

Removal Action Report for the C-Area Groundwater Operable Unit Bio-Barrier Non-Time Critical Removal Action

SEMS Number: 82

SRNS-RP-2019-00584

~~Revision 0~~ Redline Revision 1.0

~~December 2019~~ June 2020

- 1) Inject an emulsified oil mixture and bioaugmentation supplement along two transects to create two treatment barriers in the MAZ perpendicular to the groundwater flow (Figure 4). The treatment barriers will sequester and biodegrade TCE.
- 2) Establish and utilize fifteen DPT injection points to construct the treatment barriers (Figure 4): five injection points ~20.2- to 23.2-m (66- to 76-ft) below ground surface (bgs) and ten injection points ~10.1- to 13.1-m (33- to 43-ft) bgs in the distal portion of the groundwater plume location. Inject within a 3.05-m (10-ft) section of the MAZ where the groundwater TCE contamination is present. Within Oil Injection Area 1 the MAZ depth and thickness were determined by the core described at well CRW024C. Within Oil Injection Area 2 the MAZ depth and thickness was determined by the core described at well CRW023C. Lithology CPTs CGW-68, CGW106, CSB-107, CSB-108 and CSB-122 provided a regional context for the MAZ depth and thickness. A schematic cross section of the area is shown in Figure 5.
- 3) Inject an emulsified oil mixture consisting of EOS Remediation, LLC (EOS) emulsified oil, dilution water with a dechlorination agent (e.g., ascorbic acid), and a buffer (e.g., EOS CoBupHMg™).
- 4) Inoculate the emulsified edible oil mixture with 2 liters (L) (0.528 gallons [gal]) of unconcentrated EOS Bioaugmentation Culture 9 (BAC-9), an enriched bioaugmentation culture of *Dehalococcoides mccartyi* and enzymes in a water-based medium.

Several changes were made to the CAGW OU removal action design based on an independent technical review, which are documented in Section 3.0 of this document.

1.4 Chronology of Events

Table 1 provides the Chronology of Events.

2.0 CONSTRUCTION ACTIVITIES

The CAGW OU NTC RA construction activities consisted of creating two subsurface bio-barriers by injecting an oil mixture, microbes, and buffer into the aquifer using DPT.

dilution water; 136 kilograms (kg) (300 pounds [lbs]) of sodium bicarbonate (baking soda); 0.91 kg (2 lbs) of ascorbic acid (vitamin C) used to dechlorinate and deoxygenate the dilution water; 2.37 L (80 fluid ounces [fl oz]) of vitamin B-12 (an essential nutrient for the microbes); and 1,041 L (275 gal) of EOS emulsified oil. After all the emulsified oil mixture and EOS BAC-9 was injected, 151 L (40 gal) of EOS CoBupHMg™ was mixed with 757 L (200 gal) of water and injected into the aquifer. Finally, 1,136 L (300 gal) of chase water was injected into the aquifer. Domestic water, used as chase water and dilution water, was sourced from N-Area Central Shops. A total of 8,290 L (2,190 gal) of oil mixture, buffer and chase water were injected at each injection location.

Upon injecting the required volume for that location, the rod string was retracted. The rods and screen were then removed from the ground, grout rods were inserted into the borehole to the total depth and grout was used to abandon each injection borehole. Grouting activities and decontamination of the equipment (rods, mixing tanks, hoses and pumps) was completed on August 12, 2019. All equipment was demobilized from the injection site on August 14, 2019.

2.2 Construction Delays

No major delays were encountered during the construction/injection process of this RA. While minor operational delays were encountered, the overall time spent in the field injecting the emulsified oil mixture into the aquifer was less than the 30 days estimated by SRS. Fewer days in the field were required as the average injection rates ranged from 22.9 liters per minute (Lpm) (6.04 gallons per minute [gpm]) to 55.3 Lpm (14.6 gpm), which were twice as high as anticipated by SRS based on previous experience.

2.3 Waste Management

~~There was no radioactive or hazardous waste associated with this project, as determined by waste management guidance. All job waste and personal protective equipment was disposed of as sanitary waste. All decontamination water was land applied on location.~~

There was no radioactive or hazardous waste associated with this project, ~~as determined by waste management guidance.~~ All job waste from well installations (CRW023C and CRW024C) and DPT oil injections, including personal protective equipment was disposed of as sanitary waste (SGCP 2017). All decontamination water and soil were land applied on location for well installations (CRW023C and CRW024C), including the soil cores from these wells. All decontamination water, including any incidental soil on the outside of the DPT rods, was land applied on location for DPT oil injections.

3.0 DEVIATIONS FROM ORIGINAL DESIGN

After submittal and regulatory approval of the CAGW OU RADP (SRNS 2018a) and CAGW OU Underground Injection Control (UIC) Permit Application (SRNS 2019), an independent technical review identified several design and construction changes to improve the CAGW OU NTC RA performance and likelihood for success. The project team reviewed and agreed with all proposed changes, provided those changes to the CAGW OU UIC Permit to Operate to SCDHEC (Appendix A), and obtained approval from SCDHEC prior to implementation to ensure compliance with regulatory requirements (Appendix B). SRS notified SCDHEC prior to the start of injection activities, as appropriate (Appendix C).

Table 2 provides a summary of all such changes, including the basis and resolution of deviations from the original design. Where applicable, a statement is provided on whether the deviation still meets a performance criterion.

4.0 VERIFICATION SAMPLING, TESTING, ANALYSIS, PERFORMANCE STANDARDS, AND CONSTRUCTION QUALITY CONTROL

4.1 Performance Requirements/Standards

The CAGW OU RADP with EMP (SRNS 2018a), the CAGW OU UIC Permit Application (SRNS 2019), and the CAGW OU UIC Permit to Operate changes letter (Appendix A) specify the performance requirements for the CAGW OU NTC RA.

- to affect the RA performance, because the oil mixture and buffer will flow into the more permeable MAZ sand zone and not into the clay layers above or below the MAZ sand (Appendix D).
- b) The emulsified oil mixture injections were primarily within the MAZ where the groundwater contamination is present. Within Oil Injection Area 1 the MAZ depth and thickness was determined by the core described at well CRW024C. Within Oil Injection Area 2 the MAZ depth and thickness was determined by the core described at well CRW023C. Lithology CPTs CGW-68, CGW106, CSB-107, CSB-108 and CSB-122 provide a regional context for the MAZ depth and thickness.
- c) The emulsified oil mixture contained 136 kg (300 lbs) of sodium bicarbonate, per the final design. After all the emulsified oil mixture was injected into the subsurface, an additional 151 L (40 gal) of EOS CoBupHMg™ buffer mixed with 757 L (200 gal) of dilution water was injected into the subsurface, per the final design. The goal of these two buffers is to raise groundwater pH to the optimal range, 6 to 8, for bioremediation by the microbes. Five wells (CRW023C, CRW024C, CRW026C, CRW027C and CRW028C) monitor the groundwater chemistry near Oil Injection Areas 1 and 2. These wells have pH measurements taken every sample event and will identify pH changes in the groundwater. These data will be reported in the annual CAGW OU Removal Action Effectiveness Monitoring Reports.
- d) Within Oil Injection Area 1 a total of 5,205 L (1,375 gal) of EOS emulsified oil, 4.55 kg (10 lbs) of ascorbic acid, 11.8 L (400 fl oz) of vitamin B-12, 10 L (2.64 gal) of unconcentrated BAC-9, 680 kg (1,500 lbs) of sodium bicarbonate, 755 L (200 gal) CoBupHMg™ buffer was injected into the subsurface, per the final design. 35,490 L (9,375 gal) of dilution water was injected into the subsurface in Oil Injection Area 1, as this was a sufficient amount of water for the emulsified oil mixture, CoBupHMg™ buffer and chase water.
- e) Within Oil Injection Area 2 a total of 10,410 L (2,750 gal) of EOS emulsified oil, 9.1 kg (20 lbs) of ascorbic acid, 23.7 L (800 fl oz) of vitamin B-12, 20 L (5.28 gal) of unconcentrated BAC-9, 1,360 kg (3,000 lbs) of sodium bicarbonate, 1,510 L (400 gal)

- 4) 136 kg (300 lbs) of sodium bicarbonate;
- 5) 2 L (0.528 gal) of unconcentrated BAC-9;
- 6) 151 L (40 gal) CoBupHMg™ buffer; and
- 7) 7,098 L (1,875 gal) of dilution and chase water.

The minimum average flow rate for the oil mixture was 22.9 Lpm (6.04 gpm), and the maximum average flow rate for the oil mixture was 55.3 Lpm (14.6 gpm) for all fifteen of the injection locations (Table 3). The minimum average injection pressure was 3.45 bar (50 pounds per square inch [psi]), and the maximum average injection pressure was 10.7 bar (155 psi) for all fifteen of the injection locations. PAH parameters and amounts were monitored and recorded in field notes (Table 4), provided by the subcontractor (Appendix E), as verification that the RA was completed in accordance with the final design. The oil injection crew visually monitored for day-lighting (i.e., oil observed at the ground surface) at all locations. Day-lighting was observed on two occasions: 1) On 7-18-2019 at CCIW-01 the emulsified oil mixture was observed at the ground surface around the DPT rod; 2) On 7-30-2019 at CCIW-13, the emulsified oil mixture was observed at the ground surface around the DPT rod. At CCIW-01 the injection was stopped immediately, all fittings and connectors were tightened, the DPT screen heighted was adjusted up by one foot, and injections were resumed without issue. At CCIW-13, the injection was immediately stopped, the rods were pulled, the first rod was re-taped and tightened. Then the rods were driven back to the target depth and the injection was resumed without issue. Rather than true day-lighting from over-pressurization, both observed cases were due to a loose connections at the top of the DPT rods. These two episodes caused only minor delays.

Observation of ~~theis~~ emulsified oil mixing process shortly after injection began led to a process improvement for all ten injections in Oil Injection Area 2. One-half of the emulsified oil mixture at CCIW-02 was injected on July 23, 2019, and the second half was to be injected on July 24, 2019, following injection of the BAC-9. After sitting over-night, the project team observed oil separation in the 9,464 L (2,500 gal) polyethylene tank (Figure 6). Approximately 757 L (200 gal) of EOS was still in the tank, but only about 520

L (137.5 gal) should have been in the remaining half-batch. It was determined that mixing of the oil via recirculation was occurring primarily in the lower half of the tanks because of the height of the tanks and the injection and extraction port locations being near the bottom of the tanks. Although the total amount of oil injected is not affected, it is not clear if the proportional differences in oil over the course of the injection may cause the bio-barrier to sequester less efficiently in Oil Injection Area 1. –This issue was resolved in Oil Injection Area 2 by mixing only one-half of a batch of the oil mixture at one time, and then injecting it into the aquifer to ensure a better distribution of the EOS emulsified oil in the subsurface (Figure 7). The mixing and injecting procedures were revised to reflect this change, which caused approximately a 2-day delay.

4.2.4 EOS Temperature Requirements

To ensure the EOS emulsified oil and EOS CoBupHMg™ buffer did not exceed the specified temperature range, the totes and pails were stored in a shaded area of Oil Injection Area 2 (Figure 4). The air temperature was monitored daily and during the project time frame (July 10, 2019 to August 8, 2019) the minimum air temperature was 18.3°C (65°F) and the maximum air temperature was 37.2°C (99°F) (Appendix E). In addition, the temperature was measured for each batch of oil mixture and buffer. The highest temperature measured for the oil mixture was 35.3°C (95.5°F), and the highest temperature measured for the buffer was 34.4°C (93.9°F). Collectively, temperature data indicated the EOS emulsified oil and EOS CoBupHMg™ buffer did not exceed 37.8°C (100°F), the manufacturer's upper limit.

5.0 VERIFICATION OF RA COMPLETION AND FINAL INSPECTION

As detailed in Section 4.0, construction activities required for the RA have met the performance requirements established in the approved RADP with EMP for the CAGW OU (SRNS 2018a) and the approved CAGW OU UIC Permit Application (SRNS 2019), with acceptable deviations as detailed in Section 3.0. The RA described in this RAR is expected to achieve the RAO outlined in the RSER/EE/CA for CAGW OU (SRNS 2018b). Verification of RA completion is addressed

9.0 REFERENCES

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WSRC, 1999. *Land Use Control Assurance Plan for the Savannah River Site*, WSRC-RP-98-4125, Rev 1.1, August 1999, Latest Update, Savannah River Nuclear Solutions, LLC, Savannah River Site, Aiken, SC

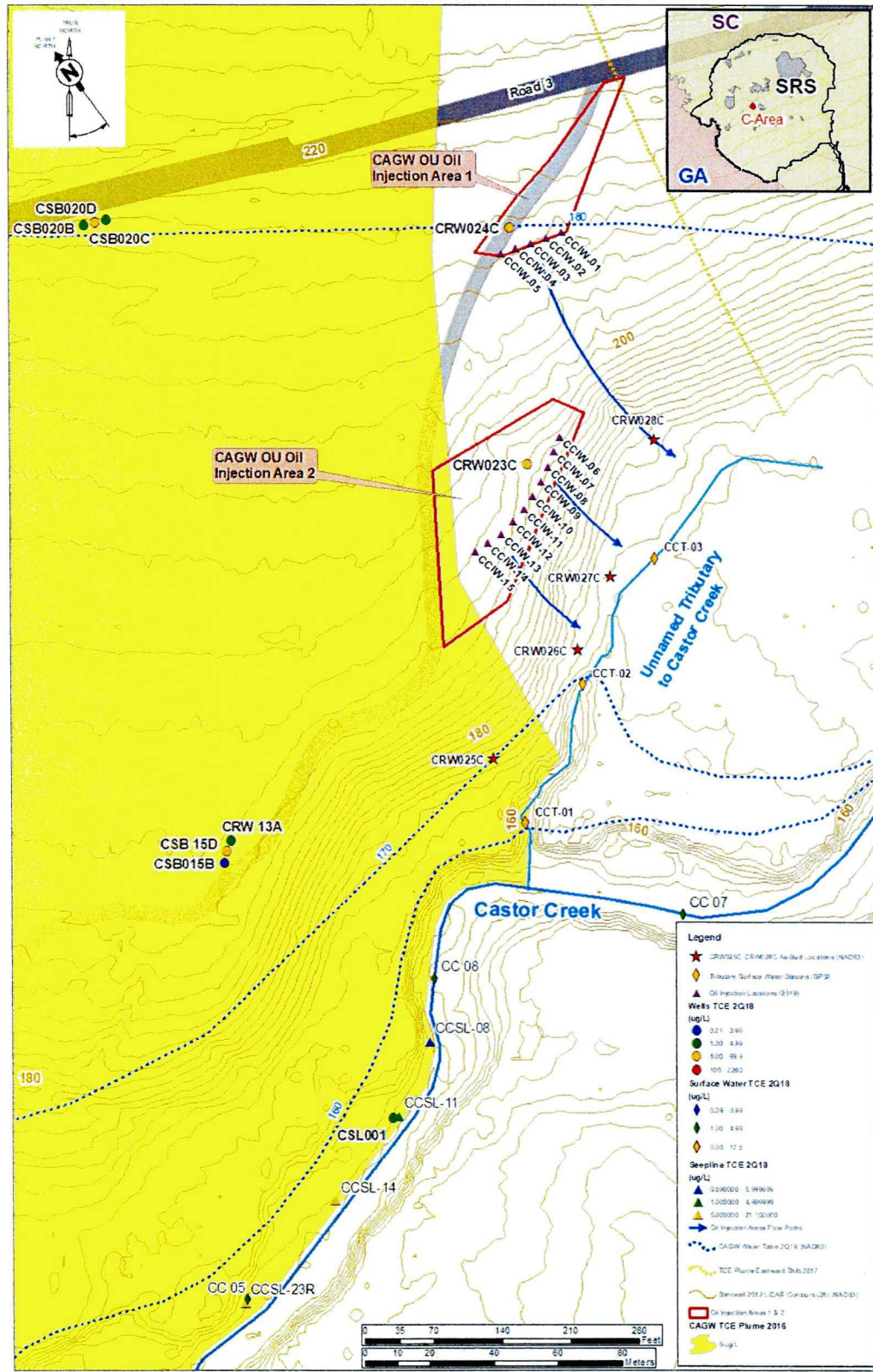


Figure 4. CAGW OU Pre-Removal Action Site Plan

Table 23. Oil Injection Locations, Depths and Injection Rates

Location ID	SRS East Coordinates	SRS North Coordinates	Ground Elevation (ft-msl)	Start Inject Date	Finish Inject Date	Injection Interval	Avg. Injection Rate of Emulsified Oil Mixture (gpm)	Avg. Injection Rate of CoBupHMg™ (gpm)	Avg. Injection Rate of Chase Water (gpm)	Total Liquid Volume Injected (Gal)	Total BAC-9 Injected (Liters)	Grout Date	Amount (Gal) of Grout	# Bags Portland	Comment
CCIW-01	41169.49	65476.32	212.3	7/18/2019	7/18/2019	66-76'	7.75	5.63	8.75	2,190	2 L	7/22/2019	25	4	Mixed oil in one batch
CCIW-02	41153.95	65481.18	213.9	7/23/2019	7/24/2019	66-78' *	6.04	5.22	16.67	2,190	2 L	7/29/2019	25	4.5	Mixed oil in one batch
CCIW-03	41138.40	65486.00	213.8	7/18/2019	7/18/2019	66-76'	13.87	15.00	9.38	2,190	2 L	7/22/2019	25	4	Mixed oil in one batch
CCIW-04	41122.82	65490.97	214.1	7/24/2019	7/24/2019	66-76'	13.98	15.00	14.29	2,190	2 L	7/25/2019	25	4	Mixed oil in one batch
CCIW-05	41107.12	65495.70	214.1	7/23/2019	7/23/2019	66-76'	12.04	11.43	9.38	2,190	2 L	7/25/2019	25	4	Mixed oil in one batch
CCIW-06	41045.98	65310.67	196.9	8/5/2019	8/6/2019	33-43'	12.60	8.89	11.54	2,190	2 L	8/7/2019	15	2	Mixed oil in two, half-batches
CCIW-07	41031.94	65301.52	195.1	8/6/2019	8/6/2019	33-43'	9.02	7.50	9.09	2,190	2 L	8/7/2019	15	2	Mixed oil in two, half-batches
CCIW-08	41018.10	65292.90	194.2	8/5/2019	8/5/2019	33-43'	10.00	13.33	11.11	2,190	2 L	8/8/2019	15	2	Mixed oil in two, half-batches
CCIW-09	41003.70	65284.99	194.1	8/1/2019	8/1/2019	33-43'	13.64	14.12	14.29	2,190	2 L	8/6/2019	15	2.5	Mixed oil in two, half-batches
CCIW-10	40987.88	65278.46	194.7	8/7/2019	8/7/2019	33-43'	12.41	9.60	12.00	2,190	2 L	8/8/2019	15	2	Mixed oil in two, half-batches
CCIW-11	40972.68	65272.56	196.5	7/31/2019	7/31/2019	33-43'	14.60	20.00	14.29	2,190	2 L	8/1/2019	15	2	Mixed oil in two, half-batches
CCIW-12	40957.10	65269.40	197.8	8/7/2019	8/8/2019	33-43'	13.20	11.43	15.00	2,190	2 L	8/8/2019	15	2	Mixed oil in two, half-batches
CCIW-13	40939.21	65266.34	199.3	7/30/2019	7/31/2019	33-43'	10.78	10.00	10.71	2,190	2 L	8/1/2019	15	2	Mixed oil in two, half-batches
CCIW-14	40922.68	65267.05	199.5	8/8/2019	8/8/2019	33-43'	10.65	8.57	11.11	2,190	2 L	8/12/2019	15	2	Mixed oil in two, half-batches
CCIW-15	40906.62	65268.11	199.8	7/30/2019	7/30/2019	33-43'	13.87	13.33	12.50	2,190	2 L	8/1/2019	15	2	Mixed oil in two, half-batches

* = Please note that the oil injectables were injected at the interval of 66-76ft, but the CoBupH buffer and chase water were injected in the 68-78ft interval per SRNS direction due to low injection rates at 66-76ft.

Table 4. Oil Injection Field Parameters

Station	Matrix	Tank 1			Tank 2			Comments
		Temp. (°C)	DO (mg/L)	pH	Temp. (°C)	DO (mg/L)	pH	
CCIW-01	Emulsified Oil Mixture				34.2	0.40	8.21	Mixed in 1 Batch.
CCIW-02	Emulsified Oil Mixture	33.7	0.78	8.26				Mixed in 1 Batch.
CCIW-03	Emulsified Oil Mixture	35.3	0.94	8.24				Mixed in 1 Batch.
CCIW-04	Emulsified Oil Mixture				30.2	0.66	8.15	Mixed in 1 Batch.
CCIW-05	Emulsified Oil Mixture				32.2	0.93	8.11	Mixed in 1 Batch.
CCIW-06	Emulsified Oil Mixture	28.7	0.95	8.17	30.6	0.64	8.15	Mixed in 2 Batches.
CCIW-07	Emulsified Oil Mixture	29.0	0.70	7.86	28.6	0.12	8.39	Mixed in 2 Batches.
CCIW-08	Emulsified Oil Mixture	25.7	0.98	8.05	25.3	0.98	8.25	Mixed in 2 Batches.
CCIW-09	Emulsified Oil Mixture	31.3	0.95	8.21	29.6	0.98	8.26	Mixed in 2 Batches.
CCIW-10	Emulsified Oil Mixture	29.2	0.97	7.23	28.7	0.91	8.47	Mixed in 2 Batches.
CCIW-11	Emulsified Oil Mixture	30.9	0.95	8.51	30.7	0.16	8.43	Mixed in 2 Batches.
CCIW-12	Emulsified Oil Mixture	30.1	0.90	8.14	32.0	0.66	8.08	Mixed in 2 Batches.
CCIW-13	Emulsified Oil Mixture	29.6	0.94	8.18	30.4	0.95	8.23	Mixed in 2 Batches on 7/30.
CCIW-13	Emulsified Oil Mixture	---	---	---	29.8	0.96	8.27	Injected on 7/31.
CCIW-14	Emulsified Oil Mixture	32.1	0.91	8.10	31.6	0.91	8.25	Mixed in 2 Batches.
CCIW-15	Emulsified Oil Mixture	31.0	0.43	8.38	30.7	0.22	8.36	Mixed in 2 Batches on 7/29
CCIW-15	Emulsified Oil Mixture	29.8	0.79	9.22	30.0	0.82	8.14	Injected on 7/30.

Table 53. Project Cost Comparison

Cost Comparison Summary			
	RSER/EE/CA Cost (\$)	Actual Cost (\$)	Delta Cost (%)
Total Capital Costs	799,744	987,996	+23.5
Total O&M Costs	517,322	TBD	TBD
Total Project Costs	1,317,066	TBD	TBD