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ORNL/M--5813

**Removal Action Report on Waste Area Grouping 4
Seeps 4 and 6 at Oak Ridge National Laboratory,
Oak Ridge, Tennessee**

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LOCKHEED MARTIN

LTR/ERPS-96-059

December 13, 1996

Mr. J. T. Sweeney, ORNL Program Manager
Environmental Restoration Division
Department of Energy
Oak Ridge Operations Office
Post Office Box 2001
Oak Ridge, Tennessee 37831-8501

Dear Mr. Sweeney,

Contract DE-AC05-84OR21400: Removal Action Report on Waste Area Grouping 4 Seeps 4 and 6 at Oak Ridge National Laboratory, Oak Ridge, Tennessee (DOE/OR/01-1544&D1)

Enclosed for your review are eight (8) copies of the D1 version of the Removal Action Report (RmAR) associated with the Oak Ridge National Laboratory Waste Area Grouping (WAG) 4 Seeps 4 and 6 Removal Action Project. This transmittal completes the process of meeting the FFA milestone of December 31, 1996, for submitting the D1 version of the RmAR to DOE.

We request that you forward this D1 version of the RmAR to the regulators.

If you have any questions or need additional information, please call Steve Laman, at (423) 574-5766.

Sincerely,

K. A. Bradley, Manager
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J. T. Sweeney
Page 2
December 13, 1996

ACKNOWLEDGMENT

I acknowledge receipt of eight (8) copies of the *Removal Action Report on Waste Area Grouping 4 Seeps 4 and 6 at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE/OR/01-1544&D1) and will transmit the required number of copies of this document to the Environmental Protection Agency and the Tennessee Department of Environment and Conservation.

Mr. J. T. Sweeney, ORNL Program Manager
Department of Energy
Oak Ridge Operations Office

Date

Energy Systems Environmental Restoration Program

**Removal Action Report on Waste Area Grouping 4
Seeps 4 and 6 at Oak Ridge National Laboratory,
Oak Ridge, Tennessee**

Date Issued—December 1996

Prepared for the
U.S. Department of Energy
Office of Environmental Management
under budget and reporting code EW 20

Environmental Management Activities at the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
for the
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under contract DE-AC05-84OR21400

PREFACE

This *Removal Action Report on Waste Area Grouping 4 Seeps 4 and 6 at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE/OR/01-1544&D1) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to document removal action activities for the Waste Area Grouping 4 Seeps 4 and 6 Removal Action. This work was also performed under Work Breakdown Structure 1.4.12.6.1.04, Activity Data Sheet 3004, "ORNL WAG 4 Seeps" in accordance with the criteria set forth in the *Action Memorandum for the Waste Area Grouping 4 Seeps at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs ER Team 1996). Background information and recommendation of the selected alternative were presented in the *Engineering Evaluation/Cost Analysis for Waste Area Grouping 4 Seeps, Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs ER Team 1995).

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ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Ci	curie
cm/s	centimeter per second
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
ft ³	cubic feet
³ H	tritium
km	kilometer
m ³	cubic meters
MS	monitoring station
NCP	National Contingency Plan
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
WAG 4	Waste Area Grouping 4
SLLW	solid low level waste
⁹⁰ Sr	strontium 90
SWSA 4	Solid Waste Storage Area 4
TBC	to be considered

EXECUTIVE SUMMARY

The Oak Ridge National Laboratory (ORNL) is a federal facility managed by Lockheed Martin Energy Research, Inc. for the U.S. Department of Energy (DOE). The ORNL is on the Oak Ridge Reservation (ORR) in East Tennessee at the Anderson and Roane County lines, approximately 24 km (15 miles) west of Knoxville, Tennessee, and 16 km (10 miles) southwest of the city of Oak Ridge. Waste Area Grouping 4 (WAG 4) is situated in Melton Valley, southwest of the ORNL main complex.

WAG 4 contains a shallow burial ground for radioactive and industrial wastes that was operated from 1951 until 1974. The waste disposal trenches are seasonally inundated with percolating surface water and upwelling groundwater that transports contaminants off site via an ephemeral tributary to White Oak Creek. The primary contaminant of concern at WAG 4 is strontium 90 (^{90}Sr), based on concentration, mobility, and radiotoxicity. A site investigation conducted in 1994 and 1995 (ORNL 1995) concluded that portions of four waste disposal trenches were responsible for approximately 70 percent of the ^{90}Sr released from the site.

This report documents removal action activities for a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) non-time-critical removal action as described in the Action Memorandum prepared by Jacobs ER Team (1996). The technical objective of this removal action was to reduce the release of strontium 90 (^{90}Sr) into an ephemeral tributary to White Oak Creek from WAG 4 seeps, as measured at Monitoring Station (MS) 1 at ORNL, Oak Ridge, Tennessee.

Design was initiated in early January 1996 and grouting activities were completed in late October 1996. Portions of four waste disposal trenches were injected using low-pressure permeation grouting technology with multiple formulations of grouts to reduce the in situ hydraulic conductivity of the waste materials and ultimately reduce the off-site transport of ^{90}Sr .

The results of in situ hydraulic conductivity tests performed through more than 20 check pipes after grouting indicate that the average in situ hydraulic conductivity of the waste materials was reduced to a value less than $1 \times 10^{-6} \text{ cm/sec}$ by grouting. This value is at least two orders of magnitude lower than that of the surrounding ground, which renders the grouted waste materials relatively impermeable to groundwater flow as compared to the surrounding ground. The significance of achieving this technical criteria is that through implementation of this removal action, groundwater should tend to flow around the grouted ^{90}Sr source areas of the waste disposal trenches, rather than through them, and the off-site transport of ^{90}Sr should ultimately be reduced.

A surface water monitoring program will be implemented over the next five years to measure the effectiveness of this source control remedy and to provide the basis for any final action decisions.

1. SITE DESCRIPTION

The ORNL is on the DOE-ORR in East Tennessee at the Anderson and Roane County lines, approximately 24 km (15 miles) west of Knoxville, Tennessee, and 16 km (10 miles) southwest of the city of Oak Ridge. (See Figure 1).

WAG 4 is situated in Melton Valley, southwest of the ORNL main complex. The site layout and boundaries are depicted in Figure 2. The area of interest within WAG 4 is Solid Waste Storage Area 4 (SWSA 4); a 23-acre area used for burial of radioactive and industrial wastes originating from ORNL and other DOE and U.S. Department of Defense facilities and their contractors over a 23-year period, beginning in 1951. The waste disposal process typically consisted of excavating unlined trenches 3 to 4.5 meters (10 to 15 feet) deep, dumping wastes into the open trenches, then covering the trenches with a thin layer of excavated soil about 1 meter (3 feet) thick. The preponderance of the early waste disposal records were destroyed by fire in 1957; consequently, disposal records and information regarding waste disposal trench locations are very limited. Construction debris was used as a filler and cover for the area. Containers of elemental sodium, which reacts violently with water, may also have been buried at the site; however, the location and quantity of sodium containers cannot be confirmed. At the time of initiation of removal action activities, the site was a grassed meadow which sloped gently from north to south. Access to WAG 4 is restricted, and the contaminated areas are well marked.

The waste disposal trenches are seasonally inundated by percolating surface water and upwelling groundwater. This water flows down through the waste materials, collecting contaminants and discharging down slope in the form of contaminated seeps and contaminated groundwater. Surface water drainage and a sizable portion of groundwater flow is directed to an ephemeral tributary to White Oak Creek which flows from west to east at the southern side of the site. From White Oak Creek, surface water flows across White Oak Dam and off the ORR into the Clinch River.

The contaminant of concern for this removal action was ^{90}Sr , a hazardous substance as defined by CERCLA. Several other radiological contaminants have been detected in and around the subject trenches; however, ^{90}Sr was the only subject of this removal action, based on concentration, mobility, and radiotoxicity. A total of 0.7 Ci of ^{90}Sr was released from WAG 4 in 1994, which is equal to about 20 percent of the ^{90}Sr estimated to have exited over White Oak Dam that year (ORNL 1995). The sources for two seeps (Seeps 4 and 6) apparently contributed over 90 percent of the strontium releases measured at MS 1, which translated to over 70 percent of all WAG 4 ^{90}Sr releases. This removal action was directed toward source control of the portions of four waste disposal trenches associated with Seeps 4 and 6, assuming that contamination in soil and water will abate once control over primary contaminant sources is implemented.

Fig. 1. Location of WAG 4 seeps—Oak Ridge, Tennessee.

Fig. 2. WAG 4 burial trenches and associated seeps—Oak Ridge, Tennessee.

2. PROJECT REQUIREMENTS

This report documents removal action activities for a CERCLA non-time-critical removal action as described in the Action Memorandum prepared by Jacobs ER Team (1996). The technical objective was to reduce the release of ^{90}Sr into an ephemeral tributary to White Oak Creek (located at the southern side of WAG 4) from WAG 4 seeps, as measured at MS 1 at ORNL, Oak Ridge, Tennessee. The goal of this removal action was to reduce the ^{90}Sr released from WAG 4 seeps by 35 percent within the first 3 years and 75 percent within 10 years. As a limited action to control sources and prevent contaminant migration, this removal action is expected to significantly reduce the amount of ^{90}Sr entering White Oak Creek and reduce the risks to human health and the environment until additional and/or permanent actions to eliminate or further control the sources of contamination are taken.

Four alternatives, including the no action alternative, were evaluated as a removal action to reduce ^{90}Sr releases from the WAG 4 seeps (Jacobs ER Team 1995). Because this was a removal action only, limited in scope to 20 years, all retained alternatives assumed that present institutional controls will remain in effect, including limitations on access and use. All alternatives would be most effective if existing catch basins and the drainage system on the north side of Lagoon Road are maintained and kept clear of debris. The action alternatives included (1) source control by reducing in situ hydraulic conductivity (water flow) using grout; (2) enclose, collect and treat; and (3) cap, collect, and treat. Two versions of the source control alternative were evaluated: (1) source control by grouting and (2) source control by cryogenics.

Three important considerations during the evaluation process included (1) the time frame implied by the removal action, (2) health and safety concerns, and (3) management of uncertainties. Short-term effectiveness and cost/benefit considerations were given extra weight in the evaluations. Health and safety concerns included the possibility of the violent reaction of containerized elemental sodium if exposed to water. A safety and analysis report addressed uncertainties associated with transuranic constituents that could present a criticality issue if present in the wastes. Remaining uncertainties were associated with the delineation of the trenches and implementability due to heterogeneity of the construction debris.

The alternative of choice at the WAG 4 seeps, as identified in the Engineering Evaluation/Cost Analysis (EE/CA) prepared by Jacobs ER Team (1995), was source control by low-pressure permeation grouting to reduce hydraulic conductivity. This in situ remedy has neither continuing treatment nor contingency actions. The source control by grouting alternative consisted of in situ control of the ^{90}Sr sources in four trench sections associated with Seeps 4 and 6 (identified as having elevated contamination).

A goal of the design was to lower the in situ hydraulic conductivity of the waste materials sufficiently by grouting such that groundwater would tend to flow around the treated portions of the waste disposal trenches, rather than through them. This would effectively control the identified ^{90}Sr sources. A review of available groundwater data suggested that the surrounding natural ground in Melton Valley has an average in situ hydraulic conductivity on the order of 1×10^{-4} cm/sec (ORNL 1992). Based on this information, the project team established a design goal to reduce the average in situ hydraulic conductivity of the target trench areas to a value less than or equal to 1×10^{-6} cm/sec, as measured through the check pipes and selected sleeve pipes after grouting. Achievement of this design goal, would render the treated portions of the waste disposal trenches

relatively impermeable to groundwater flow as compared to the surrounding natural ground, and should cause groundwater to flow around the treated sections of waste disposal trenches, rather than through them.

Multiple grout formulae were injected into these four trench sections using low-pressure permeation grouting technology to provide physical stability and to reduce hydraulic conductivity. Thus, the volume of groundwater flow to the ^{90}Sr contamination sources was reduced and stabilization of the ^{90}Sr source areas was enhanced. The trench surfaces were covered with crushed stone and re-graded during construction activities to reduce potential exposure of workers and equipment to contamination and to provide a stable working surface.

Future surface water monitoring will verify the overall effectiveness of the action and provide a basis for any final action decisions. Spatial and temporal profiles of ^{90}Sr flux will be developed from measurements taken over the first 5 years following construction activities. These will be made at five surface water monitoring locations shown in Figure 3 (WAG4-MS1, W4T4, SCS4, W4T6, and SCS6) by collecting samples at each location for ^{90}Sr analysis and taking simultaneous stage measurements to determine surface water discharge rates. Continuous discharge records will be used with the measured flow rate versus ^{90}Sr concentration to estimate releases at each location. The need for continued monitoring will be evaluated at the CERCLA 5-year review.

In accordance with Section 300.415(I) of the National Contingency Plan (NCP), on-site removal actions conducted under CERCLA are required to meet applicable or relevant and appropriate requirements (ARARs) to the extent practicable. The NCP identifies two factors that should be considered in determining whether identifying and complying with ARARs is practicable (1) the urgency of the situation and (2) the scope of the removal action to be taken. Based on the above guidance, ARARs specific to the preferred alternative were presented in the EE/CA. Identification of ARARs is an iterative process. Resultant ARARs for this removal action are presented in Table 1. No endangered or threatened species or habitats, or archaeological or historic resources were identified at the site. The project was designed so that no activities were performed in wetlands areas or within the 100-year floodplain.

3. REMOVAL ACTION ACTIVITIES

The schedule objective of the project was to complete grouting activities this calendar year. Due to significant rise in groundwater levels in the trenches during the wet season, it was decided that the grouting activities should be completed prior to October 31, 1996, in order to avoid significant potential project delays and cost impacts associated with removal of large volumes of groundwater from the trenches and weather delays. For this reason, the project schedule was fast-tracked, even though it was a "non-time-critical removal action." Design for the project was initiated in early January 1996. The grouting subcontract package was issued certified for construction March 14, 1996. Site preparation activities were performed in March through May 1996. The grouting subcontract was awarded in late May and grouting activities were completed October 21, 1996 ahead of the October 31, 1996 targeted completion date.

Prior to grouting, the site was prepared for ready access by the grouting subcontractor. The purpose of this stage of the project was to remove any physical obstructions and to reduce the potential exposure of the grouting subcontractor's personnel and equipment to contamination and

Fig. 3. WAG 4 target trenches, radioactive seeps, and flow sites.

Table 1. Potential ARARs/TBC guidance common to all the alternatives for interim remedial action at WAG 4 seeps, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Action	Requirement	Applicability	Citation
<i>Chemical-specific</i>			
Release of airborne radionuclides			
During construction, remediation, or transport activities	Public exposure, airborne emissions—10 mrem/year	Applicable to releases of airborne emissions of radionuclides from all sources at DOE facilities	40 CFR 61.92
	General public exposure all sources—100 mrem/year Temporary exemption, maximum limit—500 mrem/year	TBC (proposed as 10 CFR 834)	DOE Order 5400.5, II.1a. ("Radiation Protection of the Public and Environment")
	All releases shall be as low as reasonably achievable	TBC (proposed as 10 CFR 834)	DOE Order 5400.5, I.4
<i>Location-specific</i>			
Undiscovered archaeological resources			
Action impacting any federally owned, administered, or controlled prehistoric or historic resources -or- the likelihood of undiscovered resources	Consultation with the State Historic Preservation Office (SHPO) should be conducted if cultural resources are inadvertently discovered during remediation activities	Applicable if actions uncover any undiscovered archaeological resources	National Historic Preservation Act (16 USC 470a-w) Executive Order 11593 36 CFR 800
	Consultation should be initiated with (SHPO) and Advisory Council on Historic Preservation before the initiation of any groundbreaking activities to determine the need for any additional archaeological or historic survey work and the need for an memorandum of agreement regarding protection of archaeological resources		

Table 1. (continued)

Action	Requirement	Applicability	Citation
Action involving alteration of terrain, which might cause irreparable loss or destruction of significant scientific prehistoric, historic, or archaeologic resources	The Secretary of the Interior must be advised of the presence of the data. A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data therefrom or request that the U.S. Department of the Interior do so	Applicable if actions impact any such identified resources	Archaeological and Historic Preservation Act of 1974 (16 USC 469a-c)
Action impacting any archaeological resources on public land (i.e., within the ORR boundaries)	Steps must be taken to protect archaeological resources and sites	Applicable if actions impact any such identified resources	Archaeological Resources Protection Act of 1979 (16 USC 470aa-II) 43 CFR 70
<i>Action-specific</i>			
Fugitive dust emissions Release of such emissions during construction or remediation activities	Take reasonable precautions to prevent particulate matter from becoming airborne; no visible emissions permitted beyond property boundary lines for more than 5 minutes/hour or 20 minutes/day	Applicable	TDEC Chapter 1200-3-8-.010
Releases to surface water Stormwater discharges associated with construction activities at industrial sites, which result in a disturbance of greater than 5 acres of total land area	Implement good site planning and best management practices (BMPs) to control stormwater discharge, including: <ul style="list-style-type: none"> • documenting BMPs in a stormwater control plan or equivalent document, • minimal clearing for grading, • removal of vegetation cover only within 20 days of construction, • performance of weekly erosion control inspections and maintenance, • control measures to detain runoff, and • discharges must not cause erosion. 	Relevant and appropriate to activities that result in a disturbance of less than 5 acres of total land area	40 CFR 122; TDEC Chapter 1200-4-10-.05

Table 1. (continued)

Action	Requirement	Applicability	Citation
Within area encompassing or affecting waters of the state of Tennessee as defined in TCA 69-3-103(32)	Abate existing pollution of Tennessee waters	Applicable	Tennessee Water Quality Control Act of 1977 [(TCA 69-3-102(b))]
Waste characterization			
	A person who generates solid waste must determine whether that waste is hazardous using various methods, including the Toxicity Characteristic Leaching Procedure (TCLP) or application of knowledge of the hazardous characteristics of the waste based on information regarding the materials or processes used	Applicable to any excavated soils or water, treatment residuals, or contaminated personal protective equipment	TDEC 1200-1-11-.03(1)(b) 40 CFR 262.10(a)(2)
Radionuclide contaminated material			
On-site management, storage and transportation of waste	Must meet waste acceptance criteria of any permitted, on-site storage facility	Applicable to any radioactively contaminated soils, treatment residuals, or personal protective equipment (TBC guidance)	DOE Order 5820.2A (III.3e and III. 3a, respectively) ("Radioactive Waste Management")
	Management of low-level waste must meet the performance objectives of DOE Order 5820.2A		
	Allows storage of mixed waste on the ORR for periods longer than one year pending development of treatment capacity	Applicable if any radioactively contaminated materials also contain RCRA-characteristic waste (TBC guidance)	EPA/DOE LDR-FFCA/ORR June 12, 1992
Institutional controls	Institutional controls shall be required for all areas where containment is a remedial action; controls shall include, at a minimum, deed restrictions for sale and use of property and securing the area to prevent human contact with hazardous substances	Applicable when hazardous substances are left in place	TDEC 1200-1-13-.08(a)(4)(iv)

Table 1. (continued)

Action	Requirement	Applicability	Citation
	Active controls include fences, warning signs, and restrictions on land use	Long-term management of residual radioactive material (TBC guidance)	DOE Order 5400.5, IV.6c
Residual radioactivity left in place	Residual radioactive material in soil are those concentrations in excess of background concentrations averaged over an area of 100 m ² . These derivations are obtained by means of environmental pathway analysis and basic dose limits	Applicable if residual radioactive material is left in place (TBC guidance)	DOE Order 5400.5, IV.4a
	Residual concentrations of radionuclides in air and water shall not exceed 100 mrem (1 mSv) per year		DOE Order 5400.5, IV.4e
	Administrative controls shall include (but are not limited to):		DOE Order 5400.5, IV.6c(2)
	<ul style="list-style-type: none"> • periodic monitoring as appropriate, • appropriate shielding, • physical barriers to prevent access, and • appropriate radiological safety measures 		

CFR = Code of Federal Regulations

DOE = U.S. Department of Energy

FFCA = Federal Facility Compliance Agreement

LDR = land disposal restriction

m = metermrem = millirem

ORR = Oak Ridge Reservation

SHPO = State Historic Preservation Office

TBC = to be considered

TDEC = Tennessee Department of Environment and Conservation

other hazards. Site preparation included the creation of a "clean" working surface, so the threat of worker contamination and associated need for protective clothing could be minimized. The working areas over the trenches and other areas accessed regularly by site personnel were covered with multiple layers of geotextile and crushed stone to avoid worker contact with the contaminated ground surface as shown in Figure 4. The crushed stone pads over the trenches were also designed to drain surfacing groundwater and grout away from the work area. The site entrances were enlarged to allow access by semi-trucks for delivery and removal of equipment and supplies. Simultaneously, overhead power transmission lines and communication lines which formerly traversed the trench areas to be grouted were re-routed to the south side of Lagoon Road to avoid interference with subsequent operations. Straw bales, silt fencing, and sand bags were installed around the trenches to be grouted to control movement of grout that would surface during grouting operations. Also, a concrete cap which was discovered over Trench II was pre-drilled semi-remotely (from a distance) to allow easy penetration of the grout pipes into the trench.

During site mobilization, the grouting subcontractor installed a temporary, above-ground water line and above-ground power and communication lines to support grouting operations. The temporary utilities were removed by the grouting subcontractor during de-mobilization.

Grout pipes and groundwater monitoring wells were installed semi-remotely (from a distance) using a small track-mounted pile driver. Sleeve pipes (or *tube-a-manchettes*) were used to inject the grout into the subsurface. Once driven into the ground, a pipe could not be removed because of the potential for spreading contamination. In cases where the pipes did not penetrate completely to the bottom of the trench, additional sleeve pipes were added to surround the impenetrable object. Driving records were kept for each pipe to help delineate subsurface conditions and to verify that the pipes were installed in the trench. The hole patterns were modified slightly during driving, because the orientations of the trenches were different than expected. After completion of driving pipes in a given trench, samples of the groundwater were obtained and analyzed in the laboratory for potential chemical and radiological changes that could occur by breaching containers. In Trench I, sulfate concentrations were elevated as a result of driving pipes (concentrations ranged up to about 1100 mg/l), which raised the possibility of premature deterioration of the grout. The grout mixes for that trench were reviewed to confirm sulfate resistance at the measured concentration levels based on published information. No significant chemical or radiological changes were observed in groundwater samples taken after driving pipes in the three other trenches.

After installation of the sleeve pipes and groundwater monitoring wells, grout pads were cast around each pipe to seal the opening made in the ground surface. A weak, brittle casing grout was injected into the annulus between the sleeve pipes and the subsurface to prevent grout from flowing immediately upward to the ground surface. Upon curing, the casing grout at selected sleeves was cracked by applying water pressure to provide access out of the sleeve pipe to the subsurface. Subsequently, water tests were performed through selected sleeves to measure in situ hydraulic conductivity and test for large voids prior to grouting. Since the hydraulic conductivity is related to void sizes in the subsurface target volume, this information was used to determine the starting grout mixes. The installation of casing grout and performance of in situ hydraulic conductivity tests were also performed semi-remotely to offset potential violent reaction hazards associated with the presence of elemental sodium.

Once the in situ hydraulic conductivity tests were completed, grouting began. The grouting subcontractor was required to be able to batch up to 20 different formulae of Type III Portland cement-based grouts, up to 5 different formulae of ultra fine cement-based grouts, and a wide range of concentrations of acrylamide grouts. Production grouting was initiated at the down-hill end of each trench and progressed up-hill pushing groundwater ahead of the grout front. At Trenches I, III,

Fig. 4. Aerial view of WAG 4 taken during grouting.

and IV, the grouting program was started at mid-trench locations. Bulkheads were built with grout to keep subsequent grout injections from flowing down hill by gravity. Grouting was conducted in multiple holes simultaneously, with multiple injections made into the same zone of waste.

Grout flow rates and injection pressures were recorded continuously using real time monitoring equipment and analyzed via computer to allow changes in the grouting program to be made promptly, during injection, based on the response of the formation.

Apparent lugeon values (numerical calculation of in situ hydraulic conductivity using the grout as the permeating fluid) were calculated throughout the grouting shift and the grout formulae were adjusted continuously to optimize permeation and economy. Grout injection quantities were continuously compared to estimated theoretical quantities of grout take. The waste deposits were injected at least twice with Type III Portland cement-based grouts, once with ultra fine cement-based grouts, and finally with acrylamide grouts. A total of approximately 34 m³ (9,100 gallons) of casing grout, 370 m³ (97,700 gallons) of Type III Portland cement-based grouts, 65 m³ (17,200 gallons) of ultra fine cement-based grouts, and 51 m³ (13,600 gallons) of acrylamide grouts were injected into the waste disposal trenches. Figures 5 through 7 show grouting operations in progress. Figures 8 and 9 show the "as-built" locations of the grout pipes.

Upon completion of grouting operations, the grout spread and in situ hydraulic conductivity of the grouted waste materials were assessed via check pipes (sleeve pipes that were installed prior to grouting, but not used during production grouting). The test results indicate that the average (statistical calculation of geometric average) residual in situ hydraulic conductivity of the grouted waste materials, measured in more than 20 check pipes, was reduced to a value less than 1×10^{-6} cm/sec. Also, during installation of grout pipes and performance of initial in situ hydraulic conductivity tests (prior to grouting), it was observed that the natural soil berms between the target trenches were badly weathered and that the in situ hydraulic conductivity was in most cases orders of magnitude greater than the 1×10^{-4} cm/sec value used to establish the hydraulic conductivity goal for the grouted waste materials. Consequently, the grouted waste materials are believed to be considerably less permeable to groundwater flow, relative to that of the surrounding ground, than initially planned (more than two orders of magnitude lower). This should further increase the tendency for groundwater to flow around the treated portions of the waste disposal trenches, rather than through them. The end result is that the off-site transport of ⁹⁰Sr should be reduced.

After completion of the post-grouting hydraulic conductivity tests, the grout pipes were cut off approximately one foot above the ground surface and capped. In sleeve pipes receiving injections of acrylamide grout, the acrylamide grout was left inside the sleeve pipes after gelation. The gravel pad areas were smoothed and all waste materials were removed from the site.

During grouting, the pH of the ephemeral tributary to White Oak Creek was monitored to verify that the water quality was not being adversely affected; no adverse effects were noted as the pH of the surface water remained within the range typically measured under normal conditions.

Daily grouting activity reports, results of quality control and/or quality assurance testing, photographs, as-built drawings, and all other project documentation will be maintained for permanent retention in the Administrative Record.

Fig. 5. Semi-remote control pipe driving.

Fig. 6. Trench grouting.

Fig. 7. Grout batching.

Fig. 8. As-built locations of grout pipes near Seep 6.

Fig. 9. As-built locations of grout pipes near Seep 4.

4. DEVIATIONS FROM THE ACTION MEMORANDUM

During execution of this removal action, there were no deviations from the criteria set forth in the Action Memorandum (Jacobs 1996). However, it is worth noting that during the course of the field work, it was determined that the orientations of the trenches were slightly different than depicted in the Action Memorandum. (Refer to Figures 8 and 9.)

5. WASTE MANAGEMENT AND TRANSPORTATION ACTIVITIES

Groundwater, which was displaced by the grout and tended to flow up in the groundwater monitoring wells or sleeve pipes with failed sleeves (a small percentage of sleeves were damaged during driving), was pumped out of the trenches during grouting. Waste water was also generated during flushing of the sleeve pipes at the end of each grouting shift. The waste water generated during dewatering and flushing operations was contained and pumped into polyethylene tanks for storage prior to shipment off site for treatment and disposal. Approximately 76 m³ (20,000 gallons) of contaminated water were transported by a tanker truck to the Process Waste Treatment Plant at ORNL for treatment and disposal.

A total of 25 m³ (872 ft³) of solid low-level waste (SLLW) was generated from this removal action including five B-25 boxes and one 55-gallon drum of non-compactible grout materials, one B-25 box of smeltable metal, two B-25 boxes of incinerable plastic, and one B-25 box of incinerable personnel protective equipment. The SLLW was segregated and packaged into waste containers. Because several of the polyethylene tanks contained liquid and grout solids, the liquid supernate was pumped off, the tanks were cut into small pieces, and the grout solids were removed to facilitate packaging and disposal. Polyethylene tanks not containing grout solids, will be re-used during future contaminated work. The SLLW will be transferred to the Waste Management and Remedial Action Division of Lockheed Martin for disposal. Non-contaminated solid waste such as grout material containers was trucked off-site by the grouting subcontractor to a state permitted landfill for disposal.

6. OPERATION AND MAINTENANCE PLANS

Baseline monitoring has established five locations (two seep collection system weirs and three tributary monitoring weirs) needed to evaluate the effectiveness of the removal action. The seep collection system weirs allow evaluation of how well storm runoff transport of ⁹⁰Sr has been controlled and also allow separation of the storm runoff releases from slower groundwater releases that emerge in the WAG 4 tributary. Modeling results suggest that 10 years will be required for a ten-fold decrease in ⁹⁰Sr releases, but also show that the first 5 years are expected to exhibit the greatest changes. At each of the five locations shown in Figure 3 (WAG4-MS1, W4T4, SCS4, W4T6, and SCS6), continuous records of stream stage will be obtained during the first 5 years: 1996 through 2001. These records can be converted, with proper calibration, to flow rates. In addition, sufficient samples will be taken over a range of flow rates to allow determination of the relationship between flow rate and concentration of both ⁹⁰Sr and tritium (³H) representative of conditions each year (preferably during the wet season). These relationships will be used with measured flow rates to quantify the release at any point in time. Baseline relationships were established prior to the removal

action, and new relationships must be determined each year to quantify changes in total releases from the baseline. The ^3H data provide an added basis for evaluating change, since the ^3H source was not affected by the removal action. The evaluations will compare actual releases (using flow vs. concentration observations) against expected baseline releases (using flow vs. baseline concentration relationships). Computations for both ^{90}Sr and ^3H releases will be compared. In addition, an evaluation of the impact of the removal action on the storm runoff pathway will be separated from the impact on the deeper flow pathway.

7. MONITORING SCHEDULE AND/OR EXPECTATIONS

Surface water monitoring is scheduled to begin this year and continue for the next five years (1996 through 2001). Modeling results suggest a 35 percent reduction in ^{90}Sr releases from seeps in the first three years and a 75 percent reduction in ^{90}Sr releases from seeps in ten years. However, the greatest percent reduction in ^{90}Sr releases is expected in the first five years. At the end of the five year period, a decision will be made as to whether to continue the monitoring program at the CERCLA 5-year review.

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