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25 Years Of Environmental Remediation In The General Separations Area Of The Savannah River Site: Lessons Learned About What Worked And What Did Not Work In Soil And Groundwater Cleanup – 15270

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ABSTRACT

The Savannah River Site (SRS) is owned and administered by the US Department of Energy (DOE). SRS covers an area of approximately 900 square kilometers.

The General Separation Area (GSA) is located roughly in the center of the SRS and includes: radioactive material chemical separations facilities, radioactive waste tank farms, a variety of radioactive seepage basins, and the radioactive waste burial grounds. Radioactive wastes were disposed in the GSA from the mid-1950s through the mid-1990s. Radioactive operations at the F Canyon began in 1954; radioactive operations at H Canyon began in 1955. Waste water disposition to the F and H Seepage Basins began soon after operations started in the canyons. The Old Radioactive Waste Burial Ground (ORWBG) began operations in 1952 to manage solid waste that could be radioactive from all the site operations, and ceased receiving waste in 1972. The Mixed Waste Management Facility (MWMF) and Low Level Radioactive Waste Disposal Facility (LLRWDF) received radioactive solid waste from 1969 until 1995.

Environmental legislation enacted in the 1970s, 1980s, and 1990s led to changes in waste management and environmental cleanup practices at SRS. The US Congress passed the Clean Air Act in 1970, and the Clean Water Act in 1972; the Resource Conservation and Recovery Act (RCRA) was enacted in 1976; the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) was enacted by Congress in 1980; the Federal Facilities Compliance Act (FFCA) was signed into law in 1992. Environmental remediation at the SRS essentially began with a 1987 Settlement Agreement between the SRS and the State of South Carolina (under the South Carolina Department of Health and Environmental Control - SCDHEC), which recognized linkage between many SRS waste management facilities and RCRA. The SRS manages several of the larger groundwater remedial activities under RCRA for facilities recognized early on as environmental problems. All subsequent environmental remediation projects tend to be managed under tri-party agreement (DOE, Environmental Protection Agency, and SCDHEC) through the Federal Facilities Agreement.

During 25 years of environmental remediation SRS has stabilized and capped seepage basins, and consolidated and capped waste units and burial grounds in the GSA. Groundwater activities include: pump and treat systems in the groundwater, installation of deep subsurface barrier systems to manage groundwater flow, insitu chemical treatments in the groundwater, and captured contaminated groundwater discharges at the surface for management in a forest irrigation system.

Over the last 25 years concentrations of contaminants in the aquifers beneath the GSA and in surface water streams in the GSA have dropped significantly. Closure of 65 waste sites and 4 RCRA facilities has been successfully accomplished. Wastes have been successfully isolated in place beneath a variety of caps and cover systems. Environmental clean-up has progressed to the stage where most of the work involves monitoring, optimization, and maintenance of existing remedial systems.

Many lessons have been learned in the process. Geotextile covers outperform low permeability clay caps, especially with respect to the amount of repairs required to upkeep the drainage layers as the caps age. Passive, enhanced natural processes to address groundwater contamination are much more cost effective than pump and treat systems.

SRS operated two very large pump and treat systems at the F and H Seepage Basins to attempt to limit the release of tritium to Fourmile Branch, a tributary of the Savannah River. The systems were designed to extract contaminated acidic groundwater, remove all contamination except tritium (not possible to remove the tritium from the water), and inject the tritiated groundwater up-gradient of the source area and the plume. The concept was to increase the travel

time of the injected water for radioactive decay of the tritium. The two systems were found to be non-effective and potentially mobilizing more contamination. SRS invested approximately $50 million in construction and approximately $100 million in 6 years of operation. The H Seepage Basin pump and treat system was replaced by a series of subsurface barriers that alters the groundwater velocity; the F Seepage Basin pump and treat system was replaced by a subsurface barriers forming a funnel and gate augmented by chemical treatment within the gates. These replacement systems are mostly passive and cost approximately $13 million to construct, and have reduced the tritium flux to Fourmile Branch, in these plumes, by over 70%.

SRS manages non-acidic tritiated groundwater releases to Fourmile Branch from the southwest plume of the MWMF with a forest irrigation system. Tritiated water is captured with a sheetpile dam below the springs that caused releases to Fourmile Branch. Water from the irrigation pond is pumped to a filter plant prior to irrigation of approximately 26 hectares of mixed forest and developing pine plantation. SRS has almost achieved a 70% reduction in tritium flux to the Branch from this plume. The system cost approximately $5 million to construct with operation cost of approximately $500K per year.

In conclusion, many lessons have been learned in 25 years of relatively aggressive remedial activities in the GSA. Geotextile covers outperform low permeability clay caps, especially with respect to the amount of repairs required to upkeep the drainage layers as the caps age. Passive, enhanced natural processes to address groundwater contamination are much more cost effective than pump and treat systems. In water management situations with non-accumulative contaminants (tritium, VOCs, etc.) irrigation in a forest setting can be very effective.

INTRODUCTION

The Savannah River Site (SRS) is owned and administered by the US Department of Energy (DOE). SRS covers an area of approximately 900 square kilometers in Aiken, Allendale, and Barnwell counties, in South Carolina. The General Separation Area (GSA) is located roughly in the center of the SRS, on the high ground between two (Upper Three Runs and Fourmile Branch). Figure 1 illustrates the SRS location with respect to South Carolina and Georgia, and the General Separations Area within the site.

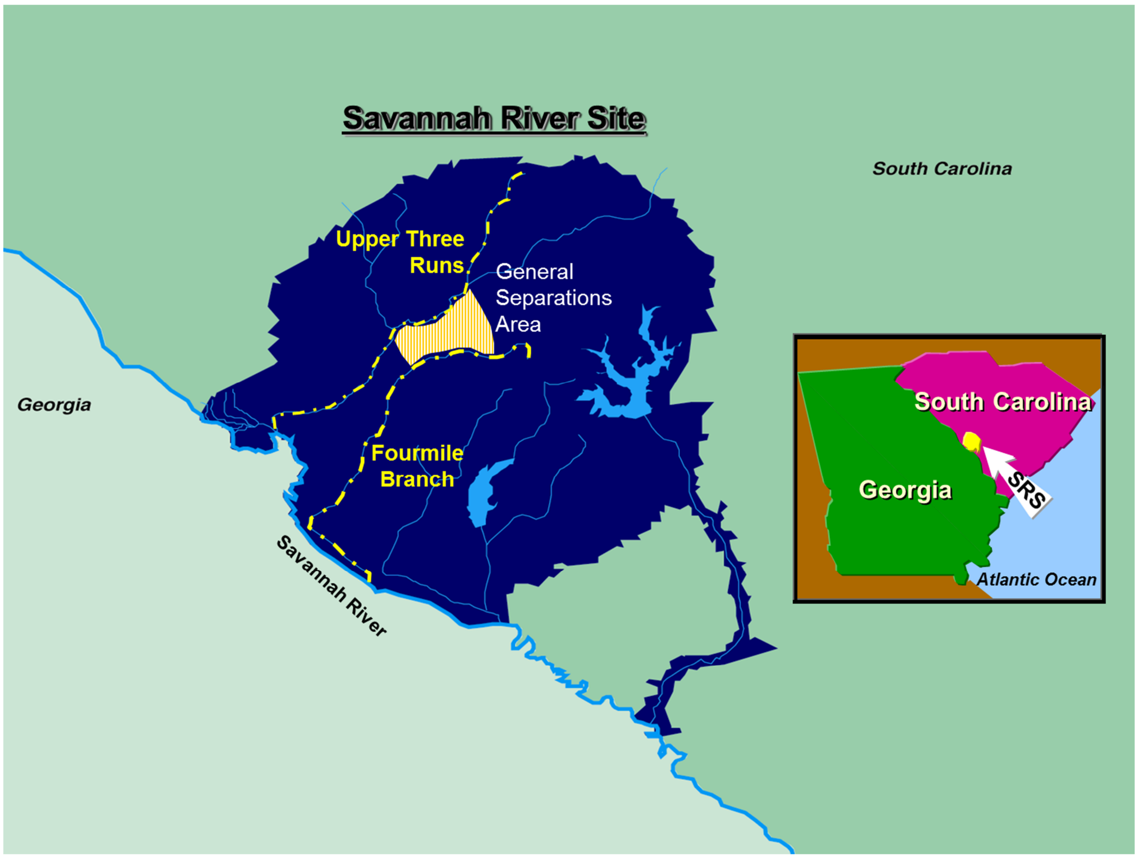

Figure 1. Savannah River Site and General Separations Area location.

The General Separations Area includes: radioactive material chemical separations facilities, radioactive waste tank farms, a variety of radioactive seepage basins, and the radioactive waste burial grounds. Radioactive wastes were disposed in the GSA from the mid-1950s through the mid-1990s. Figure 2 is a timeline of waste disposal facility startup, termination, regulation, and environmental cleanup within the GSA.

Radioactive operations at the F Canyon began in 1954; radioactive operations at H Canyon began in 1955. Waste water disposition to the F and H Seepage Basins began soon after operations started in the canyons. This time period is identified in Figure 2 as “Basin Operations”. The basins were unlined and designed for seepage of acidic low level radioactive deionized waste water into the underlying vadose zone and water table. When seepage rates within the basins were not sufficient to manage the waste water volumes, the basins were further acidified to improve percolation. Nitric acid was the primary process acid, however, oxalic acid was directly applied to the basins in later years to improve percolation.

The Old Radioactive Waste Burial Ground (ORWBG) began operations in 1952 to manage solid waste that could be radioactive from all the site operations, and ceased receiving waste in 1972. The Mixed Waste Management Facility (MWMF) and Low Level Radioactive Waste Disposal Facility (LLRWDF) received radioactive solid waste from 1969 until 1995.

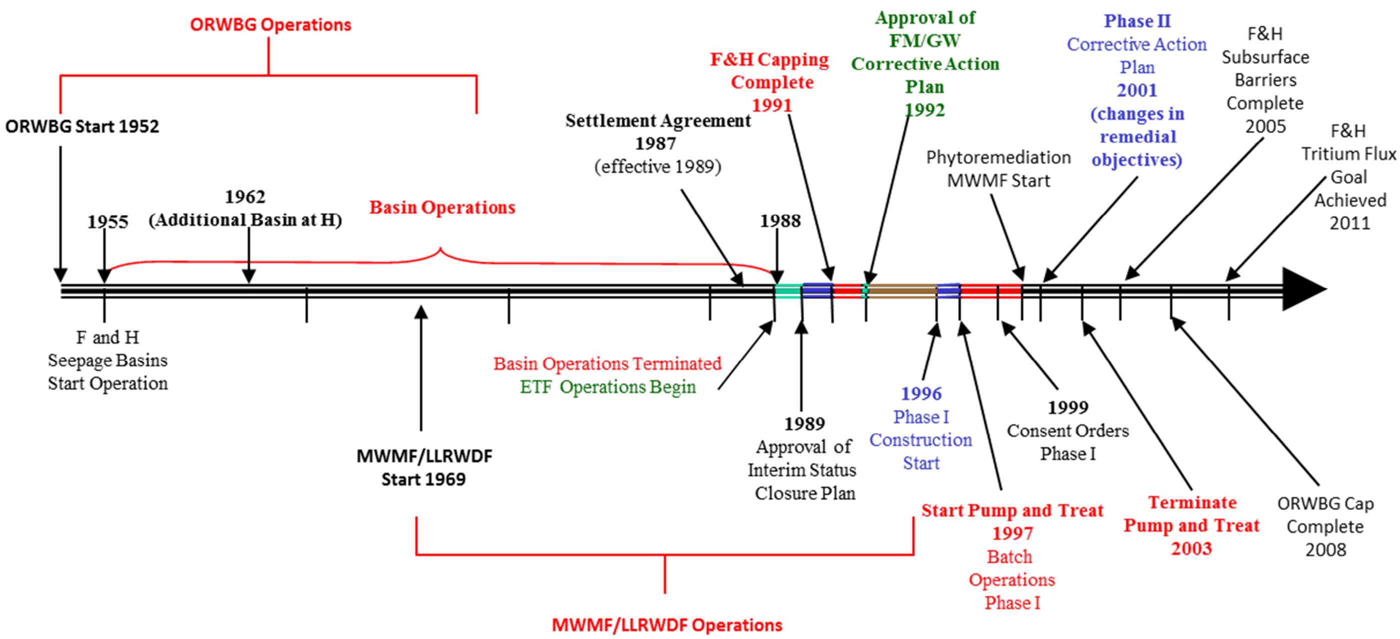

Figure 2. Timeline of waste disposal facility startup and termination, major environmental regulation, and environmental cleanup activities.

Environmental legislation enacted in the 1970s, 1980s, and 1990s led to changes in waste management and environmental cleanup practices at SRS. The US Congress passed the Clean Air Act in 1970, and the Clean Water Act in 1972; the Resource Conservation and Recovery Act (RCRA) was enacted in 1976; the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA) was enacted by Congress in 1980; the Federal Facilities Compliance Act (FFCA) was signed into law in 1992. Environmental remediation at the SRS essentially began with a 1987 Settlement Agreement between the SRS and the State of South Carolina (under the South Carolina Department of Health and Environmental Control - SCDHEC), which recognized linkage between many SRS waste management facilities and RCRA. This Settlement Agreement (SA) became effective in 1989; as shown on Figure 2.

The SRS manages several of the larger groundwater remedial activities under RCRA for facilities recognized early on as environmental problems. All subsequent environmental remediation projects tend to be managed under tri-party agreement (DOE, Environmental Protection Agency, and SCDHEC) through the Federal Facilities Agreement.

During 25 years of environmental remediation SRS has stabilized and capped seepage basins, and consolidated and capped waste units and burial grounds in the GSA. Groundwater activities include: pump and treat systems in the groundwater, installation of deep subsurface barrier systems to manage groundwater flow, insitu chemical treatments in the groundwater, and captured contaminated groundwater discharges at the surface for management in a forest irrigation system.

F and H Seepage Basins Closure and Groundwater Remediation

The SA drove the termination of the operations of seepage basin and the construction and startup of the Effluent Treatment Facility (ETF) in 1988. An Interim Status Closure Plan for the seepage basins was developed, and was approved by the SCDHEC in 1989. The basins were backfilled and capped by 1991. Figure 3 shows aerial photos of the basins in operation and after construction of the caps.

Groundwater contamination associated with the F and H Seepage Basins was recognized as a severe problem. By 1980 the acid that was released from the basins had overcome the buffering capacity of the water table aquifer, and acidic water was discharging into wetlands along the seeps along Fourmile Branch. The acid and metals carried by these waters resulted in “tree kills”. Figure 4 shows tree kills down-gradient of F Seepage Basins present in 1980 through 1992, and regrowth in 2010 and 2011.

SRS developed a corrective action plan for the groundwater and the impacts to Fourmile Branch. This corrective action plan envisioned a “pump and treat” solution for tritiated groundwater releases to Fourmile Branch at both the F and H Seepage Basins areas. The corrective action plan was approved by the SCDHEC in 1992. Design of the “pump and treat” systems began after plan approval, construction began 1996, and system startup began in 1997.

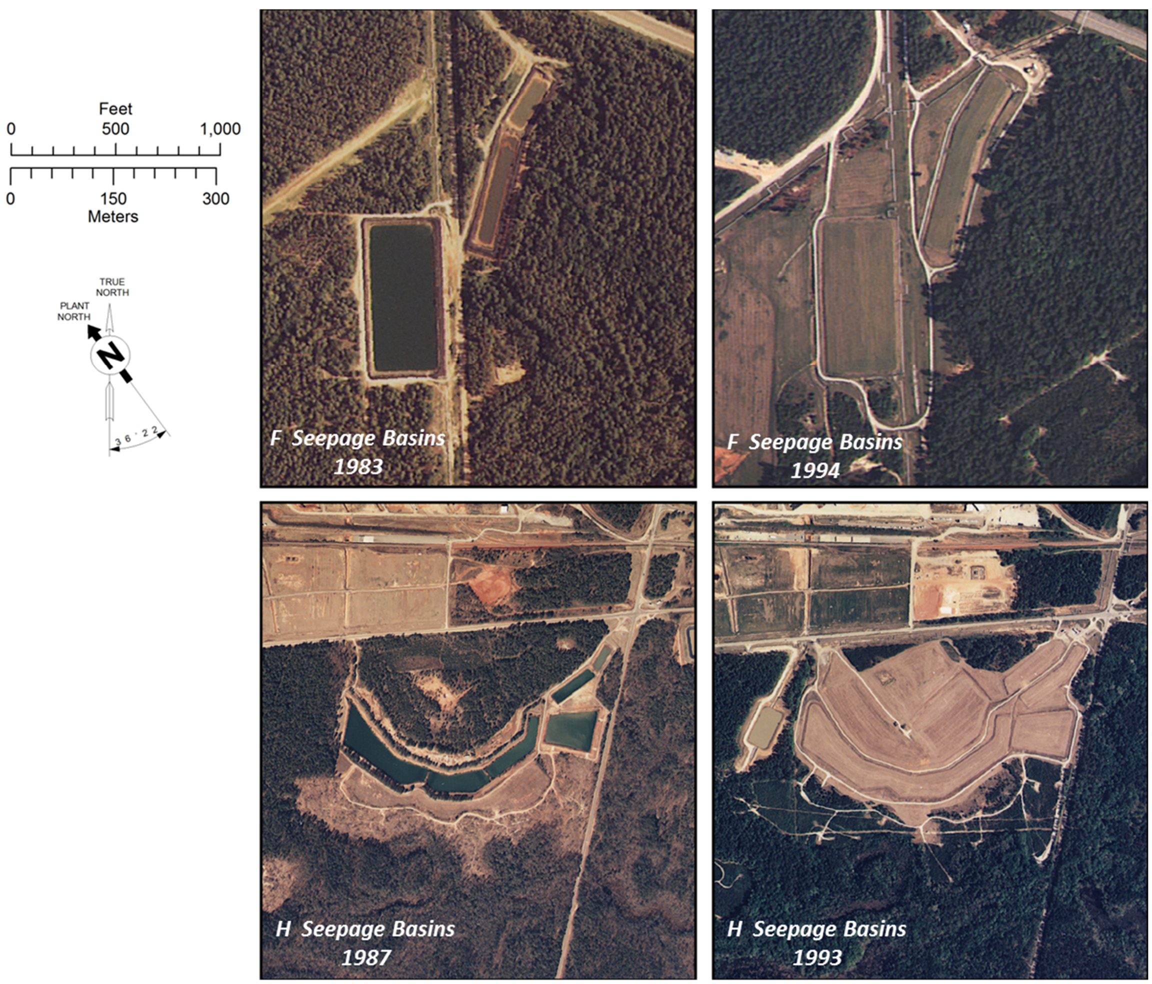

Figure 3. Aerial photograph of the F (top) and H (bottom) Seepage Basins in operation (left) and after capping (right).

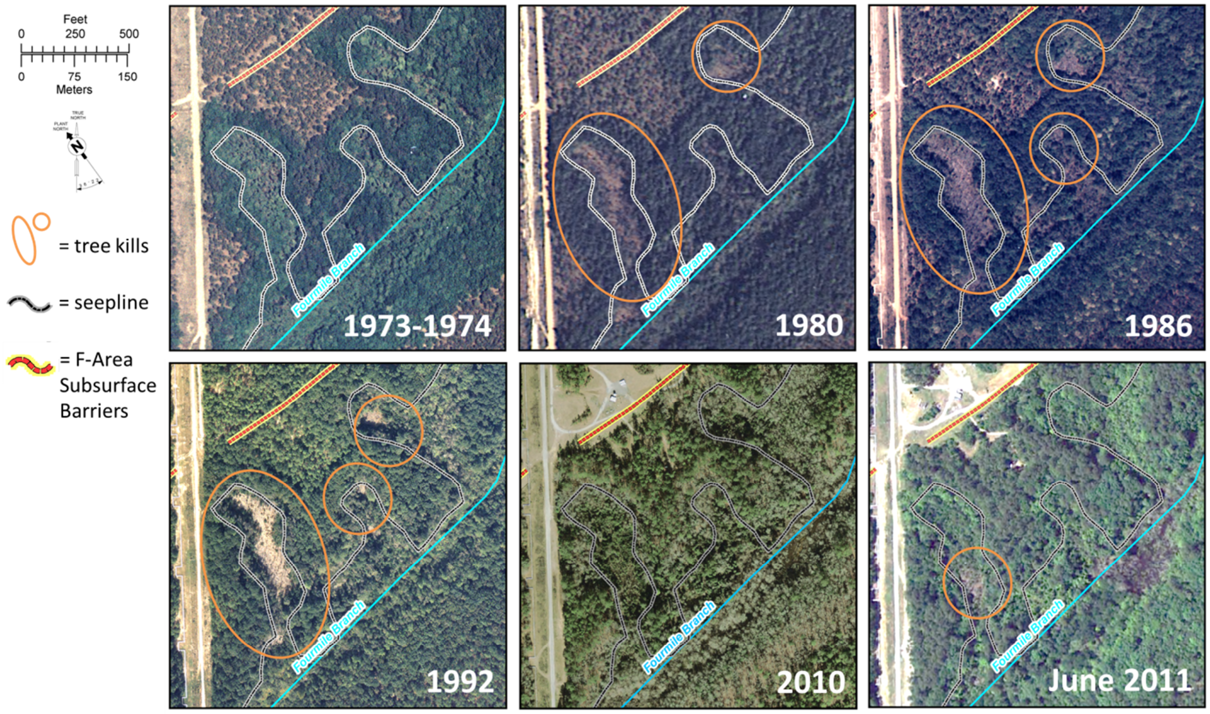

Figure 4. Tree kills between 1980 and 1992 down-gradient of the F Seepage Basins.

By 2000 it was apparent that the "pump and treat" systems were having little impact on the contaminant releases to Fourmile Branch (tritium, radioactive metals, non-radioactive metals, nitrates, etc.). Because there is no practical way to remove tritium from groundwater, the tritiated water was injected up-gradient after treatment (flocculation, reverse osmosis, and ion exchange) to remove metals and non-metals. The cost to operate the two "pump and treat" systems was over $1,000,000 per month, and the waste generated had to be managed at the Nevada Test Site. The construction and operational costs for approximately 5.5 years of operation was approximately $150,000,000. A Phase II Corrective Action Plan was developed in 2001 and approval by SCDHEC provided for the termination of operations in 2003.

The Phase II corrective action at H Area employed subsurface barriers to alter the groundwater gradient and velocity. The corrective action at F Area used subsurface barriers down-gradient of the F Seepage Basin to form a "funnel and gate" system for the injection of basic solutions to restore formation buffering capacity and precipitate metallic groundwater contaminants. Constructions of the subsurface barrier systems began with the termination of the "pump and treat", and were completed in 2005. The cost of construction was approximately $13,000,000. The initial goal of the subsurface barriers was to reduce the flux of tritiated water to the branch by 70%. The tritium flux goal was achieved for F and H basin areas in 2011.

Old Radioactive Waste Burial Ground

The tritiated groundwater releases to Fourmile Branch from the Old Radioactive Waste Burial Ground (ORWBG) were recognized as a large problem in the late 1990's. Approximately 3000 curies per year of tritium was being released from the ORWBG to Fourmile Branch in a single plume that terminated as springs at the base of the slope adjacent to Fourmile Branch. SRS recognized that another ineffective "pump and treat" process was not a solution to the tritium problem.

In 1999 SRS conceived an Interim Measures (IM) to reduce the tritium releases for Fourmile Branch. The IM envisioned the construction of a small sheet pile impoundment downstream of the springs, and the pumping of water from the impoundment for application to a mixed pine and hardwood forest in the area. The forest was expected to utilize the irrigated tritiated water and evapotranspire tritiated water to the atmosphere where the radiological dose would be very low to receptors. The management of the water prior to reaching Fourmile Branch would reduce the exposure of receptors from water use from the downstream Savannah River. Radiological modeling studies indicated that the dose reductions would be significant. Modeling of the forest water consumption potential indicated that it was possible to manage much of the tritiated water.

The system began operations in 2000 and was very effective in the management of the tritiated water from the very beginning. The system became known as the phytoremediation project. SRS has reduced the tritium flux to Fourmile Branch from the ORWBG plume by almost 70%. The irrigated forest consistently utilizes 85 to 90% of the applied water because SRS developed a method of quantifying the optimum irrigation demand without over watering the forest. Over application of water would impact the health of the forest.

The phytoremediation project has been expanded in irrigation area, and pumping and filtration capacity. The original irrigation area supported approximately 9 hectares of irrigation. The irrigation area has been expanded to approximately 26 hectares. Figure 5 illustrates the current irrigation area and water collection impoundment. The facility was constructed for approximately $5,000,000 and has an operational cost of approximately $500,000 per year. Dose modeling indicates that the potential dose to irrigation workers is very low; the work is considered non-radiological. Institutional controls are maintained in the impoundment and irrigation areas; untrained personnel are not allowed in these areas.

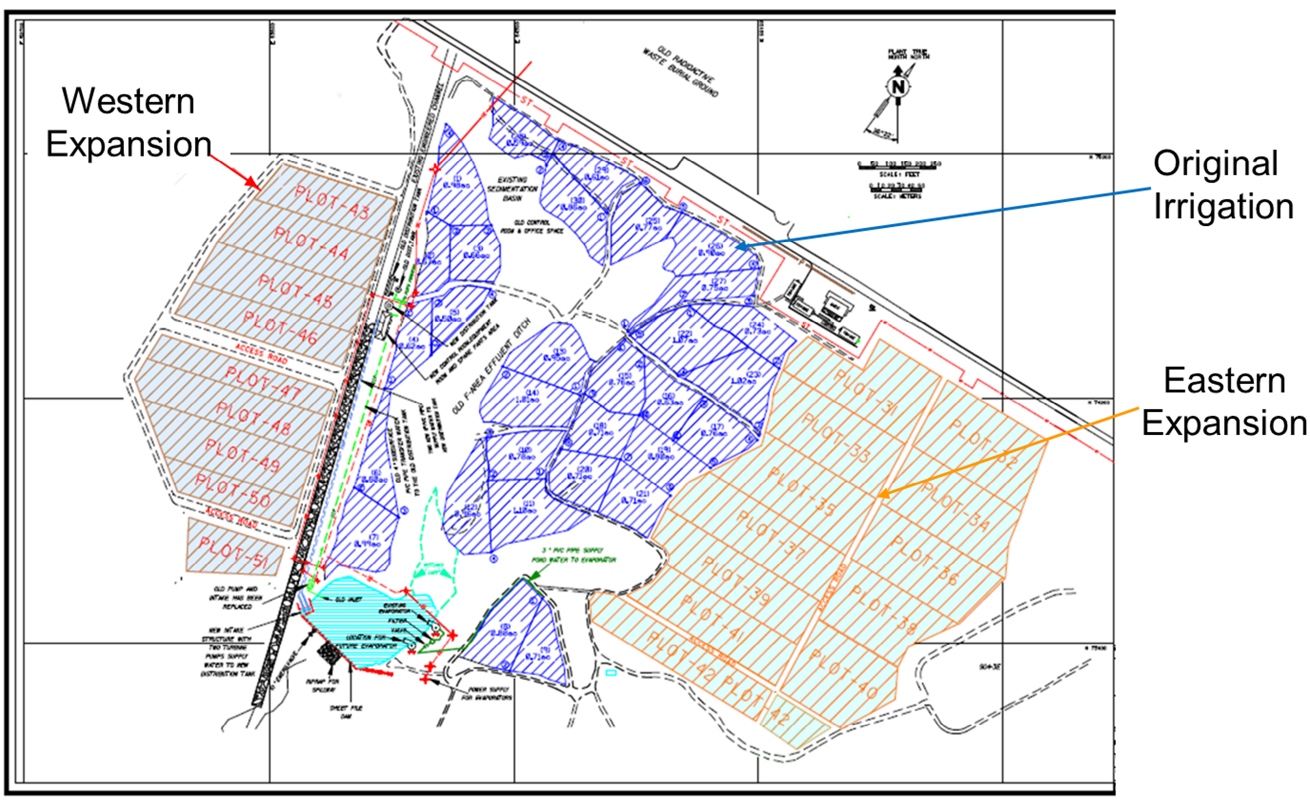

Figure 5. Phytoremediation project down-gradient of the ORWBG at the SRS; showing tritiated water collection impoundment and irrigation plots.

The Environmental Protection Agency (EPA) and SCDHEC desired a capped closure for the ORWBG to limit the flux of contaminants to groundwater, recognize intruder issues, and provided for future institutional controls. The closure was performed under CERCLA and eventually entailed the excavation of several other radioactive waste units in the area, with consolidation of radioactive soils at the ORWBG. The record of decision was finalized in 2002 and the excavations, consolidation, and capping was completed in 2008. Figure 6 shows the capped ORWBG.

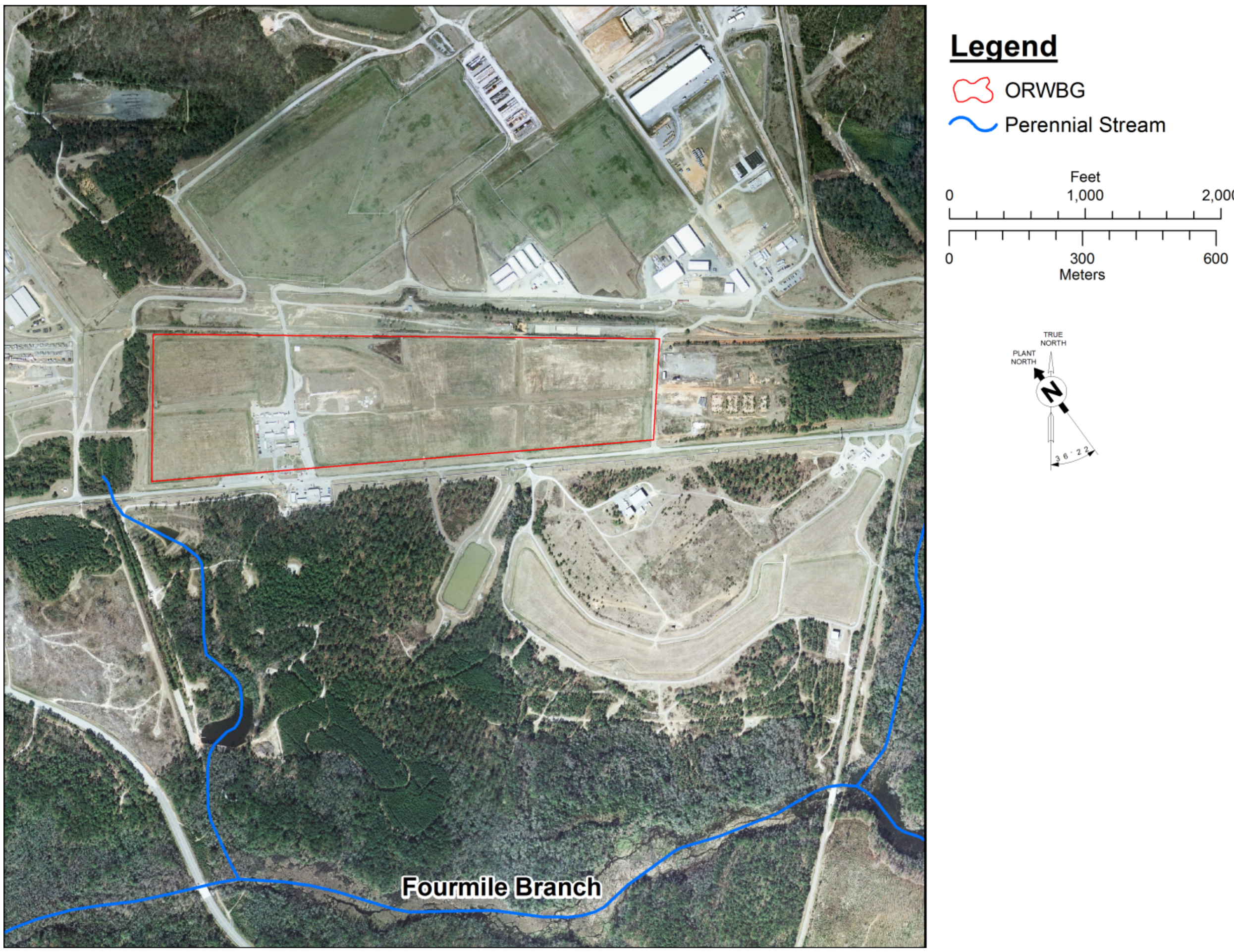

Figure 6. Capped ORWBG (outlined in red).

The phytoremediation project collection impoundment was an excellent location to observe the changes in tritium concentration caused by the capping of the ORWBG. Figure 7 illustrates the change in tritium concentration between 2000 and 2011. Radioactive decay for tritium is shown on the figure along with a marked decline in tritium concentration that started in 2008. The decline in concentration after 2008 is attributed to the capping of the ORWBG. Localized declines in tritium concentration in the impoundment are due to rainfall events that dilute the tritium concentration in the water.

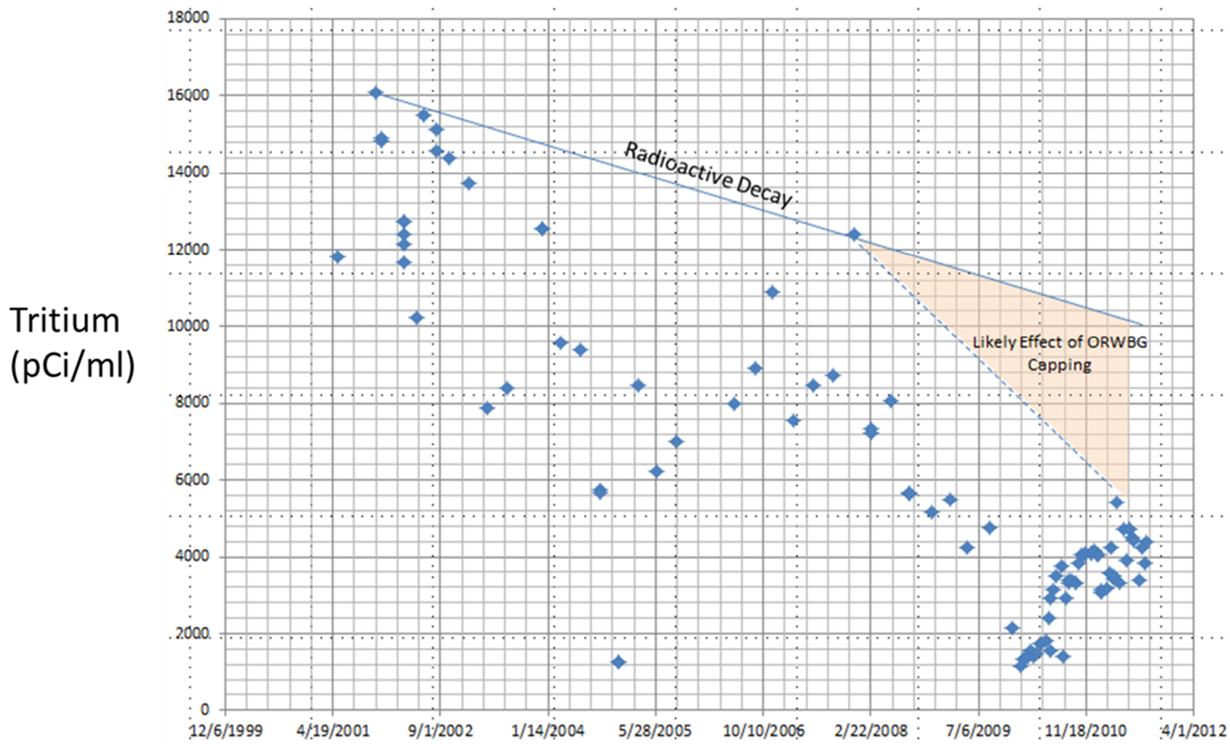

Figure 7. Decline in tritium concentration in the phytoremediation project collection impoundment that is attributed to radioactive decay and the effects of the ORWBG capping.

Changes in Tritium Concentration in Fourmile Branch due to Remediation

The goals of the remedial activities within the GSA have been generally directed toward reductions in tritium flux to Fourmile Branch. Fourmile Branch has been the main tritium source for the Savannah River. Discharges from the branch have historically caused the water in the Savannah River to exceed drinking water standard at the mouth of the branch; mixing with water in the Savannah River quickly dilutes the tritium concentration such that no standard is exceeded.

The releases from F Seepage Basin, H Seepage Basin, and the ORWBG are the main sources of tritium to the branch. A 70% reduction in tritium flux to the branch has been the remedial goal for these three source areas. Figure 8 illustrates the changes in tritium concentration in the branch from 1997 to 2013. The figure is annotated with remedial actions to demonstrate the effects of the remediation.

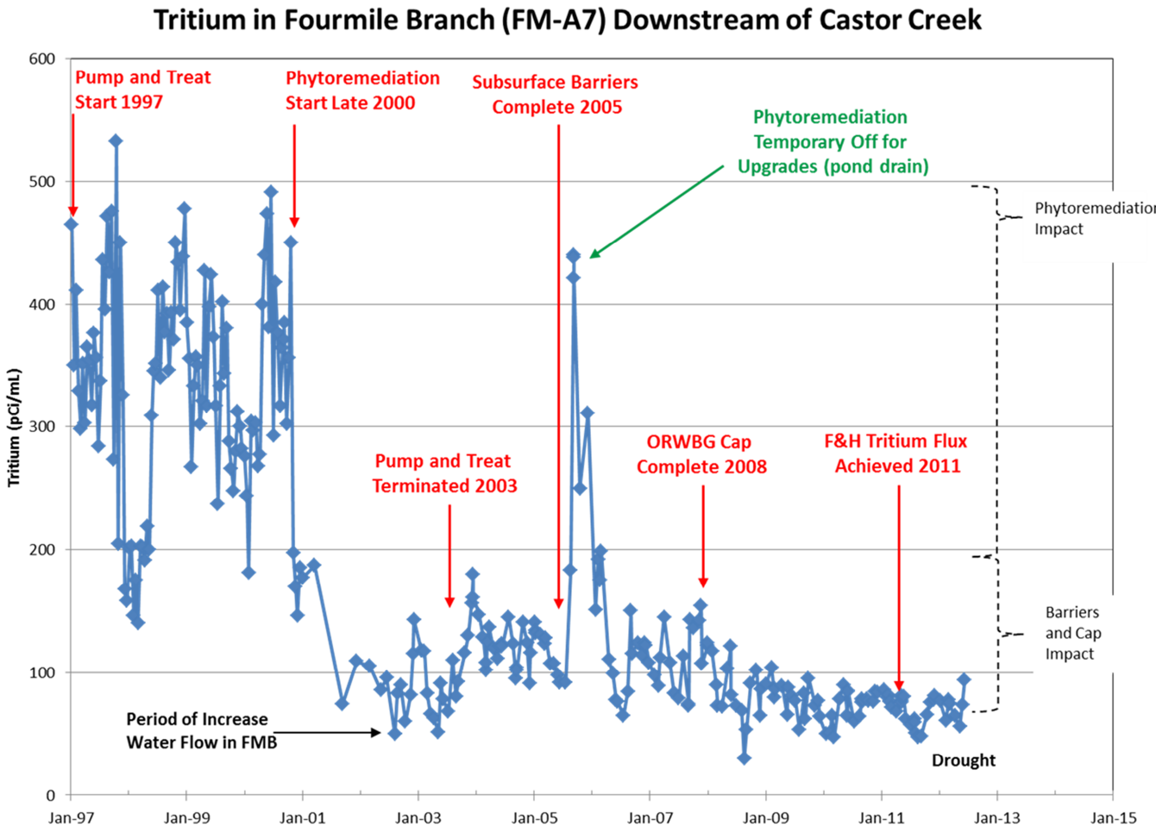

Figure 8. Tritium concentration reductions in Fourmile Branch due to remedial actions in the GSA.

Figure 8 illustrates that there was no significant change in tritium concentration in Fourmile Branch for 4 years of pump and treat operations. A very sharp drop in tritium occurred when the phytoremediation project was started in 2000 and persisted until the system was terminated for upgrades, when the system was restarted pre-upgrade conditions returned. Tritium concentrations dropped from 150 pCi/ml to less than 100 pCi/ml from subsurface barriers and the cap on the ORWBG. Approximately 75% of the overall tritium reduction appears associated with the phytoremediation project.

If the phytoremediation project is maintained, and conditions remain stable for contaminant migration at the ORWBG and F and H Seepage Basins drinking water standards in the lower reaches of Fourmile Branch can be achieved in approximately 25 years. Figure 9 illustrates the probable future change in tritium concentration in Fourmile Branch based upon decay.

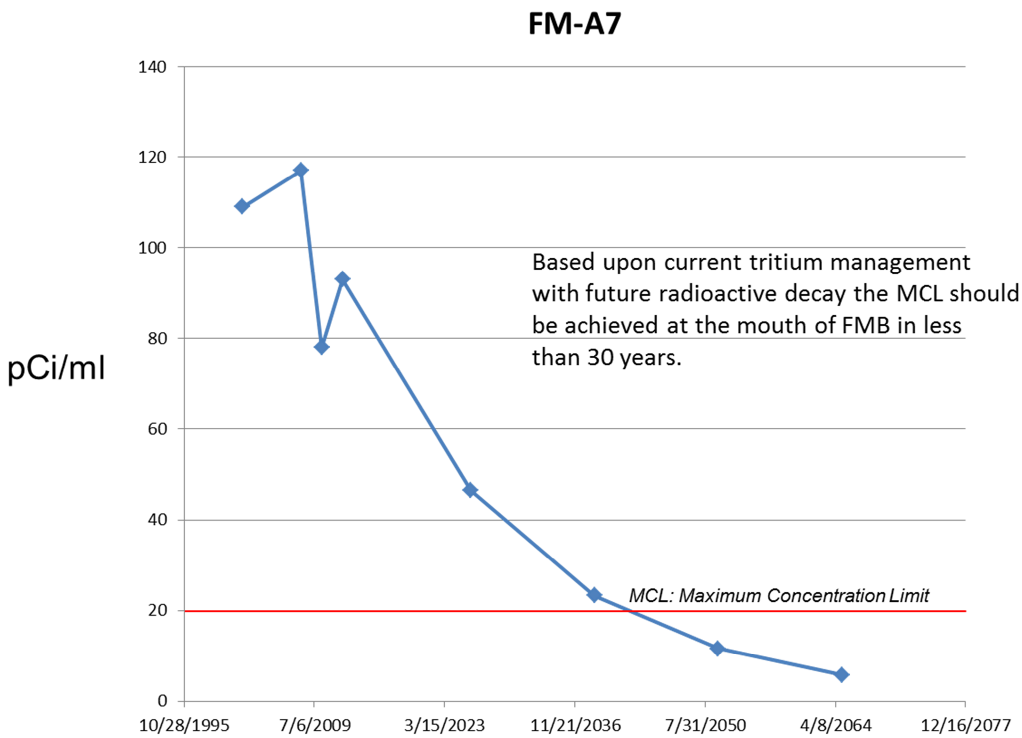

Figure 9. Prediction of future tritium concentration in Fourmile Branch based upon radioactive decay at the FW-A7 location which is in the lower reaches of the branch before reaching the Savannah River.

Conclusions

Over the last 25 years concentrations of contaminants in the aquifers beneath the GSA and in surface water streams in the GSA have dropped significantly. Closure of 65 waste sites and 4 RCRA facilities has been successfully accomplished. Wastes have been successfully isolated in place beneath a variety of caps and cover systems. Environmental clean-up has progressed to the stage where most of the work involves monitoring, optimization, and maintenance of existing remedial systems.

Many lessons have been learned in the process. Geotextile covers outperform low permeability clay caps, especially with respect to the amount of repairs required to upkeep the drainage layers as the caps age. Passive systems with enhanced natural processes to address groundwater contamination were more effective in contaminant reduction to Fourmile Branch and much more cost effective than pump and treat systems. In water management situations with non-accumulative contaminants (tritium, VOCs, etc.) irrigation in a forest setting can be very effective.

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