium-238	4.4
Plutonium-239/240	3.9

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

Analyte	RSL (mg/kg)
Barium	15,000
Beryllium	160
Cadmium	70
Total Chromium	23**
Copper	3,100
Lead	400
Manganese	1,800
Mercury	11
Nickel	1,500
Zinc	23,000

Note:

**The DHEC lab analyzes soil samples for total chromium; however, a RSL is not established for total chromium. The value provided in the table above is the ecological screening value for total chromium in soil.

TABLES AND FIGURES

Figure 1. 2015-2019 DHEC and DOE-SR Trending Averages for Cesium-137 (SRNS, 2016a-2020; DHEC, 2016-2019)

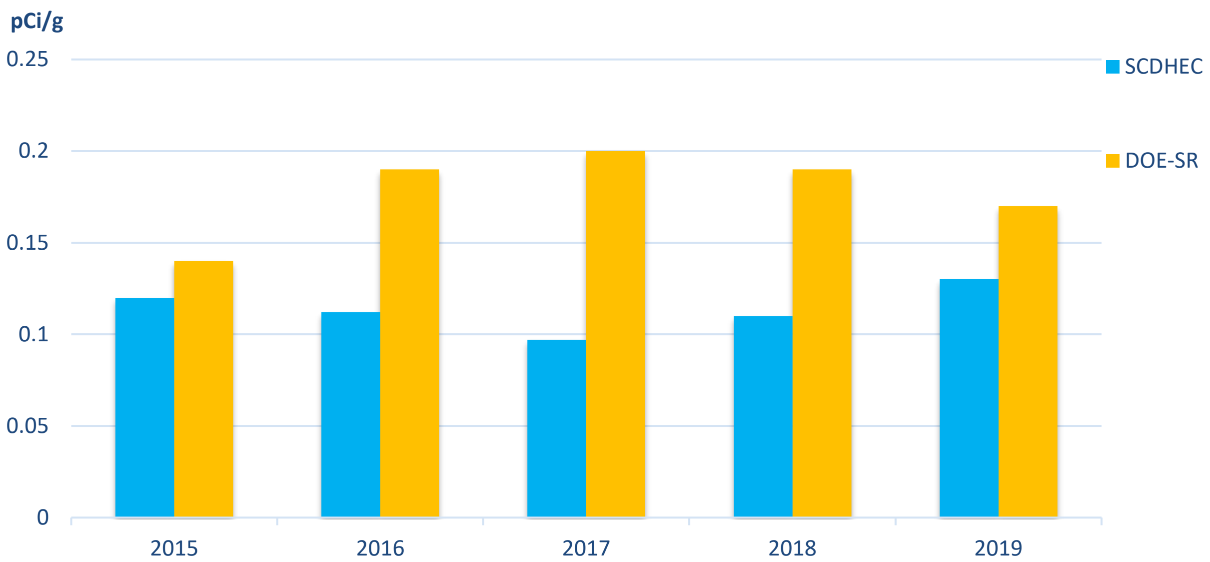
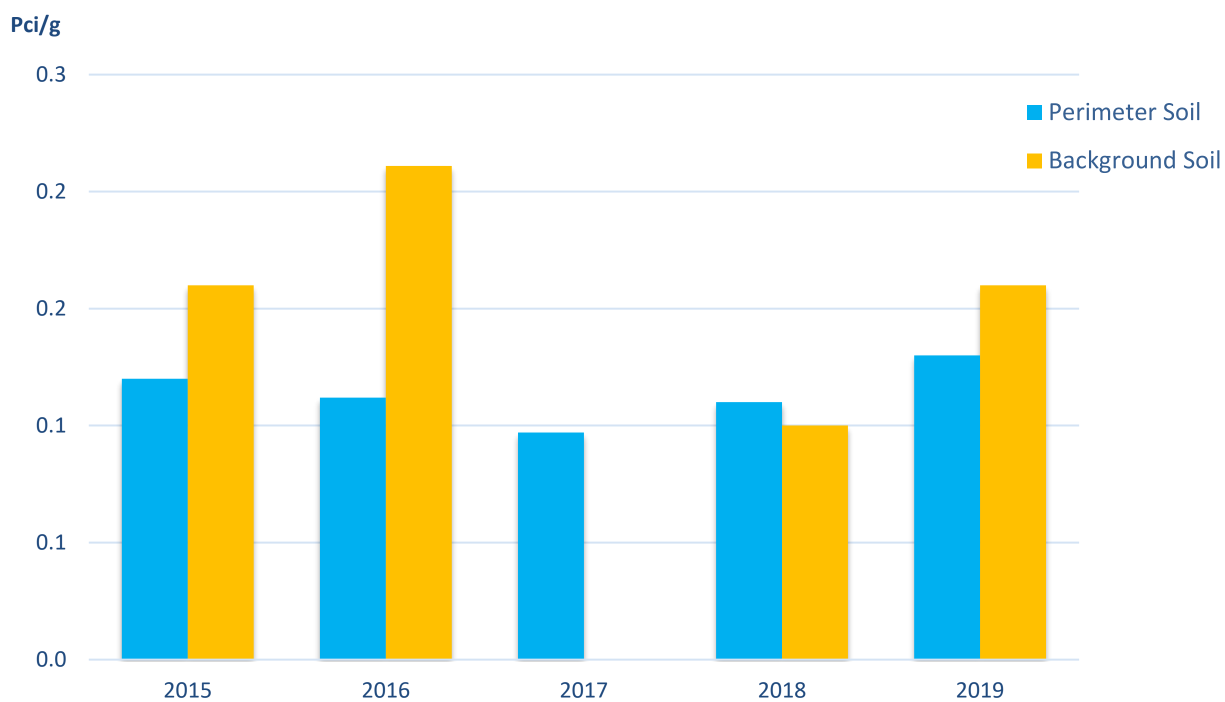


Figure 2. 2015-2019 Perimeter and Background Trending Averages for Cesium-137 (DHEC 2016 – 2019)



***Background samples were not collected in 2017

7.6.0 SUMMARY STATISTICS

2019 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	6.03	0.82	5.68	5.45	6.97	3	9
Gross Beta	7.61	2.12	6.89	5.96	10.70	4	9
Cs-137	0.13	0.08	0.11	0.03	0.28	8	9

2019 DHEC Radiological Statistics -- Background Sample

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	ND	NA	NA	<LLD	<LLD	0	1
Gross Beta	ND	NA	NA	<LLD	<LLD	0	1
Cs-137	0.16	NA	0.16	0.16	0.16	1	1

2019 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	17.96	10.97	14.00	7.90	43.00	9	9
Chromium	3.97	1.02	4.30	2.80	5.50	9	9
Copper	2.46	1.26	2.10	1.10	4.30	8	9
Lead	9.10	3.37	9.90	5.40	12.00	3	9
Manganese	62.11	63.01	42.00	17.00	210.00	9	9
Nickel	3.05	0.86	2.90	2.30	4.10	4	9
Zinc	10.23	3.84	11.00	5.50	18.00	9	9

2019 DHEC Non-radiological (Metals) Statistics -- Background Sample

Analyte	Concentration (mg/kg)	Number of Detections	Number of Samples
Barium	12.00	1	1
Chromium	3.90	1	1
Copper	ND	0	1
Lead	ND	0	1
Manganese	16.00	1	1
Nickel	ND	0	1
Zinc	7.70	1	1

Note:
1). NA is Not Applicable and ND is Not Detected
2). All samples were analyzed for Beryllium, Cadmium, and Mercury; however, there were no detects for both the perimeter and background locations, so these chemicals were not included in the charts.

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, 2020). In 2019, DHEC began sampling Bermuda grass (*cynodon dactylon*) to align with DOE's methodology and is no longer collecting leaves from broad-leafed evergreen trees and shrubs. DHEC and DOE-SR locations are collocated with samples being obtained from 10 locations at the SRS perimeter, one on-site location at the burial grounds, and three locations 25 miles from the center of SRS. The 25-mile samples allow comparisons to be made between tritium levels at the SRS perimeter and in the general SRS area. DHEC also monitors a background location at Pinckney Island National Refuge. DHEC and DOE-SR perimeter stations sampled in 2019 are shown in Section 8.4.0, Map.

Preparing grass samples for lab analysis

8.2.0 RESULTS AND DISCUSSION

Terrestrial Vegetation Data

Terrestrial Vegetation Monitoring Data can be found in the 2019 DHEC Data File.

In 2019, DHEC detected tritium in only one of the ten perimeter locations (Darkhorse at 2000 pCi/L) and at the center location (Burial Ground North at 7857.14 pCi/L) (Section 8.5.0). DOE-SR had tritium detects in one perimeter location (Barnwell Gate at 276.67 pCi/L) and at the center location (Burial Ground North at 5285.71 pCi/L). The 25-mile locations for both DHEC and DOE-SR did not have any detects nor did DHEC's background location.

Weighing grass samples

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

<u>Gamma</u>

In 2019, DHEC detected actinium-228, beryllium-7, potassium-40, lead-212, and lead-214. These isotopes are NORM; therefore, the results will not be discussed in this section, but are presented in the 2019 DHEC Data File. A list of radionuclides in the gamma spectroscopy analysis are in List of Analytes, Table 1, page ix.

DHEC detected Cs-137 at five of the ten perimeter locations, two of the 25-mile locations, and at the background location (with 0.17 pCi/g). DOE-SR detected Cs-137 at six of perimeter locations and one of the 25-mile sampling stations. Gamma analysis results for Cs-137 from DHEC and DOE-SR sampling in 2019 are presented in Section 8.5.0, Table 2.

Collection bags for Bermuda grass

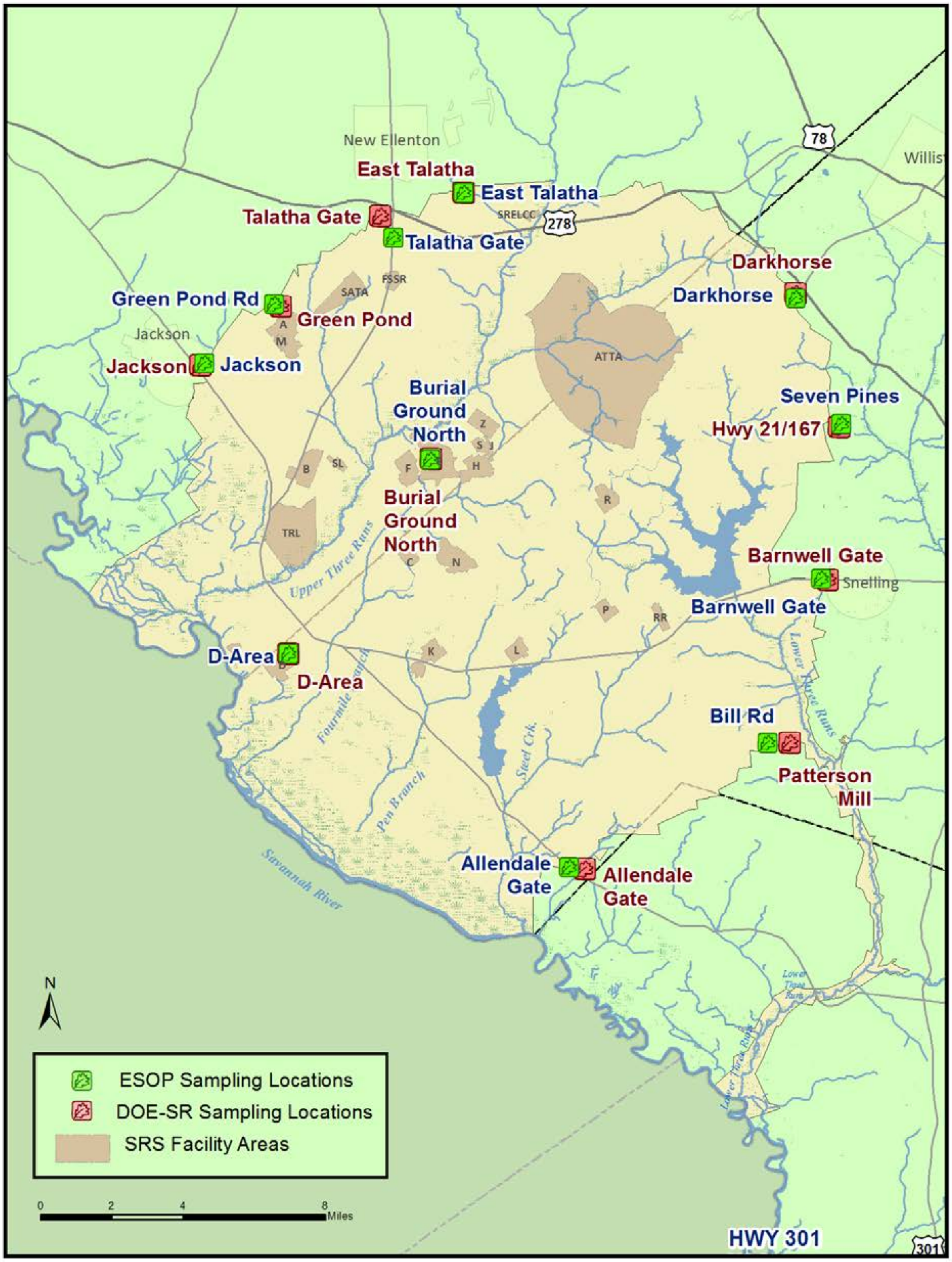
The man-made isotopes Co-60 and Am-241 were not detected in the DHEC 2019 samples.

8.3.0 CONCLUSIONS AND RECOMMENDATIONS

DHEC's revision of beginning to sample Bermuda grass on an annual basis in 2019 allows for a more direct comparison with the data collected by DOE-SR. By having parallel sampling techniques with DOE-SR, DHEC will potentially observe less differences in the detection levels among the media.

8.4.0 MAP

Terrestrial Vegetation Sampling Locations



2019 ESOP Terestrial Vegetation Monitoring Map

www.scdhec.gov

8.5.0 TABLES AND FIGURES

Table 1. 2019 Tritium Data Comparison for DHEC and DOE-SR Sampling Locations (SRNS, 2020)

Stations	DHEC Result (pCi/L)	DOE-SR Result (pCi/L)
Burial Ground North	7857.14	5285.71
Sample Perimeter Locations		
Talatha Gate	ND	ND
Green Pond Rd	ND	ND
Jackson	ND	ND
East Talatha	ND	ND
Darkhorse	2000	ND
Seven Pines/ Hwy 21/167[a]	ND	ND
Barnwell Gate	ND	276.67
Bill Rd / Patterson Mill Rd[a]	ND	ND
Allendale Gate	ND	ND
D-Area	ND	ND
25-Mile Radius Locations	**DHEC Result (pCi/L)**	**DOE-SR Result (pCi/L)**
Hwy 301 Welcome Center	ND	ND
Lock - n - Dam	ND	ND
Aiken Airport	ND	ND

Notes:
1. NS is No Sample
2. ND is Not Detected
3. [a] represents that these names are in the same location but DHEC and DOE-SR use different nomenclature in these areas. Seven Pines (DHEC) = Hwy 21/167 (DOE-SR) and Bill Rd (DHEC) = Patterson Mill Rd (DOE-SR).
4. No summary statistics were shown due to the limited detections.

8.5.0 TABLES AND FIGURES

Table 2. 2019 Cesium-137 Data Comparison for DHEC and DOE-SR Sampling Locations (SRNS, 2020)

Stations	DHEC Result (pCi/g)	DOE-SR Result (pCi/g)
Burial Ground North	ND	ND
Sample Perimeter Locations		
Talatha Gate	ND	0.10
Green Pond Rd	ND	ND
Jackson	ND	ND
East Talatha	0.03	0.28
Darkhorse	0.02	ND
Seven Pines/ Hwy 21/167[a]	0.09	0.37
Barnwell Gate	ND	0.17
Bill Rd / Patterson Mill Rd[a]	ND	0.28
Allendale Gate	0.02	0.81
D-Area	0.11	ND
Perimeter Locations' Summary Statistics – Cs-137		
Average	**0.05**	**0.34**
Standard Deviation	**0.04**	**0.25**
Median	**0.03**	**0.28**

25-Mile Radius Locations	DHEC Result (pCi/g)	DOE-SR Result (pCi/g)
Hwy 301 Welcome Center	ND	ND
Lock - n - Dam	0.02	ND
Aiken Airport	0.05	0.21
Summary Statistics – Cs-137		
Average	**0.04**	**0.21**
Standard Deviation	**0.03**	**NA**
Median	**0.04**	**0.21**

Notes:
1. NS is No Sample
2. ND is Not Detected
3. [a] represents that these names are in the same location but DHEC and DOE-SR use different nomenclature in these areas. Seven Pines (DHEC) = Hwy 21/167 (DOE-SR) and Bill Rd (DHEC) = Patterson Mill Rd (DOE-SR).

Return to TOC

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**'s** 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.

Collecting peaches from a local farm

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

Collecting broccoli from a local farm

Edible Vegetation Monitoring Data can be found in the 2019 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, 2005).

DHEC did not detect tritium in any of the samples that were taken in 2019. DOE-SR detected tritium in one of the twenty samples (in greens in the SE Quadrant 0-10 miles at 0.095 pCi/g) collected in 2019 (SRNS, 2020).

Produce to be processed in the blender

In 2019, DOE-SR edible vegetation exhibited radiological detections of americium-241, curium-244, neptunium-237, plutonium-238, strontium-89/90, technetium-99, uranium-234, uranium-235, and uranium-238 (SRNS, 2020). Potassium-40 was the only gamma analyte detected in 2019 in DHEC samples. 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.

The FDA-derived Guidance Level for Cs-137 is 32.4 pCi/g (FDA, 2005). DHEC did not detect Cs-137 in any samples in 2019. DOE-SR had detections of Cs-137 in seven of the twenty samples collected in 2019 at an average of 0.03 pCi/g (the highest detection being in greens in the NE Quadrant 0-10 miles at 0.08 pCi/g).

9.3.0 CONCLUSIONS AND RECOMMENDATIONS

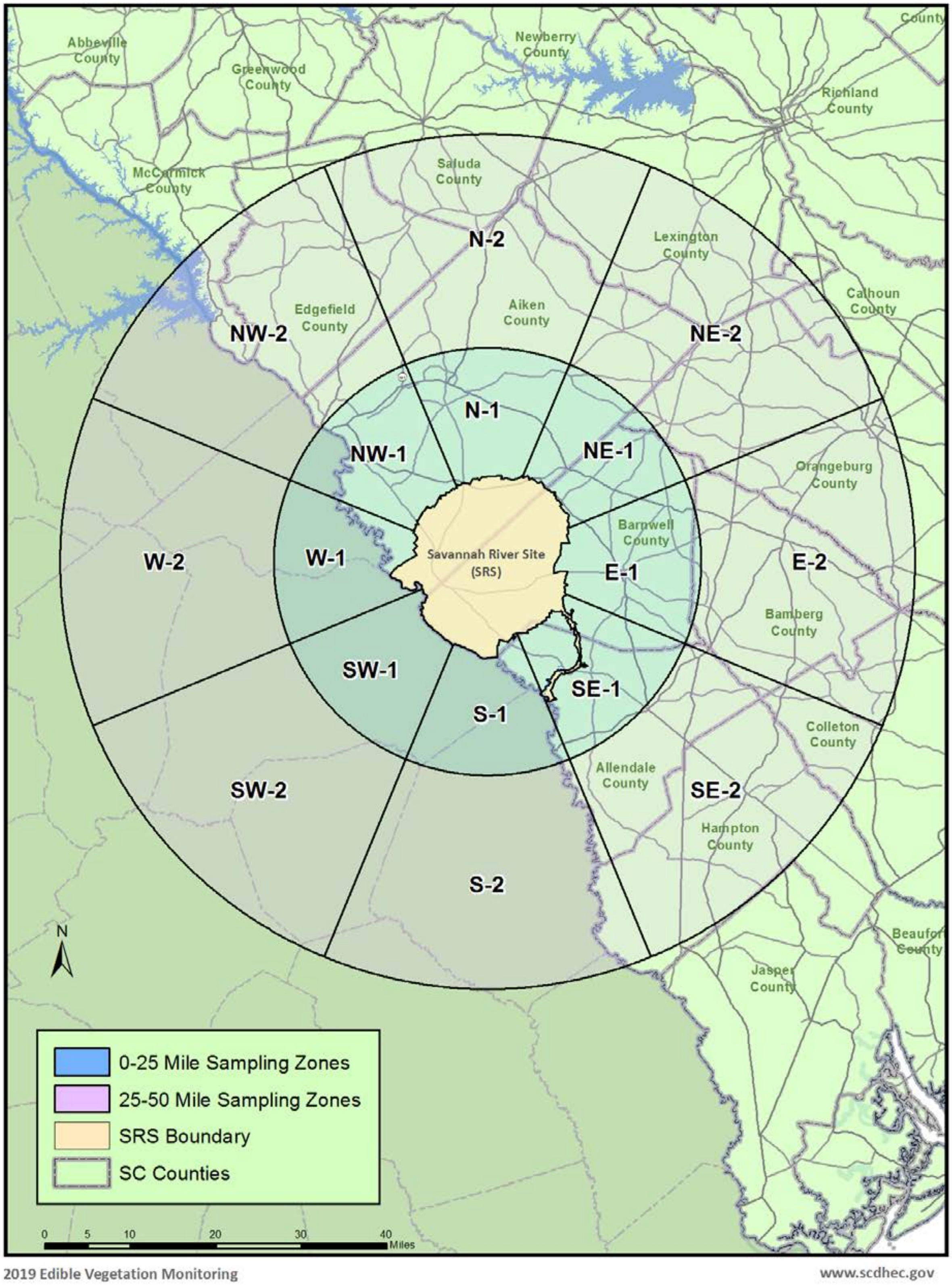
Processed samples ready for analysis

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. 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



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 2019, 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 2019. 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 2019, 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 2019 exhibited tritium activity above the LLD (2019 DHEC Data File). DOE-SR did not detect tritium in any of the samples collected in 2019 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 2019. All analytical results for these radionuclides were below the sample MDA except for naturally occurring K-40. These results can be found in the 2019 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 did not detect Cs-137 in cow milk. DOE-SR detected both Cs-137 and Sr-90 in samples 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.

Six of the 16 DHEC milk samples collected in 2019 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, 2019). DOE-SR detected Sr-89/90 in two of the 16 samples collected in 2019 in South Carolina, which found the average activity level to be 2.30 pCi/L in cow milk (SRNS, 2020).

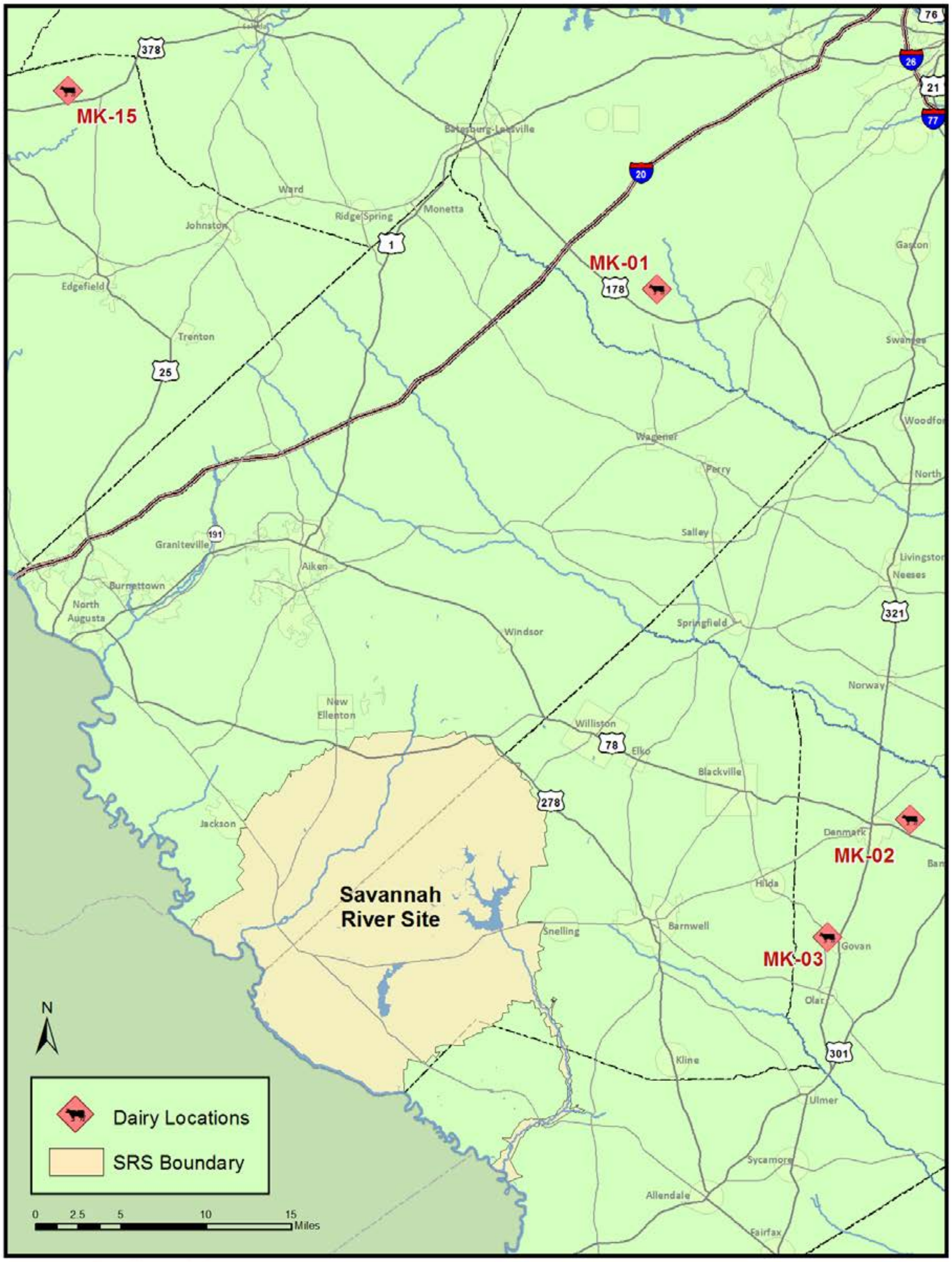
10.3.0 CONCLUSIONS AND RECOMMENDATIONS

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

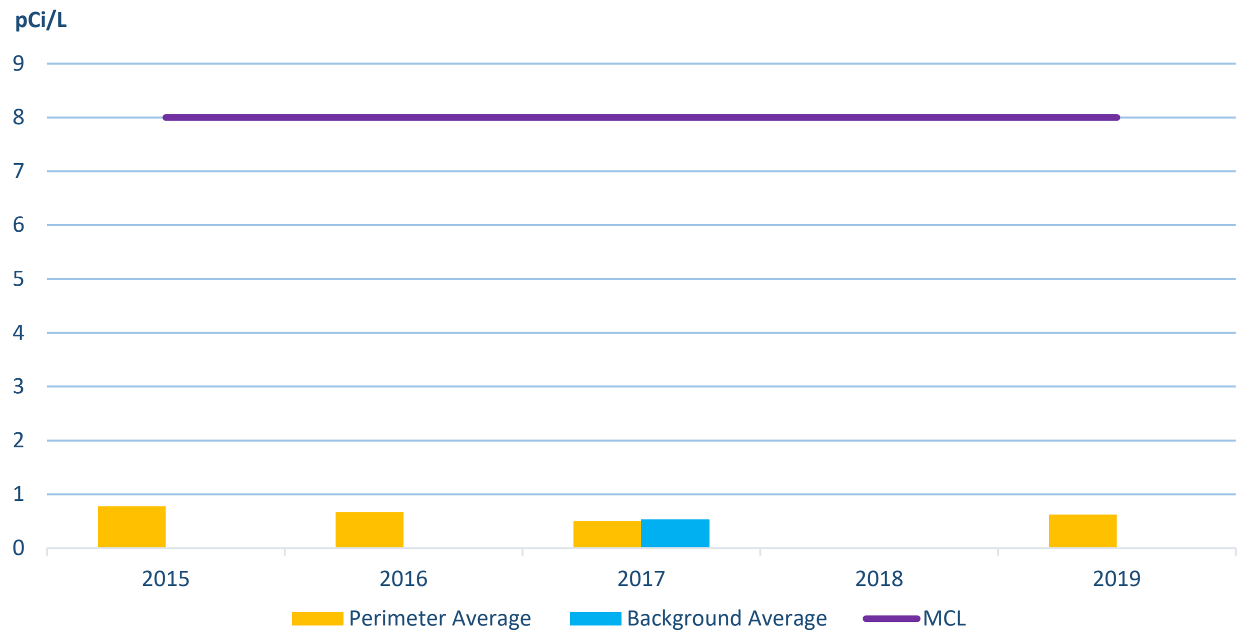
Radiological Dairy Milk Monitoring Sampling Locations



2019 ESOP Dairy Milk Monitoring Map www.scdhec.gov

10.5.0 TABLES AND FIGURES

Figure 1. DHEC Average Strontium-89/90 Data Trends for 2015-2019 (DHEC, 2016-2020)



Note: 1). No bar indicates <MDA
2). No background location was collected in 2018 and 2019

10.6.0 SUMMARY STATISTICS

2019 Strontium-89/90 All Sample Detections

Sample Location	Average (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum Detect (pCi/L)	Maximum Detect (pCi/L)	Number of Detections	Number of Samples
MK-01	0.404	NA	0.404	0.404	0.404	1	4
MK-02	0.676	NA	0.676	0.676	0.676	1	4
MK-03	0.618	0.192	0.699	0.398	0.756	3	4
MK-15	0.808	NA	0.808	0.808	0.808	1	4

Notes:
1). NA is Not Applicable
2). No background sample taken in 2019

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 2019, 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 (*Sciaenopsocellatus*) are caught). Stations sampled in 2019 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 drums and five striped mullets 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 2019 DHEC Data File.

11.2.1 Radiological Data Comparison

DHEC bass and catfish data collected in 2019 were compared to DOE-SR data (SRNS, 2020). 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 2019 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 six 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 2019. DOE-SR detected Cs-137 in catfish at all sampling locations (Section 11.5.0, Table 2). Only DHEC's bass background samples displayed Cs-137, while saltwater stations did not exhibit Cs-137 activity in any samples (Section 11.5.0, Figure 1). None of the mullet collected by DOE-SR had detectable levels of Cs-137 in 2019.

Strontium-89/90 was detected in two stations for the DHEC bass, in one station and in the background location for the catfish samples, and in red drum at the Hwy 17 saltwater location. It was found in all six stations for DOE-SR in both bass and catfish (SRNS, 2020) (Section 11.5.0, Table 3 & 4). Sr-89/90 was also detected in two of three DOE-SR mullet samples.

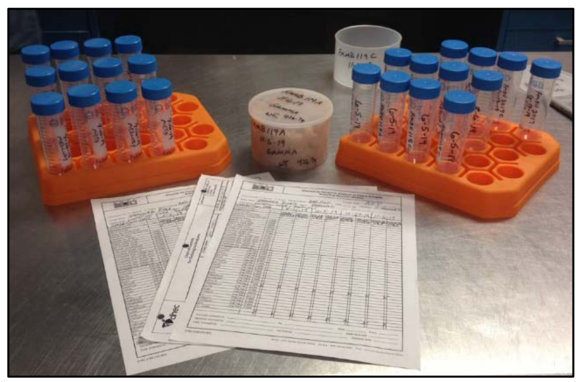
11.2.2 Non-radiological Data Comparison

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

DHEC and DOE-SR analyzed fish for antimony, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc. Due to differences in sampling 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 six DHEC bass composites and four out of the six catfish composite samples from the Savannah River stations (Section 11.5.0, Figure 3). DOE-SR detected mercury in all bass and catfish samples at all six locations. DOE-SR detected mercury in one mullet sample.

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.

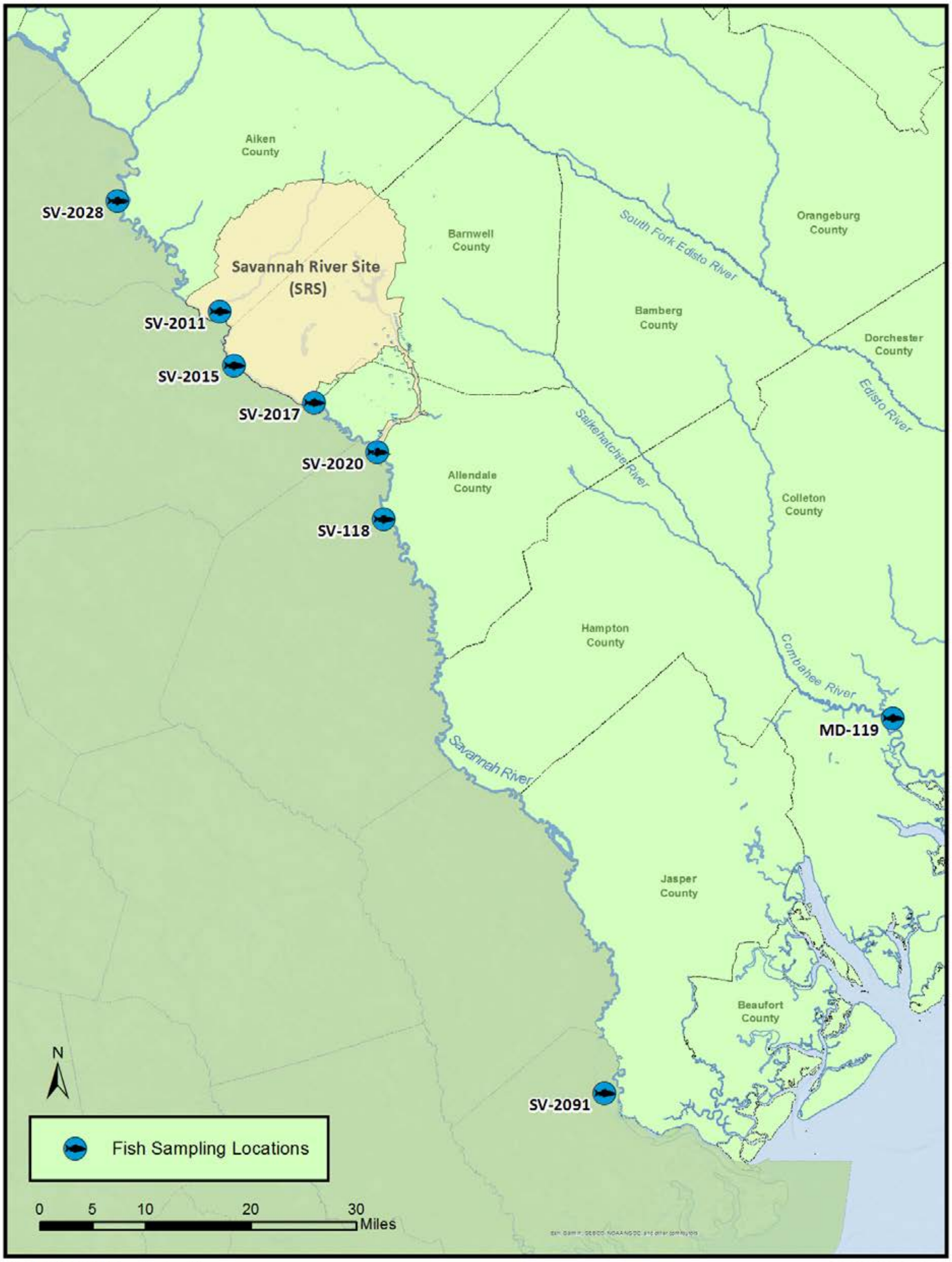


Prepared fish samples ready for laboratory analysis

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



2019 ESOP Fish Monitoring Map

www.scdhec.gov

11.5.0 TABLES AND FIGURES

2019 DHEC and DOE-SR Data Comparison (SRNS, 2020)

Table 1. Cesium-137 in Edible Bass

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	<MDA
	DOE-SR	1	0.02
Upper Three Runs	DHEC	0	<MDA
	DOE-SR	1	0.04
Fourmile Branch	DHEC	0	<MDA
	DOE-SR	3	0.10
Steel Creek	DHEC	1	0.21
	DOE-SR	3	0.09
Lower Three Runs	DHEC	0	<MDA
	DOE-SR	3	0.19
Hwy. 301	DHEC	1	0.22
	DOE-SR	3	0.02

Table 2. Cesium-137 in Edible Catfish

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	<MDA
	DOE-SR	3	0.03
Upper Three Runs	DHEC	0	<MDA
	DOE-SR	1	0.04
Fourmile Branch	DHEC	1	0.06
	DOE-SR	3	0.06
Steel Creek	DHEC	1	0.21
	DOE-SR	3	0.10
Lower Three Runs	DHEC	1	0.13
	DOE-SR	3	0.08
Hwy. 301	DHEC	0	<MDA
	DOE-SR	3	0.02

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

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	3	0.533
Upper Three Runs	DHEC	1	0.098
	DOE-SR	3	0.830
Fourmile Branch	DHEC	1	0.085
	DOE-SR	3	2.043
Steel Creek	DHEC	0	ND
	DOE-SR	3	0.816
Lower Three Runs	DHEC	0	ND
	DOE-SR	3	0.538
Hwy. 301	DHEC	0	ND
	DOE-SR	3	0.659

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

Location	Agency	Number of Detects	Result (pCi/g)
NSBLD	DHEC	0	ND
	DOE-SR	3	0.650
Upper Three Runs	DHEC	1	0.153
	DOE-SR	3	0.754
Fourmile Branch	DHEC	0	ND
	DOE-SR	3	0.794
Steel Creek	DHEC	0	ND
	DOE-SR	3	0.744
Lower Three Runs	DHEC	0	ND
	DOE-SR	3	0.711
Hwy. 301	DHEC	0	ND
	DOE-SR	3	0.780

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TABLES AND FIGURES

2019 DHEC and DOE-SR Data Comparison (SRNS, 2020)

Table 5. Mercury in Edible Bass

Location	Agency	Number of Detects	Result (mg/kg)
NSBLD	DHEC	1	0.74
	DOE-SR	7	0.35
Upper Three Runs	DHEC	1	0.32
	DOE-SR	7	0.37
Fourmile Branch	DHEC	1	0.40
	DOE-SR	7	0.51
Steel Creek	DHEC	1	0.52
	DOE-SR	7	0.49
Lower Three Runs	DHEC	1	0.44
	DOE-SR	7	0.57
Hwy. 301	DHEC	1	0.60
	DOE-SR	7	0.50

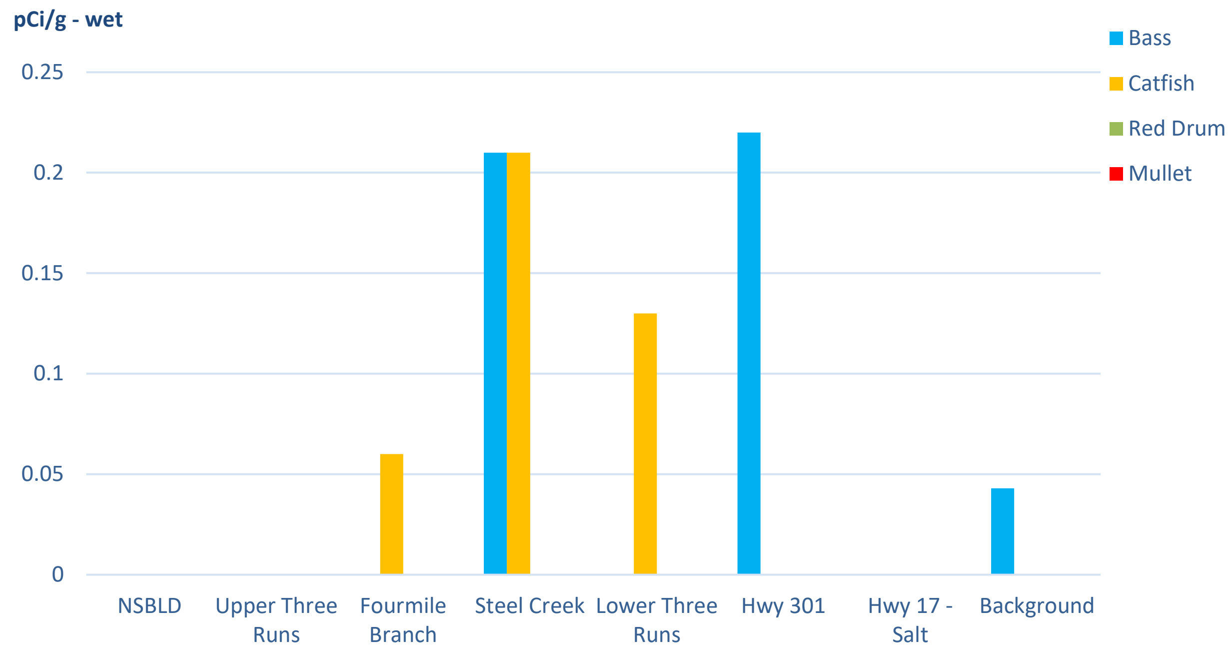
Table 6. Mercury in Edible Catfish

Location	Agency	Number of Detects	Result (mg/kg)
NSBLD	DHEC	0	ND
	DOE-SR	7	0.09
Upper Three Runs	DHEC	0	ND
	DOE-SR	7	0.20
Fourmile Branch	DHEC	1	0.14
	DOE-SR	7	0.19
Steel Creek	DHEC	1	0.15
	DOE-SR	7	0.34
Lower Three Runs	DHEC	1	0.24
	DOE-SR	7	0.17
Hwy. 301	DHEC	1	0.14
	DOE-SR	7	0.24

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

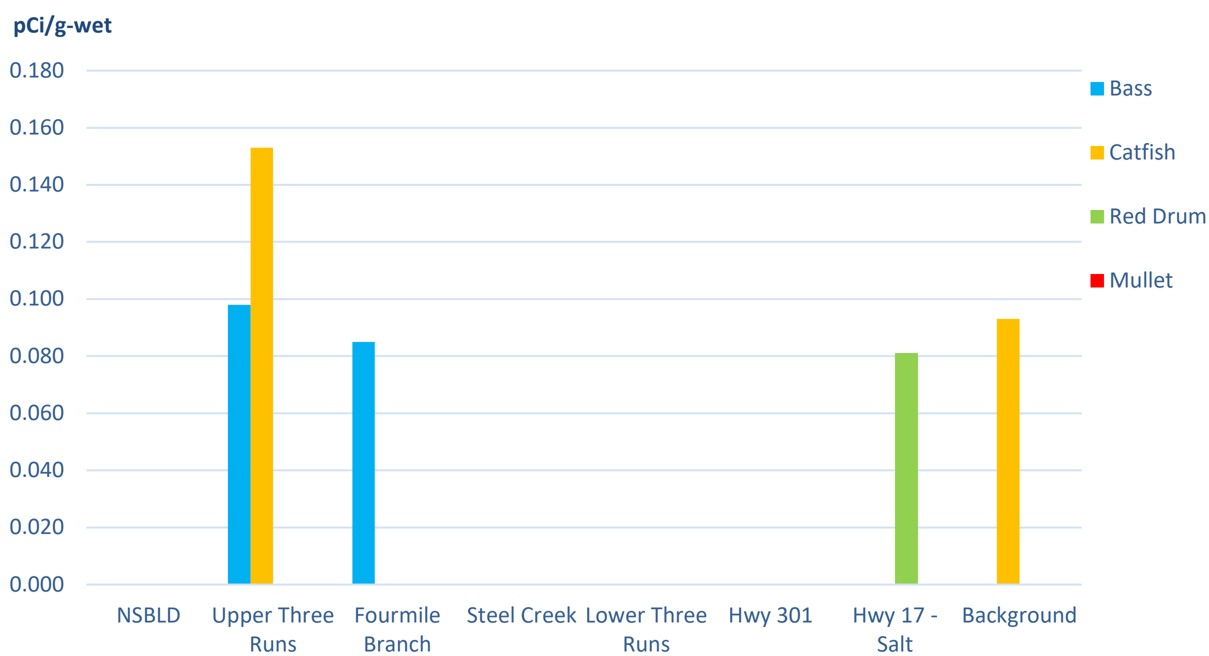
TABLES AND FIGURES

Figure 1. 2019 DHEC Cesium-137 in Fish Composites



Note: Missing bars indicate <MDA

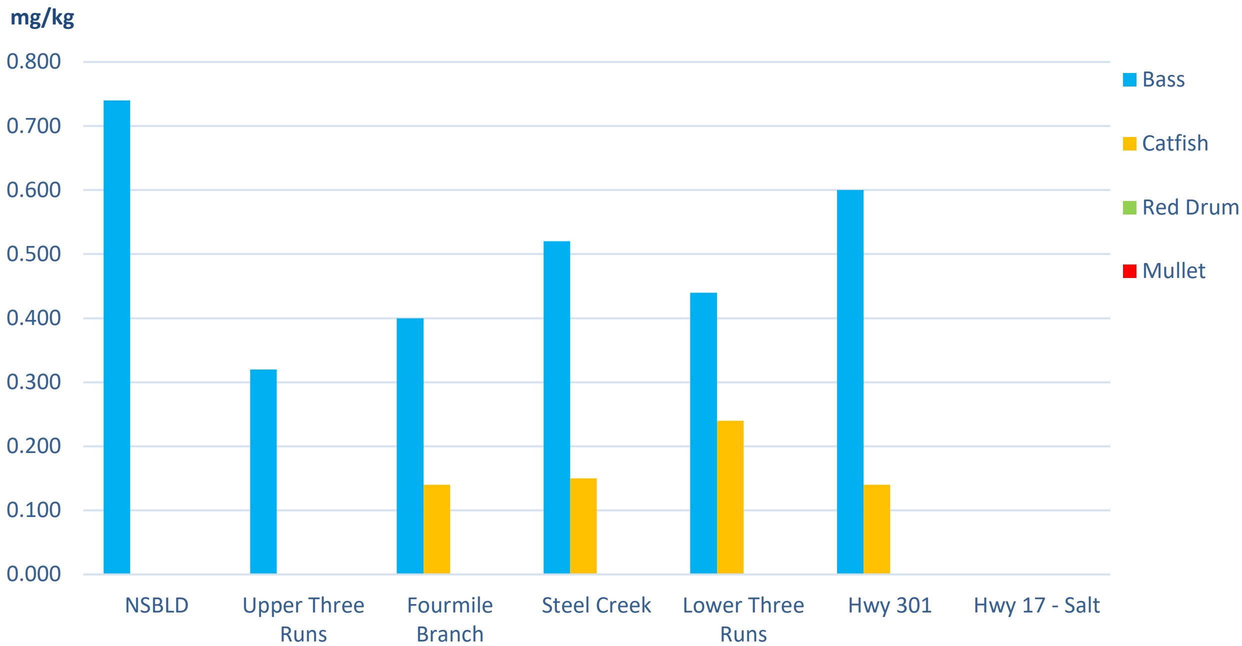
Figure 2. 2019 DHEC Strontium-89/90 in Fish Bone Composites



Note: Missing bars indicate <MDA

TABLES AND FIGURES

Figure 3. 2019 DHEC Mercury in Fish



Note: Missing bars indicate <LLD
Due to lab error, DHEC did not have a sample for the background location for mercury in 2019

11.6.0 SUMMARY STATISTICS

2019 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	0.216	0.002	0.216	0.214	0.217	2	6
Catfish	0.131	0.078	0.127	0.056	0.211	3	6

2019 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	0.092	0.009	0.092	0.085	0.098	2	6
Catfish	0.153	NA	0.153	0.153	0.153	1	6

2019 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	0.503	0.150	0.480	0.320	0.740	6	6
Catfish	0.168	0.049	0.145	0.140	0.240	4	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 2019 DHEC Data File.

DHEC analyzed muscle tissue collected in 2019 for Cs-137 from 29 deer and five 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 at Pinckney Island National Refuge. Sample size, location, and collection dates were dependent on the participating hunters.

Cesium-137 and the naturally occurring K-40 and Pb-214 were the only isotopes detected in game samples collected in 2019. 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

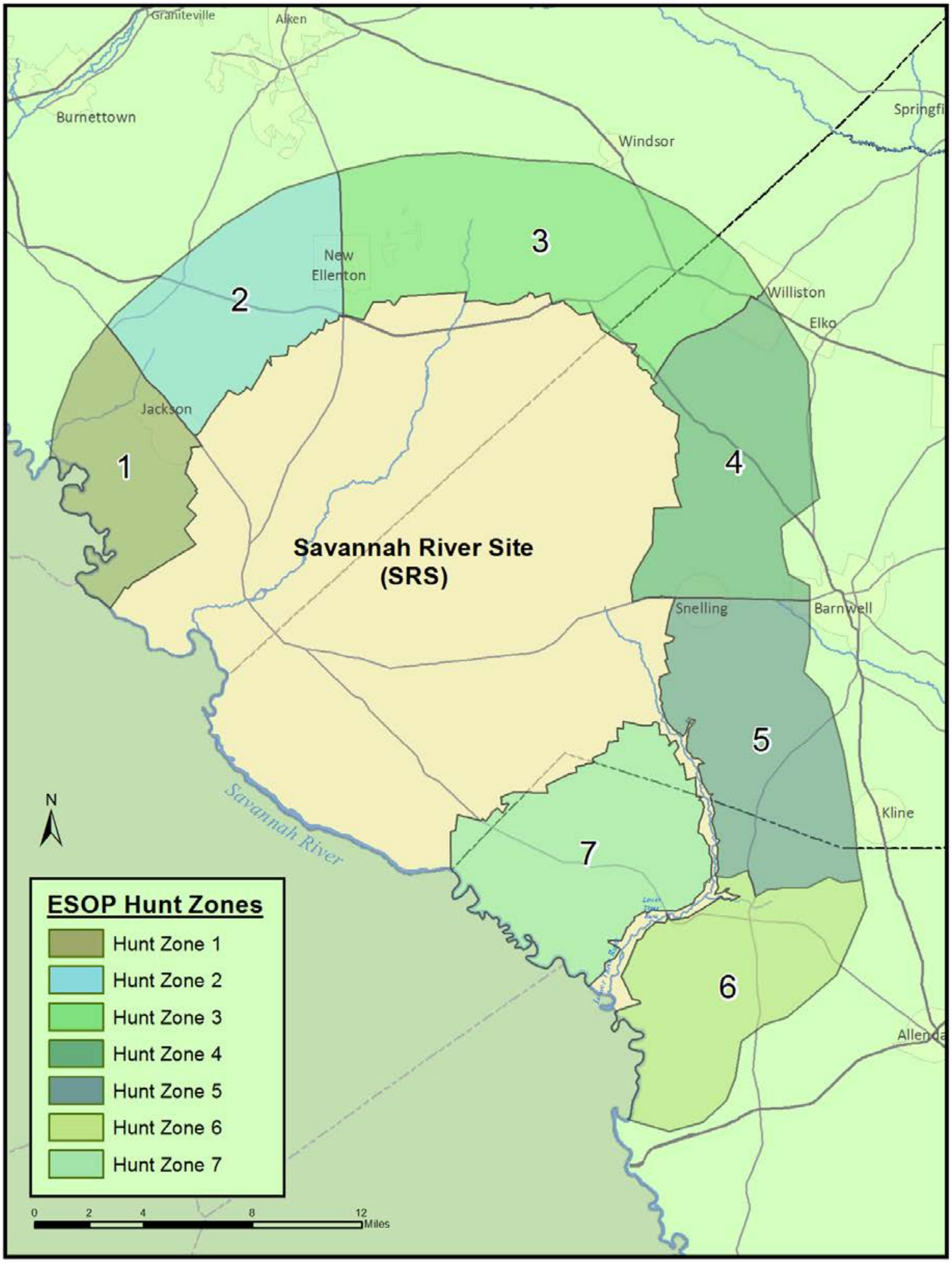
Historic SRS operations released known Cs-137 contamination to Steel Creek, Par Pond, Lower Three Runs, their floodplains, and the Savannah River swamp (Till et al., 2001), all of which impact hunt zones four, five, six, and seven (Section 12.4.0, Map). Although a portion of Cs-137 was deposited on SRS 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 2019 DHEC Critical Pathway Dose section of this 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



2019 ESOP Game Animal Monitoring

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12.5.0 TABLES AND FIGURES

Figure 1. 2019 DHEC Hunt Zone Average Cs-137 Concentration in Game

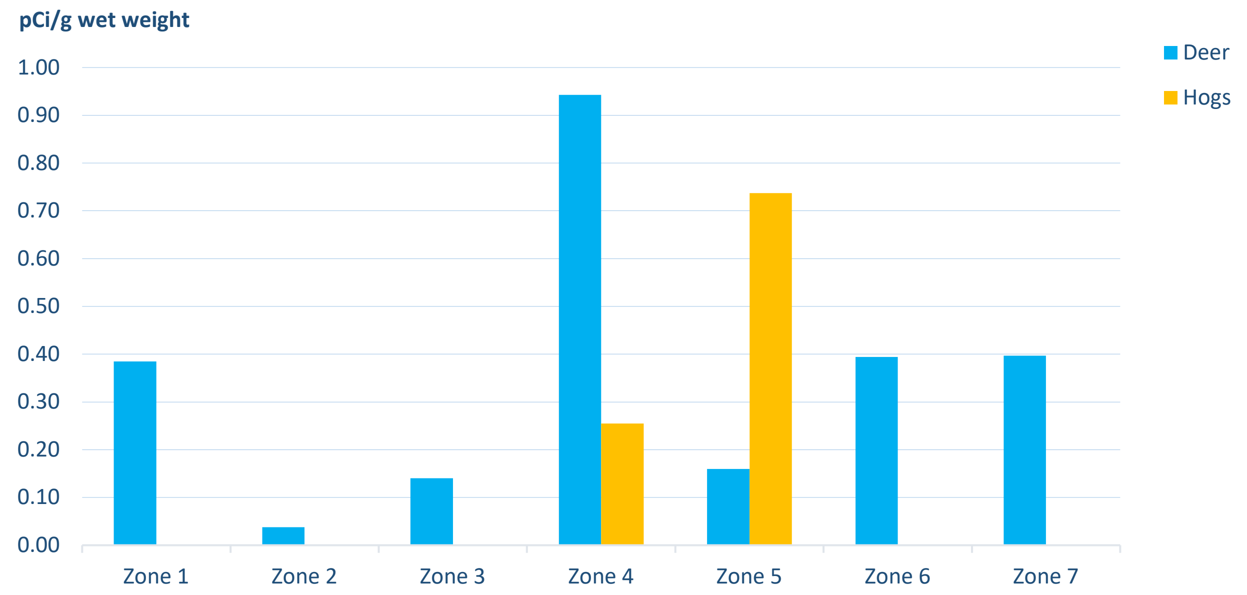
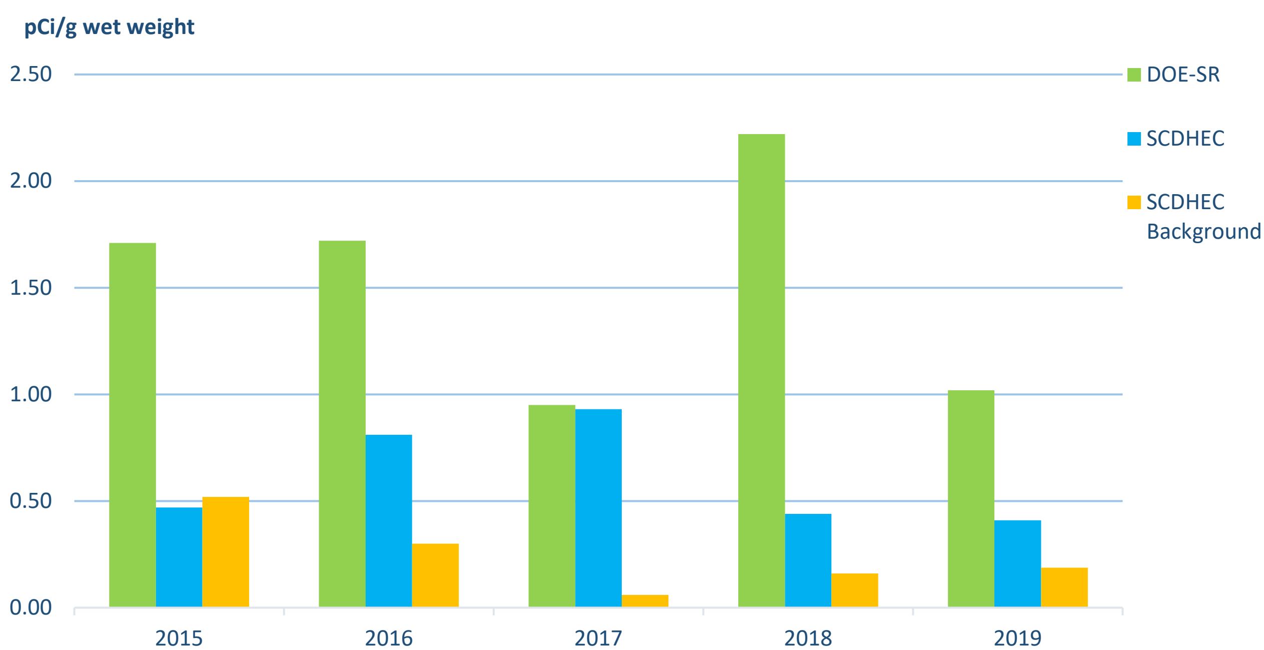


Figure 2. 2015-2019 Average Cs-137 Concentration in Deer (SRNS, 2016a-2020; DHEC, 2016-2018)



Notes:
1). 2015-2019 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 0.698 pCi/g.

12.6.0 SUMMARY STATISTICS

2019 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	0.410	0.398	0.237	0.038	1.255	20	29
Background Deer	0.187	0.126	0.132	0.053	0.366	5	5

2019 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	0.385	0.304	0.348	0.095	0.822	5	5
Zone 2 Deer	0.038	NA	0.038	0.038	0.038	1	3
Zone 3 Deer	0.140	0.109	0.086	0.069	0.265	3	5
Zone 4 Deer	0.943	0.412	1.066	0.387	1.255	4	5
Zone 5 Deer	0.160	0.050	0.160	0.112	0.209	3	4
Zone 6 Deer	0.394	NA	0.394	0.394	0.394	1	4
Zone 7 Deer	0.397	0.457	0.202	0.069	0.092	3	3

2019 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	0.255	0.212	0.155	0.111	0.499	3	3
Zone 5 Hogs	0.737	0.114	0.737	0.656	0.817	2	2

Note: Zones 1, 2, 3, 6, 7 and the background did not have samples collected in 2019

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Chapter 13 Critical Pathway and Dose

13.1.0 PROJECT SUMMARY

DHEC implemented a Radionuclide Dose Calculation Project/Critical Pathway Project to calculate the potential exposure or dose to the public within 50-miles of an SRS center point. This study area was chosen for comparison to the 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 2019 Dose Data can be found in Section 13.5.0.

The DHEC MEI is a hypothetical subsistence and survivalist type of individual who resides downriver in the 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 2019 data and dose results are discussed under the following headings in this section: 2019 AEI and MEI Dose, Critical Pathways 2019 Summary, and DOE-SR and DHEC 2019 Comparisons. Total AEI Dose covers the 2010-2019 period, whereas other headings discuss only 2019 data. Not all media were collected for all years during this summary period (2010-2019).

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.

13.2.1 2019 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 2019, the calculated AEI dose was 0.964 mrem (Section 13.4.0, Table 1), with 0.955 mrem from food dose. If wild game is not consumed, the AEI dose falls to 0.074 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 2019, the total calculated MEI dose was 6.352 mrem, of which 6.318 mrem was attributable to food consumption. If wild game is not consumed, the MEI dose falls to 0.552 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 2019. 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. Unspeciated dose assignments were discontinued in 2010 and replaced by calculating a MEI dose potential from the single highest detection per radionuclide per media.

13.2.2 Critical Pathways 2019 Summary

Atmospheric Pathway 2019 Summary

The DHEC 2019 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 0.893 mrem, at 92.63 percent, of dose to the AEI and 5.811 mrem, at 91.48 percent, of dose to the MEI. The primary contributor to the atmospheric pathway was Cs-137 in wild game.

Liquid Pathway 2019 Summary

The DHEC 2019 liquid pathway estimated AEI dose to the individual was from the consumption of fish and drinking water from the Savannah River (Section 13.4.0, Table 2). The liquid pathway contributions to dose exposure were second to those contributed by the atmospheric pathway. In 2019, the liquid pathway contribution to the AEI was 0.071 mrem, accounting for 7.37 percent of dose. The contribution to the MEI dose was 0.541 mrem, at 8.52 percent. The primary contributor to dose in the liquid pathway was Cs-137 in fish.

Food Sub-pathway 2019 Summary

The food sub-pathway was covered under the atmospheric and liquid pathways except for these additional observations. The annual 2019 DHEC AEI food sub-pathway dose order, highest to lowest for averages, was wild game (deer; 0.47 mrem), wild game (hog; 0.42 mrem), fish (0.064

mrem), and milk (0.001 mrem). Edible vegetation, fungi, and incidental soil ingestion did not contribute any quantifiable dose.

The 2019 MEI food pathway order was wild game (deer; 4.65 mrem), wild game (hog; 1.15 mrem), fish (0.515 mrem), and milk (0.003 mrem). Edible vegetation, fungi, and incidental soil ingestion did not contribute any quantifiable dose. Cs-137 was the predominant dose contributor to food through the consumption of deer for the AEI and 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. Cs-137 also contributed to dose from fish and Sr-89/90 contributed to dose from milk.

Isotopic Contribution Summary

Most of the AEI dose exposure in 2019 was due to Cs-137: 0.954 mrem (98.96 percent) of the 0.964 mrem total. The primary contributor to the Cs-137 AEI dose was wild game (deer). Tritium was the second highest dose contributor in 2019 at 0.009 mrem (0.93 percent). Cesium-137 and H-3 were both found in the atmospheric and the liquid pathways while Sr-89/90 was found in the atmospheric pathway only.

Cs-137 was also the primary contributor to the MEI, at 6.315 mrem (99.42 percent) of the 6.352 mrem total, with H-3 second, at 0.034 mrem. Cs-137 in wild game (deer) was the single largest dose contributor to the MEI.

13.2.3 2010-2019 Total AEI Dose

Section 13.4.0, Table 4 summarizes dose associated with all media on an AEI basis from 2010-2019. The critical pathway basis of comparison for DHEC detected dose comes from releases of radionuclides that were deposited outside of SRS during 2010-2019 and within 50 miles of the SRS center point although animals that are harvested off-site may have migrated from on-site.

Table 4 illustrates the dominance of the atmospheric pathway accumulated dose which accounted for 92.74 percent, over the liquid pathway, at 7.26 percent. The food sub-pathway was the dominant route, accounting for 99.34 percent of accumulated exposure. The AEI received a 31.19 mrem average dose per year during the 2010-2019-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 2019, 0.964 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 2010-2019 was wild game (deer and hog). In total it accounted for 23.024 mrem, which amounts to 73.83 percent of the total accumulated AEI exposure (31.185 mrem) during that time period. Following wild game were fungi (4.623 mrem; 14.82 percent), fish (2.086 mrem; 6.69 percent), and edible vegetation (1.031 mrem; 3.31 percent). Furthermore, wild game accounted for 79.61 percent of the accumulated dose from the atmospheric pathway and 74.32 percent of the food sub-pathway.

The predominant routes of accumulated exposure from 2010-2019 for water sources were public system water from the Savannah River (0.099 mrem) and water from private wells (0.022 mrem). The primary routes for minor sources of accumulated dose were incidental ingestion from swimming (0.031 mrem) and from the inhalation of tritium in air (0.020 mrem).

13.2.4 DOE-SR and DHEC 2019 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, 2020). 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, milk, and inhalation doses, serve as a means of comparison of the dose a 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 DOE-SR off-site hog consumption, off-site deer consumption, and swamp fisherman doses and the DHEC hog, deer, and fish doses at the mouth of 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.

3. With DOE-SR creek mouth fisherman dose being derived from fish caught at the mouth of Lower Three Runs, DHEC uses only that location to calculate a comparable creek fisherman dose.

The DOE-SR all-pathways representative person dose and the DHEC all-pathway approximation were the most relevant dose estimates that represent the potential dose exposure for the general public in 2019. The DOE-SR all-pathways representative person dose for 2019 was 0.18 mrem (Section 13.4.0, Table 3). The sum of the DHEC fish, wading, swimming, public system drinking water from the Savannah River, vegetation, milk, and inhalation doses was 0.29 mrem in 2019. The DHEC all-pathway approximation for 2019 is 0.29 percent of the DOE all-pathway dose standard of 100 mrem/yr (SRNS, 2020).

In 2019, the DOE-SR creek mouth fisherman dose (0.227 mrem), which uses fish caught from the mouth of Lower Three Runs, was higher than DHEC’s estimate from the same location (0.156 mrem). The DOE-SR off-site deer hunter dose estimate of 2.12 mrem was lower than DHEC’s 4.65 mrem estimate while the off-site hog hunter estimate of 7.74 mrem was higher than DHEC’s 1.15 mrem estimate (Section 13.4.0, Table 3).

13.2.5 Dose Critique

In 2019, most sampling resulted in less than minimum detectable activity (MDA) determinations and was not included in the DHEC summary statistics, which used detections only. The use of detections only in calculations was protective and biases the measures of central tendency higher (Gilbert, 1987).

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 using detections only was to allow for undetected radionuclides and media. 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 media were stored and consumed over the entire year.

The DHEC 2010 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 2019 results indicated that monitoring of the primary inhalation, ingestion, and direct exposure routes from the atmospheric and liquid pathways should continue. Groundwater, 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 off-site 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

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	0.002	0.007
Air Inhalation Total			**0.002**	**0.007**
Liquid	Ingestion	Fish	0.064	0.515
Atmospheric	Ingestion	Cow Milk	0.001	0.003
Atmospheric	Ingestion	Wild Game (Deer)	0.47	4.65
Atmospheric	Ingestion	Wild Game (Hog)	0.42	1.15
Atmospheric	Ingestion	Vegetation (Fruit, and Vegetables)	ND	ND
Atmospheric	Ingestion	Fungi	ND	ND
Atmospheric	Ingestion	Soil Ingestion with Food	0.000	0.000
Food Ingestion Total			**0.955**	**6.318**
Liquid	Ingestion	Public System Drinking Water - Savannah River	0.007	0.025
Liquid	Ingestion	Public System Drinking Water - Groundwater	ND	ND
Liquid	Ingestion	Private Wells	ND	ND
Liquid	Ingestion	Ingestion from Swimming	0.000	0.001
Drinking Water Total			**0.007**	**0.026**
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			**0.964**	**6.352**

Note:
1. ND is No Detections in 2019
2. Aquifers from which private wells are drawn were sampled in 2019. Individual private wells were not sampled.

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

Critical Pathway Summary	AEI	MEI
The Atmospheric Pathway Totals	0.893	5.811
The Liquid Pathway Totals	0.071	0.541
Combined Dose	**0.964**	**6.352**

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]	0.18	0.29
Sportsman	On-site Hunter	17.4	NS
Sportsman	On-site Turkey	ND	NS
	Swamp Fisherman (fish only)[4]	0.118	0.257
	Creek Mouth Fisherman[5]	0.227	0.156
	Off-site Hunter Deer	2.12	4.65
	Off-site Hunter Hog	7.74	1.15
	Edible Fungi	NS	ND

Notes:
1. DOE-SR data from Table 6-5a and Table 6-6 (SRNS, 2020).
2. Based on DHEC maximums or single highest detection basis for all media per route of exposure unless otherwise specified (Table 1).
3. Sum of DHEC highest Steel Creek fish, wading exposure, swimming ingestion, Savannah River derived drinking water (treated only), vegetation, milk, and atmospheric inhalation.
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).

TABLES AND FIGURES

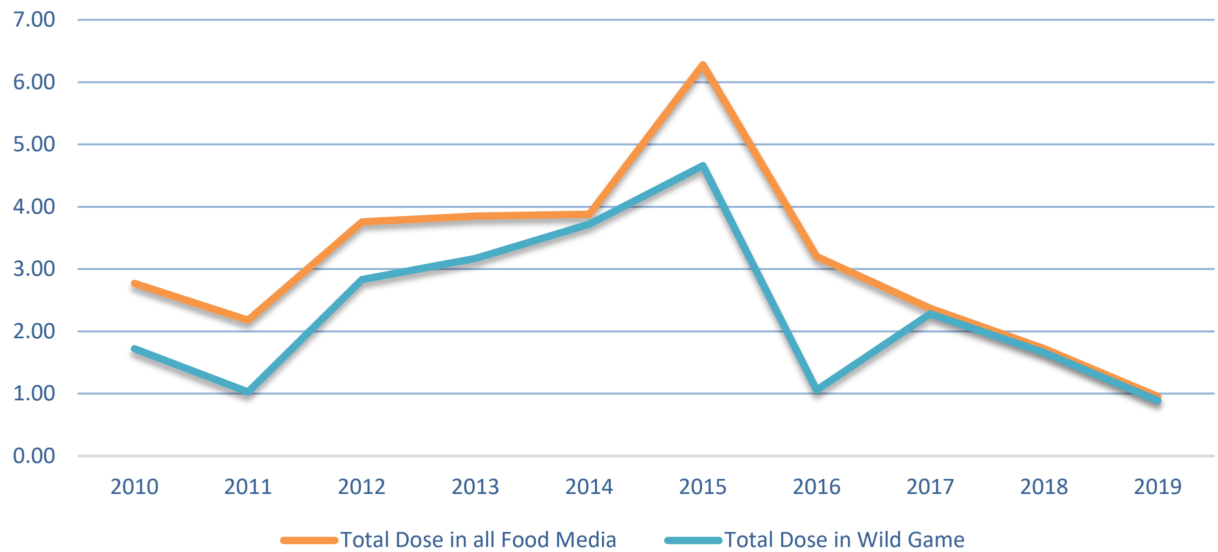
Table 4. 2010-2019 AEI Exposure: Total AEI Dose (mrem) and Percentage

Pathway	AEI Media Categories	2019[1]	2010-2019[2]	2010-2019 % AEI[3]
Atmospheric	Surface Soil Resuspension Inhalation	0.000	0.009	0.03
Atmospheric	H-3 Inhalation	0.002	0.020	0.06
Liquid	Fish	0.064	2.086	6.69
Atmospheric	Cow Milk	0.001	0.214	0.69
Atmospheric	Wild Game	0.890[4]	23.024	73.83
Atmospheric	Vegetation (Leafy, Fruit, and Nuts)	ND[5]	1.031	3.31
Atmospheric	Fungi	ND[5]	4.623	14.82
Atmospheric	Soil Ingestion with Food	0.000	0.000	0.00
Liquid	Public System Water from the Savannah River	0.007	0.099	0.32
Liquid	Public System Water from Groundwater	ND[5]	0.015	0.05
Liquid	Private Wells	ND[5]	0.022	0.07
Liquid	Ingestion from Swimming	0.000	0.031	0.10
Liquid	Direct Exposure from Swimming	0.000	0.000	0.00
Liquid	Direct Exposure from Wading	0.000	0.010	0.03
Atmospheric	Direct Exposure from Farm Soil	0.000	0.001	0.00
Totals		0.964	31.185	100%

Notes:
1. The 2019 column is average dose in mrem during 2019.
2. The 2010-2019 column is total dose in mrem over the 2010-2019 ten-year period.
3. The AEI % basis column is the percentage of the 2010-2019 total dose due to a given media.
4. Deer and hog in 2019.
5. There were no detections in 2019.

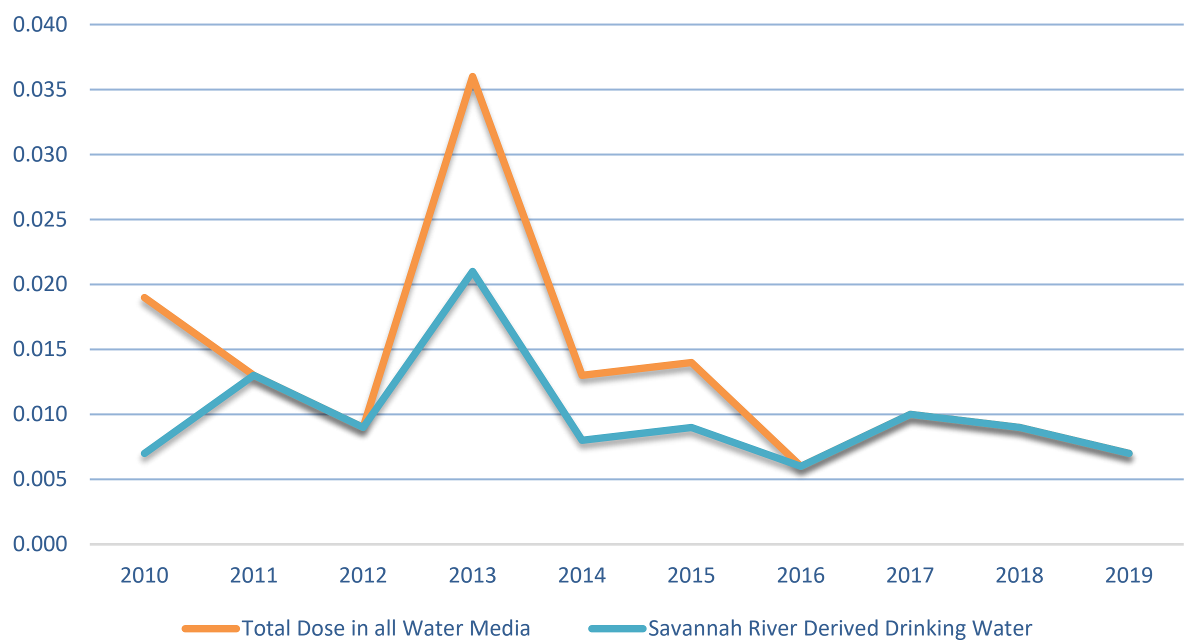
TABLES AND FIGURES

Figure 1. 2010-2019 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 2019 in mrem. Sources are DHEC, 2012, 2013a, 2014a, 2015, 2016, 2017, 2018, 2019, and 2020.

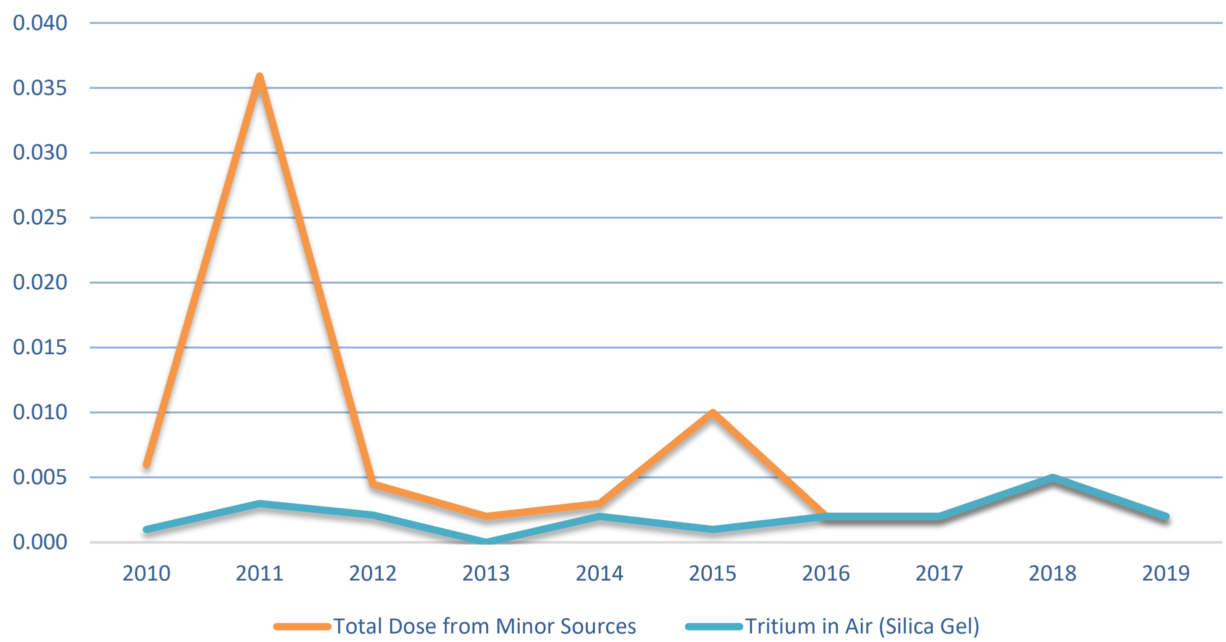
Figure 2. 2010-2019 DHEC AEI Water Dose



Note: This graph shows the total water AEI dose trend and the trend for the primary contributor to that dose from 2019 in mrem. Sources are DHEC, 2012, 2013a, 2014a, 2015, 2016, 2017, 2018, 2019, and 2020.

TABLES AND FIGURES

Figure 3. 2010-2019 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 2019 in mrem. Sources are DHEC, 2012, 2013a, 2014a, 2015, 2016, 2017, 2018, 2019, and 2020.

13.5.0 2019 DOSE DATA

AEI Fish Dose

Dose from Fish Ingestion (AEI)				
Media	**Radionuclide**	**Activity (pCi/g)**	**Consumption Rate (kg/yr)**	**Dose (mrem)**
Bass	Cs-137	0.216	3.7	0.040
Bass	Sr-89/90	0.092	3.7	0.000
Catfish	Cs-137	0.131	3.7	0.024
Catfish	Sr-89/90	0.153	3.7	0.000
Drum	Cs-137	ND	3.7	ND
Drum	Sr-89/90	0.081	3.7	0.000
Mullet	Cs-137	ND	3.7	ND
Mullet	Sr-89/90	ND	3.7	ND
Fish Total				0.064

MEI Fish Dose

Dose from Fish Ingestion (MEI)				
Media	**Radionuclide**	**Activity (pCi/g)**	**Consumption Rate (kg/yr)**	**Dose (mrem)**
Bass	Cs-137	0.217	24.0	0.261
Bass	Sr-89/90	0.098	24.0	0.000
Catfish	Cs-137	0.211	24.0	0.254
Catfish	Sr-89/90	0.153	24.0	0.000
Drum	Cs-137	ND	24.0	ND
Drum	Sr-89/90	.081	24.0	0.000
Mullet	Cs-137	ND	24.0	ND
Mullet	Sr-89/90	ND	24.0	ND
Fish Total				0.515

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; EPA, 2011; and SRNS, 2020.

2019 DOSE DATA

AEI Milk Dose

Dose from Milk (AEI)				
Media	**Radionuclide**	**Activity (pCi/L)**	**Consumption Rate (kg/yr)**	**Dose (mrem)**
Milk	H-3	ND	69.0	ND
	Cs-137	ND	69.0	ND
	Sr-89/90	0.624	69.0	0.001
	I-131	ND	69.0	ND
Milk Total				**0.001**

MEI Milk Dose

Dose from Milk (MEI)				
Media	Radionuclide	**Activity (pCi/L)**	**Consumption Rate (kg/yr)**	**Dose (mrem)**
Milk	H-3	ND	260.0	ND
	Cs-137	ND	260.0	ND
	Sr-89/90	0.808	260.0	0.003
	I-131	ND	260.0	ND
Milk Total				**0.003**

AEI Wild Game Dose

Dose from Wild Game (AEI)		
Media	**Radionuclide**	**Dose**
Deer	Cs-137	0.47
Hog	Cs-137	0.42
Game Total		**0.89**

Note: Deer AEI is based on an edible portion of 52 lbs.; Hog AEI is based on an edible portion of 44 lbs.

MEI Wild Game Dose

Dose from Wild Game (MEI)		
Media	**Radionuclide**	**Dose**
Deer	Cs-137	4.65
Hog	Cs-137	1.15
Game Total		**5.80**

Note: Deer MEI is based on an edible portion of 212 lbs.; Hog MEI is based on an edible portion of 70 lbs.

2019 DOSE DATA

AEI Edible Vegetation Dose

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

2019 MEI Edible Vegetation Dose

Dose in Edible Vegetation (MEI)				
Media	**Radionuclide**	**Activity (pCi/g)**	**Consumption Rate (kg/yr)**	**Dose (mrem)**
Fruit and Vegetables	NA	ND	248	ND
	NA	ND	248	ND
Fruit and Vegetable Total				**ND**
Nuts	NA	NS	NA	NA
	NA	NS	NA	NA
Nuts Total				**NA**
Fungi	NA	ND	10	ND
	NA	ND	10	ND
Fungi Total				**ND**
Combined Vegetation Total				**ND**

2019 DOSE DATA

2019 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**	**343**	**300**	**0.007**
Groundwater Sourced Drinking Water		pCi/L	L/yr	mrem
Groundwater	**H-3**	**ND**	**300**	**NA**
Private Wells Groundwater		pCi/L	L/yr	mrem
Groundwater	**H-3**	**ND**	**300**	**NA**
Ingestion from Surface Water and Wells Total				**0.007**

Note: Groundwater aquifers that are known to be used for drinking water were used and samples were collected as part of the groundwater project. Individual groundwater sourced drinking water taps were not sampled.

2019 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**	**491**	**800**	**0.025**
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				**0.025**

Note: Groundwater aquifers that are known to be used for drinking water were used and samples were collected as part of the groundwater project. Individual groundwater sourced drinking water taps were not sampled.

2019 DOSE DATA

AEI Incidental Water Ingestion and Direct Exposure from Water Dose

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		**1475**	**0.189**	**0.000**
Surface Water Swimming	H-3	pCi/L	hrs/yr	mrem
Surface Water Immersion		**1475**	**9**	**0.000**
Savannah River Creek Mouth Total				**0.000**

MEI Incidental Water Ingestion and Direct Exposure from Water Dose

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		**8593**	**2.57**	**0.001**
Surface Water Swimming	H-3	pCi/L	hrs/yr	mrem
Surface Water Immersion		**8593**	**36**	**0.000**
Savannah River Creek Mouth Total				**0.001**

2019 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**	**0.585**	**9**	**0.000**
Boat Landings	**Cs-137**	**0.292**	**9**	**0.000**
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**	**1.84**	**36**	**0.000**
Boat Landings	**Cs-137**	**0.532**	**36**	**0.000**
Sediment Total				**0.000**

Return to TOC

2019 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	0.131	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	0.280	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	0.131	2602	0.000
Soil Shine Total				**0.000**

Note: The consumption rate is from Edwards et al., 2012.

2019 MEI Soil Shine Dose

Soil Shine (MEI)				
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**
Surface Soil		pCi/g	hrs/yr	mrem
Ingestion	Cs-137	0.280	2602	0.001
Soil Shine Total				**0.001**

Note: The consumption rate is from Edwards et al., 2012.

2019 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	0.131	5000	0.000
Surface Soil Resuspension Total				**0.000**
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**mrem**
Inhalation	H-3	5.62	5000	0.002
Atmospheric Inhalation Total				**0.002**

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	0.280	6400	0.000
Surface Soil Resuspension Total				
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**Mrem**
Inhalation	H-3	16.12	6400	0.007
Atmospheric Inhalation Total				**0.007**

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