OAK RI
TE

Decontamination and D

DOE NATIONAL LABORATORY
TECHNOLOGY LOGIC DIAGRAM

VOLUME 2

TECHNOLOGY LOGIC DIAGRAM

PART A Decommissioning

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Prepared for the
Office of Technology Development
U.S. Department of Energy

**1993
Edition**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

**Oak Ridge National
Technology Log**

**Volume
Technology Log**

**Part
Decontamination and**

Prepared for the Office of Technology
U.S. Department of Energy

September

Prepared by
Oak Ridge K-25
Oak Ridge, Tennessee
managed by
MARTIN MARIETTA ENERGY SERVICES, INC.
for the
U. S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

al Laboratory
gic Diagram

e 2
gic Diagram

A Decommissioning

chnology Development
of Energy

1993

oy
5 Site
see 37831
oy
BY SYSTEMS, INC.

OF ENERGY
15-84OR21400

MASTER

ds
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Acknowledgments	v
Foreword	vii
Explanation and Understanding Key	ix
Characterization	1
General Problems	
Sampling Design	3
Sample Collection	3
Sample Preparation	4
Detection/Measurement—Field Methods	5
Detection/Measurement—Laboratory Methods	6
Data Analysis/Management	7
Radioactive Elements	10
Inorganics	12
Organics	14
Physical	17
Oils and Purex Chemicals	18
Polychlorinated Biphenols	19
Dismantlement	21
Massive Containment	23
Reactor Pools	23
Buried Tanks	25
Structural-Only Concrete	26
Steel Containment Structures (Highly Contaminated)	28
Structural Steel	30
Asbestos	32
Major Equipment Removal	32
Entombment	36
Needed Enabling Technologies	40

Decontamination	45
Concrete	47
Painted Concrete	56
Stainless Steel, Structural Steel, Cu and Al Pipe	61
Concrete Block and Tiled Concrete (Tile Removed)	72
Tiled Concrete (Tile Decontaminated In Situ)	82
Building Materials (Wood, Sheetrock, Tar and Felt Roofing)	85
Piping (Steel, INOR, Al, and Cu)	87
Stainless Steel Tank	97
Zincalloy, Steel, and Al with Activation Products	105
Asphalt Pavement	107
Robotics and Automation	113
Mechanical—Mobility	115
Mechanical—Manipulation	116
Mechanical—Mechanisms	116
Mechanical—End-of-Arm-Tooling	117
Controls Algorithms	117
Controls—Human/Machine Interface	118
Sensors—Perception	119
Sensors—Controls	119
Other Technologies	120

Acknowled

The authors acknowledge the significant contributions made by the
and Development: Robert Benedetti, Holmer Dugger, Mitchell Erickson, Ned

A special thanks to R. K. Kibbe, who participated in the initial plann
with initial software evaluation.

Project Manager

R.L. Fellows K-25 Technical

Assistant Project Manager

D.W. Phifer, Jr. K-25 Technical

Team Leaders and Section Editors

R.D. Bundy Decontamination (K-25 Technical)
W.H. Griest Characterization (ORNL Analytical Chemistry)
L.C. Hensley Dismantlement (MMES Engineering)
C.G. Jones Regulatory Compliance (MMES Environmental Compliance)
S.L. Schrock Robotics/Automation (ORNL Robotics and Process Systems)
S.P.N. Singh Waste Management (Chemical Technical)
J.S. Watson Remedial Action (Environmental Restoration)

Deputy Team Leaders and Section Editors

G.D. DelCul Waste Management (K-25 Technical)
H.M. Henson Characterization (K-25 Technical)
J.P. Hitch Regulatory Compliance (ORNL Health Sciences Research)
W.S. Key Dismantlement (ORNL Applied Technical)
J.W. Kubarewicz Remedial Action (CH2M HILL)
J.K. Kuhaida Remedial Action (ORNL Environmental Restoration)
J.H. Wilson Decontamination (ORNL Chemical Technical)

Senior Advisory Group

N.H. Cutshall Office of Environmental Technical Development
R.K. Genung ORNL Chemical Technical
J.M. Googin Y-12 Development
B.L. Kimmel II ORNL Remedial Action
A.L. Lotts Consultant (Information Management Services)
A.P. Malinauskas Office of Environmental Technical Development
L.E. McNeese ORNL Waste Management
J.R. Merriman Environmental Restoration and Waste Management
J.O. Moore DOE-Oak Ridge
T.H. Row ORNL Central Management

Planning/Oversight/Coordination

T.W. Burwinkle ORNL Decontamination and Decommissioning
R.L. Fellows K-25 Technical
S.B. Garland ORNL Remedial Action
R.K. Kibbe Decontamination and Decommissioning Integrated Demonstration Coordinator
R.C. Mason ORNL Waste Management
R.L. Snipes Hazardous Waste Remedial Action Program
J.S. Watson MMES Environmental Restoration

gments

DOE Overview Team for the Technology Logic Diagram Review
Hutchins, William Schutte, and Randall Snipes.
ng for this effort, and Monica Schmidt and Janie Ortiz, who helped

ublications

M. French	Secretary (K-25 Technical)
A. Getsi	Technical Editor (Publications)
J. Harnett	Technical Editor (Publications)
G. Jones	Technical Editor (Publications)
W. Llanos	Electronic Publisher (Publications)
J. McCracken	Graphic Designer (Analysas Corporation)
A. Palmer	Graphic Designer (Analysas Corporation)
W. Phifer, Jr.	Publications Coordinator (K-25 Technical)
V.C. Russell	Technical Editor (Publications)
A. Schutte	Graphic Designer (Analysas Corporation)
C. Smith	Electronic Publisher (Publications)
W. Walton	Electronic Publisher (Publications)

Contributors

B. Alderfer	Decontamination (K-25 Technical)
F. Allen	Remedial Action (Radian Corporation)
E. Arnold	Regulatory Compliance (ORNL Health Sciences Research)
D. Arnold	Waste Management (ORNL Chemical Technical)
W. Autry	Remedial Action (ORNL Environmental Restoration)
Barnes	Dismantlement (Machine Kinetics Corporation)
V.K. Barry	Remedial Action (Bechtel Corporation)
V.D. Barton	Remedial Action, Dismantlement (MMES Engineering)
E. Benson	Decontamination (Chemical Technical)
A. Blankenship	Dismantlement (MMES Engineering)
L. Bock	Characterization (K-25 Quality)
S. Boes	Waste Management (ORNL Chemical Technical)
A. Bostick	Waste Management (ORNL Chemical Technical)
V.D. Bostick	Waste Management (K-25 Technical)
K. Brill	Remedial Action (Ogden Environmental)
H. Bunch	Decontamination (K-25 Technical)
S. Burnett	Remedial Action (Radian Corporation)
M. Chiang	Waste Management (MMES Engineering)
R.M. Counce	Remedial Action (MMES Chemical Technical/UT)
L. Daugherty	Waste Management (ORNL Waste Management and Remedial Action)
J. Davidson	Waste Management (ORNL Chemical Technical)
K. Davis	Remedial Action (MMES Environmental Sciences)
E. Denny	Dismantlement (Penn. State)
R. Devore	Decontamination (MMES Engineering)
S. Dudley	Characterization (ORNL Health Sciences Research)
H. Dukes	Waste Management (MMES Engineering)
Z. Egan	Waste Management (ORNL Chemical Technical)
L. Etnier	Regulatory Compliance (ORNL Health Sciences Research)
R.E. Eversole	Robotics/Automation (ORNL Chemical Technical)

Contributors (continued)

R.L. Fellows	Decontamination (K-25 Technical)
J.J. Ferrada	Waste Management (ORNL Chemical Technical)
C.W. Francis	Remedial Action (ORNL Environmental Sciences)
B.A. Fredrick	Remedial Action (Ogden Environmental)
R.B. Gammage	Characterization (ORNL Health Sciences Research)
W.L. Gardner	Decontamination (ORNL Fusion Energy)
S.B. Garland	Remedial Action (ORNL Environmental Restoration)
D.D. Gates	Remedial Action (MMES Environmental Sciences)
C.D. Goins	Regulatory Compliance (MMES Legal)
V.M. Green	Waste Management (ORNL Chemical Technical)
J.A. Greene	Remedial Action (MMES Environmental Restoration)
M.R. Guerin	Characterization (ORNL Analytical Chemistry)
R.C. Hagenauer	Characterization (International Technology)
D.C. Haley	Robotics/Automation (ORNL Robotics and Process Systems)
H.H. Haselton	Decontamination (K-25 Environmental Technical)
D.D. Haskel	Dismantlement (Machine Kinetics Corporation)
S.E. Herbes	Remedial Action (MMES Environmental Sciences)
W.H. Hermes	Waste Management (MMES Engineering)
J.N. Herndon	Robotics/Automation (ORNL Robotics and Process Systems)
J.P. Hitch	Regulatory Compliance (ORNL Health Sciences Research)
D.P. Hoffmann	Characterization (K-25 Technical)
J.H. Hooyman	Remedial Action (MMES Waste Management)
L.M. Houlberg	Regulatory Compliance (ORNL Health Sciences Research)
K.S. Jones	Remedial Action (MMES Engineering)
J. Kauschinger	Remedial Action (Law Engineering)
J.M. Keller	Characterization (ORNL Analytical Chemistry)
A.P. Kelsey	Remedial Action (Bechtel Corporation)
C.M. Kendrick	Remedial Action (MMES Chemical Technical)
J.M. Kennerly	Dismantlement (MMES Central Decontamination and Decommissioning)
T.E. Kent	Waste Management (ORNL Chemical Technical)
R.H. Kettelle	Remedial Action (MMES Energy)
W.S. Key	Dismantlement (ORNL Applied Technical)
L.N. Klatt	Robotics/Automation (ORNL Robotics and Process Systems)
H.E. Knee	Robotics/Automation (ORNL Engr., Phy., and Math.)
R.G. Lahoud	Remedial Action (CH2M HILL)
G.R. Larson	Waste Management (MMES Waste Management and Remedial Action)
S.Y. Lee	Remedial Action (MMES Environmental Sciences)
M.S. Lee	Characterization (ORNL Analytical Chemistry)
D.N. Mashburn	All areas (ORNL Applied Technical)
G.E. Michaels	Waste Management (ORNL Chemical Technical)
M.E. Mitchell	Regulatory Compliance (MMES Environmental Compliance)

Acknowledgements

J.W. Moore	Dismantlement (MMES Engineering)
T.R. Mueller	Characterization (ORNL Analytical Chemistry)
E.B. Munday	Decontamination (K-25 Technical)
J.K. Munro	Characterization, Dismantlement (ORNL Instrumentation and Controls)
W.D. Nelson	Decontamination (ORNL Fusion Energy)
M.R. Peet	Remedial Action (MMES Engineering)
J.J. Perona	Waste Management (ORNL Chemical Technical)
J.L. Pfeffer	Remedial Action (CH2M HILL)
T.J. Pierce	Dismantlement (MMES Engineering)
U.I. Pisingan	DOD Dependents Schools
K.E. Plummer	Waste Management (ORNL Robotics and Process Systems)
R.B. Pope	Waste Management (ORNL Chemical Technical)
C.C. Ragan	Remedial Action (Radian Corporation)
A.A. Richmond	Waste Management (ORNL Health Sciences Research)
A.L. Rivera	Waste Management (ESWO)
B.A. Roy	Remedial Action (SEG)
J.H. Saling	Remedial Action (MMES Fuel Recycle)
J.T. Shor	Waste Management (ORNL Chemical Technical)
R.L. Siegrist	Remedial Action (MMES Environmental Sciences)
B.H. Singletary	Robotics/Automation, Dismantlement (MMES Engineering)
D.P. Sloan	Remedial Action (CH2M HILL)
D.B. Smith	Decontamination (ORNL Applied Technical)
G.S. Smith	Dismantlement (MMES Engineering)
J.W. Smith	Dismantlement (MMES Engineering)
B.P. Spalding	Remedial Action (MMES Environmental Sciences)
R.D. Spence	Remedial Action (MMES Chemical Technical)
C.E. Strange	Dismantlement (Machine Kinetics Corporation)
L.J. Talarico	All areas (ORNL Applied Technical)
T. Tamura	Remedial Action (MMES Hazardous Waste Remedial Action Program)
S.L. Tayloe	Regulatory Compliance (ORNL Health Sciences Research)
A.P. Taylor	Remedial Action (MMES Chemical Technical)
W.T. Thompson	Remedial Action (MMES Engineering)
J.R. Trabalka	Waste Management (ORNL Environmental Sciences)
C.C. Tsai	Decontamination (ORNL Fusion Energy)
G.L. Underberg	Remedial Action (CH2M HILL)
J.M. Vance	Waste Management (K-25 Technical)
B.W. VanHoy	Dismantlement (MMES Engineering)
W. White	Characterization (Biology Engineering ORNL/UT)
J.E. Wilson	Decontamination (MMES Environmental Sciences)
E.L. Youngblood	Remedial Action (MMES Chemical Technical)
J.W. Zolyniak	Characterization (K-25 Quality)

The *Oak Ridge National Laboratory Technology Logic Diagram* that relates environmental restoration (ER) and waste management potential technologies that can remediate these problems. The *Tennessee Valley Authority Reservation* and a previous Hanford TLD.

The TLD identifies the research, development, demonstration technologies to a state that allows technology transfer and application (RA), and WM activities. It is essential that follow-on engineering studies will begin by selecting the most promising technologies that will provide a socially acceptable balance between

The TLD consists of three fundamentally separate volumes: *Part A (Technology Identification Data Sheets)* and Vol. 3 (*Technology Evaluation Data Sheets*). Part A focuses on the RA of contaminated facilities. Part C of Vols. 1 and 2, the TLD, an explanation of the program-specific responsibilities, a list of technologies. Volume 2 (Pts. A, B, and C) contains the logic linkage diagram of technologies that have the potential to solve these problems. Volume 3

Decontamination and decommissioning is the focus of Volume 3. The subelements of D&D: characterization, dismantlement, decontamination, and decommissioning address general ORNL problems, which are then broken down into specific technologies. The diagrams also contain summary information about the technology and its implementation needs. The diagram structure is explained in

The TLD *Index*, a stand-alone volume, facilitates information retrieval. It comprises three separate indexes, one for each of the corresponding problem areas: searched by specific ORNL problem, problem area/constituents, or

The technology evaluations contained in these volumes are the TLD. New or more accurate information is solicited to improve the TLD. Editor, *Oak Ridge National Laboratory Technology Logic Diagram*, Oak Ridge, TN 37831-7274. FAX (615-576-8558).

gram (TLD) was developed to provide a decision-support tool
t (WM) problems at Oak Ridge National Laboratory (ORNL) to
D uses information from the *Strategic Roadmap for the Oak*

stration, testing, and evaluation needed to develop these
ion to decontamination and decommissioning (D&D), remedial
ring studies be conducted to build on the output of this project.
ologies identified in the TLD and finding an optimum mix of
n cost and risk.

es: Vol. 1 (*Technology Evaluation*), Vol. 2 (*Technology Logic*
A of Vols. 1. and 2 focuses on D&D. Part B of Vols. 1 and 2
2 focuses on WM. Each part of Vol. 1 contains an overview of
review of identified technologies, and the rankings of remedial
es among EM goals, environmental problems, and the various
ie 3 (Pts. A, B, and C) contains the TLD data sheets.

ol. 2, Pt. A, which has been divided into the four necessary
nation, and robotics and automation. Each of these sections
by problem area/constituents and linked to potential D&D
out a technology's status, its science and technology needs,
n detail in the Explanation and Understanding Key that follows.
ation searches on specific technologies. The *Index* actually
ding parts (A, B, and C) of Vols. 1 and 2. Information can be
technology name.

e based on the best information available during compilation of
the TLD data base. Please send comments to R. L. Fellows,
n, Martin Marietta Energy Systems, Inc., P.O. Box 2003, Oak

Explanation and Understanding Key for

The logic elements described in the "Technical Approach" section of Chap. 1

for the Technology Logic Diagram

of the Executive Summary serve as column headings in this diagram.

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>es the general or generic logy approaches to m remediation.</p>	<p>Provides a specific technology that may reasonably be applied to remediate the problem.</p> <p>Technology Evaluation Data Sheet (TEDS) Codes, located after the technology names in this column, refer to TEDSs in Vol. 3. The TEDS address each technology in more detail. Each TEDS contains a single, unique logic path from the Diagrams.</p> <p>Rankings appear after the TEDS code for each technology. The technologies are ranked according to the following criteria:</p> <ul style="list-style-type: none"> • Overall assessment of usefulness (E—essential, H—high, M—medium, L—low) • Ranking of the site problem (1–5 from lowest significance to highest) • Time required to bring the technology to commercial or mature state at the site—expressed in years. • Cost for bringing the technology from its present state to large-scale commercial use (millions [\$M] or thousands [\$K] of dollars). • Projected unit processing cost for mature technology (\$ per ft³ or other unit or N for no estimate). <p>An example of a ranking follows: H-5-5 (\$3.5M;N). This technology has a high overall usefulness; the problem is of highest significance to the site; the technology is estimated to take 5 years before it is ready for application at the site; an approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness; and the unit processing cost cannot be projected at the present time.</p>	<p>Provides information on the status of the preceding technology.</p> <ul style="list-style-type: none"> • In Use—problem is in the process of being remediated with this technology. • Accepted—accepted by industry and/or the problem owner. The demonstrated technology exists for use at ORNL. • Demonstration—technology is available but is not demonstrated and/or accepted for the problem at ORNL. • Predemonstration—technology is under laboratory bench- or pilot-scale testing. • Evolving Technology—technology status is at a conceptual or preconceptual stage. <p>The following areas further define the applicability of a technology to the problem:</p> <ul style="list-style-type: none"> • Efficacy—the effectiveness of the technology in remediating the problem. Normally, quantitative measures are given for the technology's performance in standard practice, such as decontamination, estimating the final dpm/cm² of surface contamination, dismantlement, the time to cut a 24-in. pipe, and characterization, the analysis time and lower detection limit. • Waste—the potential output from the technology. This describes the nature and volume of both the waste and the potentially useful materials (recyclable) suitable for materials disposition evaluation. 	<p>Lists needs in Science and Technology where support should be applied to develop an "immature" technology to a field-deployable state.</p> <p>Science needs are related to the fundamental understanding of the scientific phenomena that form the basis for the technology. These needs are typically for laboratory or bench-scale experiments, and, when possible, experiments addressing specific areas of uncertainty are suggested.</p> <p>Technology development (TD) conversion of a scientifically understood phenomenon into an operating system (technology) that can be applied to, and can remediate an EM problem.</p> <p>Technology improvement needs relate to improvements that make a current technology more economical to apply, safer, and more effective or efficient. The demonstration of a technology on a site-specific problem is classified as a technology improvement need.</p> <p>If scientific needs are specified, it should be understood that the needs of scientific technology development or improvement are necessary to implement newly developed scientific understanding. Likewise, testing a TD opportunity implies that technology improvements are also likely to be needed.</p> <p>Past and currently funded Technical Task Plans (TTP) were correlated with the technologies. If a match was found, "TTP Match" appears in this column. The TTP number and technology number matches can be found in the TTP tables of Vol. 1, Pt. A, Pt. B, and Pt. C.</p>	<p>Covers many of the areas of concern for technology transfer activities. Specialized needs for both development of a technology and deployment of a mature technology are identified.</p> <p>These needs were evaluated in the areas of (1) resources (financial or personnel); (2) hardware (process equipment, development equipment, and computers); (3) software (models, procedures, computer programs); (4) facilities (labs, shops, and buildings); and (5) education (training classes or degreed personnel). Only extraordinary needs are highlighted (i.e., those needs that would require long lead time or unusual procurements such as line items for facility construction).</p> <p>Technology integration identifies the technologies which can be integrated to produce a safer, better or cheaper remediation system.</p> <p>The cost of applying the technology and the payback cost potential has been estimated. There are many reasons for payback, such as reducing the waste volume compared to a reference process, the sale of useable products, and the reduction of labor compared to a reference technology.</p>

Characterization for Decomtamin

The Characterization section is comprised of a large, which most of the characterization technologies are applied to problems, where a more select group of technologies is used in a section. The former section is divided into several subsections. The subsections are sampling design, sample collection, sampling methods, detection/measurements—laboratory methods, general subsections are listings under the specific subsections: organics, physical, and pathogens. Each of these is divided according to their primary deployment.

ation and Decommissioning

generally inclusive section of ORNL Problems to
cable and of smaller sections for specific ORNL
called for in addition to those offered in the general
tions under the alternatives column. These
ple preparation, detection/measurements—field
and data analysis/management. Following these
ctions of radioactive elements, inorganics,
ed into field methods and laboratory methods

Characterization for Decontamin

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems</p> <p>Including various subparts of the following facilities:</p> <p>Bldg. 3028</p> <p>Bldg. 3028E</p> <p>Bldg. 3029</p> <p>Bldg. 3030</p> <p>Bldg. 3031</p> <p>Bldg. 3032</p> <p>Bldg. 3033</p> <p>Bldg. 3036</p> <p>Bldg. 3038</p> <p>Bldg. 3517</p> <p>Bldg. 7500</p> <p>Bldg. 9219-1</p> <p>MSRE, Bldg. 9201-3</p> <p>Bldg. 9419-1</p> <p>Process Piping and Tankage</p> <p>Drain Lines</p> <p>Pulsefeeder Pumps</p> <p>Pavement over 55-gal. Drum</p>	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation (ORR), radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Sam
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					Sam

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Sampling Design	M Sequential Sampling Plans CHAR-252-OL <i>Ranking:*</i> M-3-5 (\$1M;\$5Kam*)	Accepted TTP Match	Experimental Site Data Available at X-10.	Initial Planning Time
	E Sampling Program Configuration Management System CHAR-228-OL <i>Ranking:*</i> E-5-1 (\$5M;\$50Kam*)	Accepted A range of application software to assist with configuration management is available both commercially and in the public domain. TTP Match	Enhancements to existing products may be required to provide the level of support needed for a large sampling program. Available at X-10.	Separate configuration management systems should be considered for each of (a) Characterization Sampling Program, (b) Remedial Action, (c) Waste Management, and (d) Decontamination and Decommissioning instead of setting up one large all- encompassing system.
	H Optimization of Sampling Designs CHAR-71-OL <i>Ranking:*</i> H-5-5 (\$1M;N)	Demonstration	Literary searches for finding useful sampling designs from investigations in other fields. New statistical methods for sampling design. Available at all sites.	Development Costs: \$100K
Sample Collection	M Ultrasonic Extraction CHAR-20-OL <i>Ranking:*</i> M-4-1 (\$2M;\$400/sample)	Predemonstration, technology not yet demonstrated. TTP Match	Testing needs to be performed to establish the enhancement of material retrieval from porous media using various solvents, acids, and bases.	Hardware cost: \$25K; Development Costs: \$200K. Inverse heads need to be designed for sampling from the floors and other horizontal (top-side) applications.
	M In Situ Solvent Extraction CHAR-62-OL <i>Ranking:*</i> M-4-2 (\$4M;N)	Evolving Technology (conceptual) TTP Match	Model studies are needed to develop the technique.	Development Costs: \$400K.
	E Sampling and Mixing Methods CHAR-81-OL <i>Ranking:*</i> E-5-1 (\$2M;N)	Accepted TTP Match	Need to optimize methods for collection of representative samples and to mix samples into a homogeneous state.	Requires statistical sampling design and proper laboratory blenders, mixers, and other equipment. Development Costs: \$250K
	Membranes for Sample Collection and Concentration CHAR-55-OL <i>Ranking:*</i> No Ranking.	Accepted Membranes are predominantly permeable to selected components in mixtures allowing separation for accumulation or to facilitate analysis/detection. TTP Match	System development or adaptation for specific applications; validation.	Sample collection systems for Site-specific applications.
	H Punch Cores CHAR-82-OL <i>Ranking:*</i> H-5-1 (\$3M;N)	Demonstration	None	Need to acquire and setup methods and equipment for coring sample matrices. important at ORNL. Development Costs: \$300K.
	H Metallographic Sectioning and Preparation CHAR-67-OL <i>Ranking:*</i> H-4-0 (\$0M;<\$500/sample)	Accepted	Procedure development for specific applications are needed; then protocols for standardized preparation should be developed. Available at X-10, K-25.	None
	H Multi-angle Drilling for Depth Profiling of Contaminants CHAR-64-OL <i>Ranking:*</i> H-4-1 (\$2M;N)	Demonstration	Model studies need to be performed. Available at K-25.	Development cost: \$200K

* See the Explanation and Understanding
Key in the front of this document for a
description of the ranking code/scheme.

Characterization for Decont

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems Including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Examination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Sample Collection	<p>H Sampling Interface System for Surface Contamination by Organics CHAR-271-OL</p> <p>Ranking:* H-4-3 (\$.775M;N)</p>	Conceptual TTP Match	Development of rapid heating interface and software for rapid contaminant identification by direct sampling ion trap mass spectrometry.	Development cost: of \$775K over 3 years.
	<p>H Flashlamp Heating to Release or Desorb Surface and Subsurface Contaminants CHAR-87-OL</p> <p>Ranking:* H-4-2 (\$.5M;N)</p>	Predemonstration	Depth profiling and surface area sampled must be determined for each material. Means of sampling the plume must be developed for each analyte.	To be determined for specific applications.
	<p>H Laser Ablation for Sample Collection CHAR-86-OL</p> <p>Ranking:* H-4-2 (\$.5M;N)</p>	Predemonstration TTP Match	The technology for laser ablation is just now becoming available, and a program would be needed to develop the technique for practicing application of the analysis.	Same as Science/Technology needs.
Sample Preparation	<p>H Radioactive Sample Preparation CHAR-205-OL</p> <p>Ranking:* H-4-1 (\$.1M;N)</p>	Demonstration; current work shows that methods can be adapted to meet these needs. TTP Match	Adaptation of EPA and other methods, and development of new technologies for the safe and efficient preparation of radioactive samples for analysis. Available at X-10.	Development cost: \$500K each of 2 years; personnel and facilities are available.
	<p>H Supercritical Fluid Extraction of Organics CHAR-208-OL</p> <p>Ranking:* H-4-1 (\$.33M;\$100/sample)</p>	Predemonstration; technology requires final development. TTP Match	Extraction conditions need to be optimized for the specific target analytes and matrices at the ORNL site. Available at X-10.	Hardware cost: \$30K; Development cost: \$300K.
	<p>H Adaptation of the EPA Toxicity Characteristic Leaching Process for Use with Radioactive Samples CHAR-209-OL</p> <p>Ranking:*</p>	Predemonstration; some work has been conducted, but full adaptation and testing remain to be done. TTP Match	The leaching equipment and protocol must be adapted to glove box and hot cell operations. Available at X-10.	Development cost: \$450K. Equipment must be modified and tested under containment and shielding.
	<p>M Supercritical Fluid Extraction of Inorganics CHAR-201-OL</p> <p>Ranking:* M-3-2 (\$.2M;N)</p>	Predemonstration Supercritical Fluid Extraction of Inorganics, extraction of metal ions from liquid and solid material by supercritical carbon dioxide and chelators. TTP Match	Need to determine optimum extraction conditions, including chelators. Available at X-10.	Equipment cost: \$30K; Development cost: \$400K over 2 years.
	<p>H Microwave Digestion CHAR-19-OL</p> <p>Ranking:* H-5-1 (\$.2M;\$100/sample)</p>	Accepted Demonstration TTP Match	This technology shows much promise in reducing the amount of waste produced in analyzing samples as well as increasing the quality of the data obtained. Available at X-10.	Protocols are needed to optimize the digestion of environmental samples in preparation for subsequent analytical techniques.
	<p>H High Pressure Ashing for Sample Preparation CHAR-203-OL</p> <p>Ranking:* H-4-1 (\$.1M;N)</p>	Demonstration Commercially available, but not mature.	High Pressure Ashing (HPA) is useful for the dissolution of organics and other difficult to dissolve materials. Commercially available but lacks sufficient validation to meet QA requirements. Some special sample types may be at the development stage. Available at X-10.	Some equipment/personnel currently available at ORNL to develop new procedures, but needs to be expanded to meet the increased work load. Estimated cost \$60-120K/year for 2 years.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamination

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Detection/Measurement	<div>H</div> <div>Fiber Optic Chemical Sensors CHAR-25-OL</div> <div>Ranking:*</div> <div>H-5-1 (\$1M;\$10/sample)</div>	Accepted; Demonstration. Remote detection using a variety of methods including optical absorption, Raman scattering and luminescence spectroscopy. The fiber optic is used to deliver or return light to or from the sample. This technology allows remote sensing in hazardous environments.	A combination of waveguides and spectroscopic techniques are needed that have been matched not only for each other but also for specific monitoring scenarios.	Waveguides are needed that can withstand the harsh chemical environment that may be present in some of the sampling locations.
	<div>M</div> <div>Ion Mobility Mass Spectrometry (IMMS) CHAR-264-OL</div> <div>Ranking:*</div> <div>M-5-2 (\$1M;\$50/sample)</div>	Predemonstration: Provides a means for the rapid separation and identification of complex mixtures based on the mobility of ions in an electric field at atmospheric pressure.	Software control of high-speed data acquisition, interpretation and instrument control. Available at X-10.	Hardware costs: \$30K; software development additional.
	<div>H</div> <div>Immunoassay Detection CHAR-23-OL</div> <div>Ranking:*</div> <div>H-5-3 (\$1M;\$50/sample)</div>	Accepted. Immunoassay detectors are used to determine environmentally important analytes. The technique is very selective and sensitive, extremely easy to use.	This is a mature and emerging technology. Kits are designed to perform in specialized waste streams. DOE has calibrated PCB kit in the Analytical Field Screening Program.	Automated sampling and reading systems for quick on-line testing of groundwater and waste stream contamination.
	<div>M</div> <div>Portable Raman Spectrometer CHAR-84-OL</div> <div>Ranking:*</div> <div>M-5-2 (\$1M;\$10/sample)</div>	Demonstration of field capabilities at ORNL. Raman spectra provide fingerprint identification of chemical species. No direct contact with the sample is necessary. Often interfaced with fiber optics for remote sensing in inaccessible areas. TTP Match	Need portable equipment (laser, etc.) for in-situ use. Develop methods which exploit surface enhancement and resonance excitation for vastly improved sensitivity.	Equipment available at ORNL. Not assembled yet for specific applications.
	<div>H</div> <div>Optical Absorption Spectroscopy (OAS) CHAR-27-OL</div> <div>Ranking:*</div> <div>H-5-1 (\$.6M;\$50/sample)</div>	Accepted. Demonstration. Measures the transmission of UV, visible, and near IR to determine the concentration of chemical species in gases, liquids, or solids. OAS can be applied to the analysis of any species which absorbs electromagnetic radiation in the region of excitation. UV through IR. TTP Match	Mature, field-portable technology available in IR, UV. Available at all sites.	It can be implemented for site-specific needs.
	<div>H</div> <div>Air Monitoring CHAR-59-OL</div> <div>Ranking:*</div> <div>H-5-0 (\$.25M;\$500/sample)</div>	Accepted. Encompasses several methods of monitoring particulate loading and characteristics during remedial action and decontamination and decommissioning activities. Collected samples can be analyzed for many different	This is a mature sampling technology with EPA protocols. Available at all sites.	This is a mature technology.
	<div>M</div> <div>Infrared Spectroscopy (Wavelength Dispersion) CHAR-18-OL</div> <div>Ranking:*</div> <div>M-5-1 (\$.5M;\$100/sample)</div>	Accepted. This method includes: Long path (LP-FTIR); diffuse reflectance (DRIFT); and attenuated total reflectance (ATR) for determination of compounds found in the air, water, or on surfaces. TTP Match	No units currently exist on-site. Several vendors are marketing equipment. Software development would enhance site-specific applications. Available at all sites.	Centralized mounting areas with robotically controlled unit would allow multiple site areas to be monitored with one unit.
	<div>H</div> <div>Personnel Monitoring CHAR-52-OL</div> <div>Ranking:*</div> <div>H-5-1 (\$.2M;N)</div>	Demonstration	Model studies are needed to correlate exposure and quantitative analysis from various human factors. Available at all sites.	We need a detailed monitoring program for personnel protection.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decon

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
<p>↓</p> <p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Examination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Detection/Measurement Field	M Laser Photoacoustic Spectroscopy (LPAS, PAS) CHAR-15-OL <i>Ranking:*</i> M-5-2 (\$4M;N) H-3-3 (\$.775M;N)	Accepted TTP Match	Laser detection combinations that apply to specific decontamination and decommissioning waste or monitoring scenarios are needed.	Development or enhancement of portable and in-situ capabilities is needed.
	M Portable Luminescence Detection CHAR-92-OL <i>Ranking:*</i> M-5-1 (\$.5M;\$10/sample)	Predemonstration The detection of organic and inorganic status chemicals using fluorescence, phosphorescence, and chemiluminescence. TTP	The technology is mature, but may not provide absolute identification of compounds in complex mixtures. Available at all sites.	Hardware is available at ORNL. Specific techniques need development and procedures written.
	M Electrochemical Methods CHAR-10-OL <i>Ranking:*</i> M-4-2 (\$.5M;\$100/sample)	Accepted Oxidizable or reducible species, excited by a voltage or current function in an electrical circuit, yield quantitative and qualitative information about species of interest. Selective and sensitive sampling is possible in many situations. TTP Match	Adaptation and protocols for model studies to be performed on complex systems are needed.	Hardware cost: \$50K-\$250K; Development cost: are \$250K.
Detection/Measurement Lab	H Contamination Control—Analytical Equipment CHAR-204-OL <i>Ranking:*</i> H-5-2 (\$.5M;N)	Commercially available for some systems, but usually must be done on a case-by-case basis due to facility limitations and different containment requirements. TTP Match	Contamination control for analytical equipment/instrumentation frequently requires extensive instrument modification to contain the equipment in radiochemical hoods, gloves boxes, or hot cells. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Implementation includes engineering design, fabrication of containment/shielding, and modification of facility. Typical cost for containment of an ICP in a glove box was approximately \$150K several years ago, this did not include the cost of the instrument. Requires special expertise, but must be done for higher levels of radioactivity.
	M Fourier Transform Infrared Spectroscopy (FT-IR) CHAR-8-OL <i>Ranking:*</i> M-4-1 (\$.2M;\$100–500/sample)	Accepted TTP Match	Data base for rapid materials identification and model studies of materials interaction is needed. Available at all sites.	Hardware cost: \$25K–\$500K; Development cost: ~\$200K.
	H Isotopic Dilution Mass Spectrometry (ID-MS) CHAR-48-OL <i>Ranking:*</i> H-4-0 (\$0M;\$100–1000/sample)	Accepted	Models studies are needed to enable quick analysis. Available at X-10.	Equipment, as well as the model studies mentioned above, is needed.
	M Nuclear Magnetic Resonance (NMR) CHAR-11-OL <i>Ranking:*</i> M-4-0 (\$0M;\$200–500/sample)	Accepted, available on-site TTP Match	None, available on-site. Available at X-10.	Hardware cost: \$200K–\$2M; Development cost: \$200K–\$500K.
	H Secondary Ion Mass Spectroscopy (SIMS) CHAR-3-OL <i>Ranking:*</i> H-4-0 (\$0M;\$50–400/sample)	Accepted	This is a mature technology. Model studies are needed to calibrate for depth-profiling studies. Available at all sites.	Instrumentation and personnel exist at the three plants.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamination

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	<p>Det Lab.</p> <p>Data Anal</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Detection/Measurement	H Ultraviolet/Visible (UV-VIS) Spectroscopy CHAR-9-OL <i>Ranking:*</i> <i>H-5-0 (\$.1M;\$50-200/sample)</i>	Accepted, available on-site TTP Match	Model studies and application design. Available at all sites.	Hardware cost: <\$200K; Development cost: <\$100K.
	M Laser Ionization Mass Spectrometry (LIMS, LAMMA, LIMMA) CHAR-4-OL <i>Ranking:*</i> <i>M-4-0 (\$0M;\$100/sample)</i>	Accepted TTP Match	This is a mature technology. Model studies are needed to optimize results interpretation.	Prototype instrumentation and research instrumentation exists. More equipment would be required. The necessary personnel are available.
	H Fourier Transform Infrared Spectroscopy (FTIR) CHAR-8-OL <i>Ranking:*</i> <i>H-5-0 (\$.1M;\$50-200/sample)</i>	Accepted, available on-site TTP Match	Model studies and application design. Available at all sites.	Hardware cost: <\$200K; Development cost: <\$100K.
	M Electrochemical Methods CHAR-10-OL <i>Ranking:*</i> <i>M-4-1 (\$.25M;>\$100/sample)</i>	Accepted Oxidizable or reducible species, excited by a voltage or current function in an electrical circuit, yield quantitative and qualitative information about species of interest. Selective and sensitive sampling is possible in many situations. TTP Match	Adaptation and protocols for model studies to be performed on complex systems are needed.	Hardware cost: \$50K-\$250K; Development cost: are \$250K.
Analysis/Management	Project Information Access Services (Needed Enabling Technologies) DISM-151-OL <i>Ranking:*</i> <i>No Ranking.</i>	Demonstration; an integrated project information access and management system is sufficiently different from current types of electronic information access support with DOE facilities as to warrant requiring a demonstration before deciding to proceed with implementation.	Technology to implement such a system is commercially available.	Computer networks, especially Ethernet (cable, fiber); need to be extended throughout the laboratory and other Energy Systems facilities.
	M Network Architecture with Integrated Workstations CHAR-221-OL <i>Ranking:*</i> <i>M-4-1 (\$.25M;>\$100/sample)</i>	Demonstration Commercial engineering workstations provide the capabilities to support this technology.	The greatest obstacle to use of this technology is the current legacy of older operating systems (DOS, MacOS) not designed to support integration of desktop applications with each other and with network services. Available at X-10.	This technology is best introduced in the context of a commitment to use open system standards for all new computer acquisitions.
	Client/Server Access to Standards and Regulatory Guidelines (Needed Enabling Technologies) DISM-153-OL <i>Ranking:*</i> <i>No Ranking.</i>	Demonstration	Technology development needs are greatest in developing or acquiring a good, common user interface to support integration of the component technologies.	
	E Data Access Services DISM-154-OL <i>Ranking:*</i> <i>E-5-1 (\$.5M;\$200Kam)</i>	Demonstration The particular network and communications configurations needed to support restoration activities may not exist, so would have to set up and their successful operation demonstrated.	Some software will be available commercially; some will have to be developed locally.	Requirements and specifications for such services must be identified and documented to serve as a common reference so that data can be accessed using a single set of services regardless of the type of computer at each node on the

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decont

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Examination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Data Analysis/Management	<p>E Geographic Information System for DOE sites (Needed Enabling Technologies) DISM-181-OL</p> <p><i>Ranking:*</i> E-5-1 (\$1M;\$200KAM)</p>	<p>Accepted Most information, data, and computer system components for a basic geographic information system (GIS) for each DOE site already exists but must be integrated to meet the needs of the environmental restoration program.</p>	Existing technology must be enhanced by adding a tagging mechanism to permit the system to be used for tracking activities and to link information in databases associated with a physical location to appropriate map and drawing displays on desktop computers.	A large initial effort may be required to scan and digitize diagrams and drawings for electronic storage and quick retrieval or transfer across networks.
	<p>Automated Scanning and Conversion of Engineering Drawings (Needed Enabling Technologies) DISM-155-OL</p> <p><i>Ranking:*</i> No Ranking.</p>	<p>Demonstration The basic technology is well established. Whether the current state of the art can adequately process the large number of drawings needed for reference and how effectively this technology can be integrated with other aspects of automated support needs to be demonstrated.</p>	Improvements are needed in the speed and accuracy of converting scanned images to graphical representations that will meet the needs (e.g., ability to change scale to show more detail) of the environmental restoration program.	Considerable human intervention may be required to handle large drawings or drawings that cannot easily be laid flat on a scanning bed.
	<p>E Hazard Analysis Expert System CHAR-233-OL</p> <p><i>Ranking:*</i> E-5-2 (\$.5M;\$150Kam)</p>	<p>Demonstration Expert systems have been very effective tools for some applications; success or failure depends critically on how well the problem domain has been analyzed and how thoroughly the knowledge base has been specified.</p>	Availability of and access to specification and design tools for developing the knowledge base and structure of the rules are the biggest needs.	Implementation strategy and problem analysis process used are the most important elements of developing a successful hazard analysis expert system.
	<p>E Application of Approximate Reasoning to Data Analysis/Evaluation CHAR-234-OL</p> <p><i>Ranking:*</i> E-5-2 (\$.5M;\$150Kam)</p>	<p>Demonstration Effective and successful use of this technology depends on availability of experienced and qualified technical people.</p>	Development is needed of tools (e.g., a range of graphical models designed to assist in visualizing relationships) to assist with conceptual analysis or to examine consequences of choosing a logical strategy (e.g., automated theorem provers) in the analysis of problems.	Powerful computing capabilities exist for applying approximate reasoning techniques but are not widely used. Education and training in the use of this technology will be needed.
	<p>E Simulated Walkthrough Facility for Robotics Task Sequence Analysis (Needed Enabling Technologies) DISM-171-OL</p> <p><i>Ranking:*</i> E-5-1 (\$.3: \$60K)</p>	<p>Demonstration The IGRIP applications software running on a Silicon Graphics workstation is capable of identifying situations in which collisions will occur. It can also use human factors and ergonomics data to indicate which tasks requiring human assistance are or are not possible or safe for a human operator to</p>	Development of support reference databases (e.g., human factors, ergonomics) to increase the effectiveness of this technology is an area of need.	The greatest need is to acquire the site-specific data, organize, assemble, and store it for rapid retrieval across computer networks. Integration of this technology with other networked resources will also be required at each site.
	<p>E Computer-based Training Systems (Needed Enabling Technologies) DISM-191-OL</p> <p><i>Ranking:*</i> E-6-1 (\$.3M) \$100K</p>	<p>Demonstration Application software is available that permits rapid development of courses using many media (visual, audio), including support for a variety of testing strategies.</p>	Further development is needed in the area of authoring support.	A well-defined course development life cycle does not yet exist. Currently used software engineering development life cycle methods should work well.
	<p>E Computer-aided Task Analysis and Procedure Preparation (Needed Enabling Technologies) DISM-172-OL</p> <p><i>Ranking:*</i> E-5-1 (\$.5M: \$150Kam)</p>	<p>Demonstration This technology is used extensively in planning by various federal agencies, most notably the Department of Defense in military operations planning.</p>	More natural language analysis tools are needed to assist with analysis of information used for planning, much of which is provided in text form.	Knowledge base development will require the largest effort, followed by development of expert systems and decision aids needed to make effective use of the information in the knowledge bases.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	All Problems Including various subparts of the following facilities: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum	General	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Data Man
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Analysis/ Management	E Client/Server Architecture for Database Access (Needed Enabling Technologies) DISM-157-OL Ranking:* E-5-1 (\$5M; \$200Kam)	Demonstration The effectiveness and appropriateness of a particular architecture design to meet the requirements of the restoration activities needs to be demonstrated.	This technology will benefit most from improvements in network technology (higher transmission speeds, improved transmission protocols and data access services) needed to support it.	Effectiveness depends strongly on the definition, design and implementation of the data dictionaries, data directories and data models that are the essential foundation for use of this
	E Hypertext Information Systems (Needed Enabling Technologies) DISM-158-OL Ranking:* E-5-1 (\$3M; \$150Kam)	Demonstration A range of products exists to support development of hypertext information systems having many capabilities such as mechanisms for linking related items, for starting execution and controlling other applications, and for navigating documents for faster access to information.	Authoring and design tools are needed.	Hypertext information systems must be designed with great care to avoid problems with maintenance (e.g., modifying or replacing blocks of text from which or to which many links have been made to selected text strings within the block).
	H Spatial Sample and Data Analysis Plans CHAR-253-OL Ranking:* H-3-5 (\$1M; \$5Kam)	Accepted TTP Match	Personnel and computer time, access to survey data Available at X-10.	Time and data
	M Statistical Methods for the Analysis of Large Data Sets CHAR-251-OL Ranking:* M-3-3 (\$5M; \$5Kam)	Conceptual	To allow for the survey of many areas, statistical methods to take advantage of new parallel processors may need to be developed. Available at X-10.	Possible large-scale computer needs and software development time.
	E Quality Control for Measurement Processes CHAR-250-OL Ranking:* E-4-.25 (\$05M; \$5Kam)	Accepted TTP Match	Data from standards evaluations Available at X-10.	Access to quality standard measurements
	H Analysis of Censored Data CHAR-249-OL Ranking:* H-4-.25 (\$05Kam)	Demonstration , some work is available in the literature. The application likely will have to be expanded to meet current needs.	Computer work station with access to appropriate data bases. Available at X-10.	Access to appropriate data bases, computer time, mathematical development time, and programming time.
	L Criticality Indices (CI) CHAR-44-OL Ranking:* L-2-1 (\$025M; N)	Accepted	The program must be implemented to specifically address the D&D technologies to be implemented and suggest the modifications that are needed for low- versus high-enrichment materials.	Same as Science/Technology needs.
	M Modeling of Volatile Organic Compounds Migration in Porous Materials CHAR-53-OL Ranking:* M-4-1 (\$02M; N)	Demonstration TTP Match	Models need to be developed that are applicable to site-specific scenarios.	Software and hardware are needed to implement the modeling systems.
	M Task-scheduling Aids CHAR-241-OL Ranking:* M-4-1 (0.5M; N)	Demonstration Several component technologies must be integrated to provide the level of support needed for the highly regulated environment in which restoration activities will be conducted.	A combination of automated analysis tools (e.g., automated reasoning, theorem provers) and a conceptual framework for representing regulatory requirements needs to be developed that can identify possible logical conflicts that arise in scheduling tasks on jobs for which many requirements must be met.	Validation of data used for generating schedules will require much more attention in cases in which many regulations and requirements must be met.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decon

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Data Analysis/Management	<p>L</p> <p>Technetium Geochemistry CHAR-49-OL</p> <p>Ranking:* L-1-2 (\$.5M;N)</p>	Demonstration	A better understanding of the association of Tc and its environmental matrices is needed.	Same as Science/Technology needs.
	<p>E</p> <p>3-D CAD Database of Buildings and Structures (Needed Enabling Technologies) DISM-156-OL</p> <p>Ranking:* E-5-2 (\$2M; \$300Kam)</p>	Accepted	Integration of this technology with the other supporting technologies that must work together with it to provide the high level of automation needed to assure proper compliance with environmental legislation governing restoration activities will be the main technology need.	Identification of all possible uses (e.g., "training", robots, visual "walkthroughs", tags for tracking activities) of this technology and development of database requirements to support them are very important foundations for effective use of this technology.
	<p>M</p> <p>Fractals Used to Select Models for Material Transport in Porous Media CHAR-225-OL</p> <p>Ranking:* M-2-2 (\$.5M; \$20Kam)</p>	Evolving	Application of fractal concepts to problems of flows in porous media is useful in classifying existing models according to what is appropriate to use for a particular situation. Available at X-10.	Fractal concepts may be applied to analysis of data or to output from porous flow model calculations as criteria incorporated into existing software.
Field Methods	<p>H</p> <p>Proportional Counter for Alpha and Beta Activity CHAR-108-OL</p> <p>Ranking:* H-5-0 (\$.1M; \$100/sample)</p>	Accepted	This is a well-established technology. Some minor development may be needed to distinguish Technetium activity from Uranium. Probes for measuring vertical or overhead items are needed.	Normal
	<p>M</p> <p>Passive Monitors for Weak Beta Radionuclides CHAR-102-OL</p> <p>Ranking:* M-4-2 (\$.6M; \$20/sample)</p>	Predemonstration	A thorough evaluation of this technology is needed for differentiating Tc-99 from other radionuclides in mixed-surface contaminations. Pairs of detectors, one with a beta absorber on its surface, will be needed to discriminate weak beta from more penetrating radiations.	A commercial TSEE reader is available at ORNL. Different types of ceramic exoelectron materials should be tested to select the most suitable type for H-3, Tc-99, and other applications. Approximately \$100K will be needed for development.
	<p>M</p> <p>Thermoluminescence Dosimeter Array for Spatial Characterization of Surface Alpha Contamination CHAR-103-OL</p> <p>Ranking:* M-4-3 (\$.6M; \$20/sample)</p>	Demonstration	It will need to be adapted to specific D&D needs. Size and shape of detector sheets need tailoring to specific geometries. Discriminating ability in mixed radiation fields needs further definition. Technique is well-established but investigation of potentially confounding factors is needed. Such factors include moisture, oil, and radon.	Development cost: ~\$200K.
	<p>M</p> <p>Long-Range Alpha Detector (LRAD) CHAR-65-OL</p> <p>Ranking:* M-4-1 (\$.4M; \$100/sample)</p>	Demonstration	Overall cost-\$10K/device; after commercializing price should decrease.	Adaptation for site-specific applications. Field testing is needed (~\$300K).

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Methods	M Bubble Dosimeters for Neutron Flux CHAR-216-OL <i>Ranking:*</i> M-4-1 (\$2M;\$15/sample)	Accepted These dosimeters are an integral part of a field neutron dosimetry system for use where neutron sources and shielding are not well known. They are capable of measuring neutron dose equivalent in low level fields and of providing simple spectral information.	The technique is well established in measuring neutron flux around personnel. It must be evaluated in potential confounding effects in less benign environments.	~\$200K is needed to develop acoustic coupler for applications requiring real-time measurement of neutron dose rate and for development of a less expensive, automated bubble counter for reliable processing of passive detector results.
	H Tritium/Beta/Gamma Floor Scanner CHAR-105-OL <i>Ranking:*</i> H-4-0 (\$0M;\$N)	Predemonstration A surface monitor is commercially available that utilizes, interchangeably, a tritium windowless proportional counter and a xenon-filled beta/gamma proportional counter.	None	Technology is currently available.
	H Portable Gamma-Ray Scintillometers CHAR-263-OL <i>Ranking:*</i> H-4-0 (\$0M;\$100/sample)	In either single-channel or multichannel format, they are available commercially. The instrument consists of a NaI crystal, photomultiplier tube, portable battery-operated power supply, pulse height analyzer, and readout. TTP Match	Robotic technology needed for remote control applications.	The technology is commercially available. Specialized detector holders may need to be developed for particular applications.
	M Advanced Radiation Monitors CHAR-269-OL <i>Ranking:*</i> M-4-2 (\$.4M;\$50/sample)	Predemonstration TTP Match	Development of additional probes is needed. Available at X-10.	Ca. \$400K development costs over 2 years.
	H Electret Passive Surface Alpha Monitor CHAR-95-OL <i>Ranking:*</i> H-4-1 (\$.3M;\$15/sample)	Demonstration It is a device that performs as a passive ion chamber when placed on a contaminated surface; positive ions produced by alpha particles are drawn to a negatively charged Teflon electret screwed into the roof of the chamber. Sensitivity is sufficient to quantify alpha contamination after a few hours of exposure even at the most stringent DOE release limit of 100 dmp/100cm ² .	The effects of potential confounding factors (e.g., dust, moisture, oils) need to be evaluated and ameliorated.	The limits of alpha monitoring in mixed radiation fields needs to be defined. Algorithms for multidevice deployment should be developed and tested to give a high confidence level of not missing contamination on large area surfaces. Development of needed protocols will require 1-2 years of effort.
Laboratory Methods	H Alpha Track Etch Detectors for Surface Alpha Contamination CHAR-96-OL <i>Ranking:*</i> H-4-1 (\$.4M;\$10/sample)	These are Alpha-sensitive plastics that can be cut to a size appropriate for specific applications, e.g., to fit inside pipes or in narrow crevices. After exposure, the plastic is developed chemically to visualize damage tracks produced by alpha emitting contamination.	Technique is well-established (i.e., commercially available) for measuring alpha activity in indoor air. Potentially confounding factors in surface or soil applications include: inhomogeneously sized particles, moisture, oils, and radon in soil.	Plastic monitors of differing sizes and flexibilities need to be tailored and fabricated for specific tasks to be identified in pilot testing on-site. Deployment of detectors in large numbers will require establishment of on-site chemical etching and track reading capabilities.
	H Neutron Activation CHAR-107-OL <i>Ranking:*</i> H-4-1 (\$.2M;\$300/sample)	Demonstration TTP Match	Development is needed for containers that are larger than 55-gal drums. Separate calibration standards are needed for each matrix.	Normal

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decon

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems Including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	<p>Radioactive Elements</p>	<p>Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Characterization</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 		<p>Inorganics</p>		

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	<p>H Sodium Iodide-Germanium Gamma Spectroscopy CHAR-106-OL</p> <p>Ranking:* H-4-0 (\$0M;N)</p>	Accepted TTP Match	Correction factor methodology needs to be published.	None
	<p>H Upgrade of Radioanalytical Procedures CHAR-202-OL</p> <p>Ranking:* H-4-2 (\$1M;N)</p>	Development Upgrade of Radioanalytical Procedures, general upgrade and modernization of radiochemical separation technology. TTP Match	Considerable new technology is available but lacks sufficient validation to meet QA requirements. Other areas are at the basic development stage. Available at X-10.	Some instrumentation/personnel currently exist at ORNL but needs to be expanded to meet the increased work load. Estimated cost \$600K/year for
	<p>H Proportional Counter for Activity CHAR-108-OL</p> <p>Ranking:* H-5-0 (\$.1M;\$100/sample)</p>	Accepted	This is a well-established technology. Some minor development may be needed to distinguish Technetium activity from uranium. Probes for measuring vertical or overhead items are needed.	Normal
	<p>H Photo Electron Rejecting Alpha Liquid Scintillation (PERALS) CHAR-97-OL</p> <p>Ranking:* H-4-0 (\$0M;N)</p>	A very sensitive (pCi/g) technique for measuring alpha-emitting isotopes in soil, water, and airborne dust. TTP Match	Cost effective, timely analysis of select alpha emitting radionuclides in large numbers of samples is needed to verify nonviolation of cleanup standards. Available at X-10, Y-12.	A PERALS laboratory is already set up at the ORNL DOR/SAF facility. It can be adapted for rapid "on-line" monitoring of both airborne and loose contamination.
	<p>H Neutron Activation Analysis CHAR-266-OL</p> <p>Ranking:* H-4-1 (\$.2M;\$300/sample)</p>	Accepted, mature technology TTP Match	Mature technology, startup studies to be done to evaluate possible interferences. Available at X-10.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
	<p>H Gamma-Ray Spectrometry CHAR-268-OL</p> <p>Ranking:* H-5-0 (\$.1M;\$100/sample)</p>	Mature technology TTP Match	Commercially available and mature. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Detector costs range from \$10K to \$50K.
	<p>H Liquid Scintillation Counting CHAR-267-OL</p> <p>Ranking:* H-5-0 (\$.1M;\$100/sample)</p>	Mature technology TTP Match	Commercially available and mature. Available at X-10.	Some equipment/personnel currently available at ORNL but needs to be expanded to meet the expected increase in work load. Instrumentation costs range from \$30K - \$40K.
Field Methods	<p>M Radiographic Imaging CHAR-40-OL</p> <p>Ranking:* M-4-1 (N;N)</p>	Accepted	Scattering and attenuation factors that the host matrix exhibits on the radiograph need to be better understood.	A laboratory dedicated to radiographic imaging would greatly facilitate the application of this technology.
	<p>M Atomic Emission Spectroscopy CHAR-76-OL</p> <p>Ranking:* M-4-1 (\$.2M;N)</p>	Accepted TTP Match	The technology is well-developed and applicable as is.	Technology is available at the K-25 Site.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	Inorganics	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Field
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					Lab

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Methods	<p>H</p> <p>X-Ray Fluorescence for In Situ Monitoring of Toxic Heavy Metals CHAR-219-OL CHAR-6-OL</p> <p>Ranking:* H-5-1 (\$2M;\$25/sample)</p>	<p>Accepted Can be use for in situ monitoring of toxic heavy metals in paints, on surfaces, and in soils. Portable XRF units are commercially available and have been widely used for screening painted surfaces for lead contamination. TTP Match</p>	Mature technology.	Substrate effects need to be studied. The lower limit of detection for some metals on surfaces needs to be measured (~\$200K).
	<p>H</p> <p>Laser Ablation; Inductively Coupled Plasma; Atomic Emission Spectroscopy CHAR-111-OL</p> <p>Ranking:* H-5-3 (\$1M;N)</p>	<p>Demonstration TTP Match</p>	Improvement of the robotic process for site-specific conditions (e.g., floor, wall, ceiling) is needed.	Normal
Laboratory Methods	<p>H</p> <p>Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) CHAR-78-OL</p> <p>Ranking:* H-4-2 (\$1M;\$200/sample)</p>	<p>Demonstration - available, but not fully developed.</p>	It is applicable as is for multielement analysis of aqueous solutions. Development is progress to use the technology for surface analysis using laser ablation techniques, and for low specific activity, long-lived	It is now available at the X-10 Site. \$400K development costs to extend to long-lived, low specific activity radionuclides.
	<p>H</p> <p>Inductively Coupled Plasma Spectroscopy (ICP) CHAR-77-OL</p> <p>Ranking:* H-4-0 (\$1M;\$200/sample)</p>	<p>Accepted TTP Match</p>	It is applicable as is. This is a well-developed technology.	It is available at ORNL.
	<p>H</p> <p>Atomic Emission Spectroscopy (AE) CHAR-76-OL</p> <p>Ranking:* H-4-0 (\$1M;\$200/sample)</p>	<p>Accepted TTP Match</p>	The technology is well-developed and applicable as is.	Technology is available at the K-25 Site.
	<p>H</p> <p>Ion Chromatography (IC) CHAR-50-OL</p> <p>Ranking:* H-4-0 (\$1M;\$100/sample)</p>	<p>Accepted TTP Match</p>	A detector system that is optimized for the expected waste streams that will be generated needs to be determined.	We have systems available for process control of D&D efforts.
	<p>M</p> <p>Electron Diffraction (ED, SAED, LEED) CHAR-37-OL</p> <p>Ranking:* M-4-0 (\$0M;\$100/sample)</p>	<p>Accepted TTP Match</p>	None Available at all sites.	None
	<p>Wavelength Dispersive X-Ray Spectroscopy (WDS, WDX) CHAR-36-OL</p> <p>Ranking:* No Ranking.</p>	<p>Accepted</p>	None Available at all sites.	None
	<p>M</p> <p>Energy Dispersive X-Ray Spectroscopy (EDS, EDX, EDAX) CHAR-35-OL</p> <p>Ranking:* M-4-0 (\$0M;\$100/sample)</p>	<p>Accepted TTP Match</p>	None Available at all sites.	None

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decont

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	Transmission Electron Microscopy (TEM) CHAR-34-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted TTP Match	This is a mature technology. Available at all sites.	This is a mature technology.
	Scanning Electron Microscopy (SEM) CHAR-33-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted TTP Match	This is a mature technology. Available at all sites.	This is a mature technology.
	Particle-Induced X-Ray Emission (PIXIE) CHAR-17-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted	This is not a mature technology; photon source is under development. Available at K-25.	The instrumentation is available on-site. Analysis is available at outside laboratories. Sampling scenarios could be designed to identify and use the technology which needs to be part of a mobile laboratory.
	Cold Vapor (Mercury) Analysis CHAR-24-OL M-4-0 (\$5M; \$100/sample) Ranking: "H"	Accepted	This is a mature technology which needs to be part of a mobile laboratory.	This is a mature technology which needs to be part of a mobile laboratory.
	Neutron Activation Analysis CHAR-26-OL H-4-1 (\$2M; \$200/sample) Ranking: "H"	Accepted, mature technology TTP Match	Mature technology, startup studies to be done to evaluate possible interferences. Available at X-10.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
	Powder X-Ray Diffraction CHAR-31-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted	This is a mature technology. Available at all sites.	None
	Electron Spectroscopy for Chemical Analysis (ESCA) CHAR-1-OL M-4-0 (\$5M; \$200-600/sample) Ranking: "M"	Accepted	Model studies are needed to identify binding energies for standard compounds of Tc and U for suspected matrices. Available at all sites.	Instrumentation and personnel currently exist at K-25.
	Auger Electron Spectroscopy (AES) CHAR-2-OL M-4-0 (\$5M; \$300-800/sample) Ranking: "M"	Accepted TTP Match	Mature, model studies are needed to probe the host/contaminant effects for accurate depth profiling. Available at X-10, Y-12, K-25.	Instrumentation and personnel exist within the three plants.
	Glow Discharge Ionization Mass Spectroscopy CHAR-56-OL H-4-1 (\$5M; N) Ranking: "H"	Accepted (laboratory) Predemonstration field TTP Match	Need to determine relative sensitivity factors, and use of DC and of glow discharges. Available at X-10.	Hardware cost: \$200K Development cost: \$500K
	Fluorescence Diagnosis of Contaminated Surfaces CHAR-11-OL M-3-2 (\$1M; \$10/sample) Ranking: "M"	Predemonstration TTP Match	A medium of fluorescence spectroscopy work will be required for some contaminants to fill in the gaps of published fluorescence data. Laser source would enhance sensitivity, but cost and size would increase appreciably.	The required equipment such as a laser (light source), optics, detectors, personal computers (for data acquisition), and interfaces must be purchased. Inexpensive commercial units can be purchased, detection limits ppm. Laser-based systems need to be developed. (\$500K)
Field Methods				
Field Methods	Infrared Absorption (Laser-Based Source) CHAR-85-OL M-4-2 (\$5M; N) Ranking: "M"	Accepted (for commercial units) Evolving technology (for laser-based) TTP Match	Laser source would enhance sensitivity, but cost and size would increase appreciably.	Laser source would enhance sensitivity, but cost and size would increase appreciably.
	Fluorescence Diagnosis of Contaminated Surfaces CHAR-11-OL M-3-2 (\$1M; \$10/sample) Ranking: "M"	Predemonstration TTP Match	A medium of fluorescence spectroscopy work will be required for some contaminants to fill in the gaps of published fluorescence data. Laser source would enhance sensitivity, but cost and size would increase appreciably.	The required equipment such as a laser (light source), optics, detectors, personal computers (for data acquisition), and interfaces must be purchased. Inexpensive commercial units can be purchased, detection limits ppm. Laser-based systems need to be developed. (\$500K)
	Glow Discharge Ionization Mass Spectroscopy CHAR-56-OL H-4-1 (\$5M; N) Ranking: "H"	Accepted (laboratory) Predemonstration field TTP Match	Need to determine relative sensitivity factors, and use of DC and of glow discharges. Available at X-10.	Hardware cost: \$200K Development cost: \$500K
	Auger Electron Spectroscopy (AES) CHAR-2-OL M-4-0 (\$5M; \$300-800/sample) Ranking: "M"	Accepted TTP Match	Mature, model studies are needed to probe the host/contaminant effects for accurate depth profiling. Available at X-10, Y-12, K-25.	Instrumentation and personnel exist within the three plants.
	Electron Spectroscopy for Chemical Analysis (ESCA) CHAR-1-OL M-4-0 (\$5M; \$200-600/sample) Ranking: "M"	Accepted	Model studies are needed to identify binding energies for standard compounds of Tc and U for suspected matrices. Available at all sites.	Instrumentation and personnel currently exist at K-25.
	Powder X-Ray Diffraction CHAR-31-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted	This is a mature technology. Available at all sites.	None
	Neutron Activation Analysis CHAR-26-OL H-4-1 (\$2M; \$200/sample) Ranking: "H"	Accepted, mature technology TTP Match	Mature technology, startup studies to be done to evaluate possible interferences. Available at X-10.	Instrumentation and personnel currently exist at ORNL but needs to be expanded to meet the expected work load. Estimated cost of upgrade and expansion \$250K.
	Cold Vapor (Mercury) Analysis CHAR-24-OL M-4-0 (\$5M; \$100/sample) Ranking: "H"	Accepted	This is a mature technology which needs to be part of a mobile laboratory.	This is a mature technology which needs to be part of a mobile laboratory.
	Particle-Induced X-Ray Emission (PIXIE) CHAR-17-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted	This is not a mature technology; photon source is under development. Available at K-25.	The instrumentation is available on-site. Analysis is available at outside laboratories. Sampling scenarios could be designed to identify and use the technology which needs to be part of a mobile laboratory.
	Scanning Electron Microscopy (SEM) CHAR-33-OL M-4-0 (\$5M; \$100/sample) Ranking: "M"	Accepted TTP Match	This is a mature technology. Available at all sites.	This is a mature technology.

See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none">• Clean Up Legacy Waste• Prevent Future Insult• Develop Environmental Stewardship	All Problems Including various subparts of the following facilities: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum	Organics	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Field
EM Problems <ul style="list-style-type: none">• Facility Decontamination and Decommissioning (D&D)• Remedial Action (RA)—Soils, Ground Water and Surface Water• Waste Management (WM)					Labor

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Methods				
H	Portable Gas Chromatograph/Electron Capture Detection for Analyzing PCBs in Soil/Dust CHAR-100-OL <i>Ranking:*</i> H-4-0 (\$.25M;\$50/sample)	Accepted TTP Match	Standard procedures need to be written. Available at Y-12.	We need to order GC/ECD devices (~\$15K each).
H	Portable Volatile Organic Compound Detectors CHAR-5-OL <i>Ranking:*</i> H-5-0 (\$.25M;\$10/sample)	Accepted. Has been successfully used at ORNL. A valuable, quick, and yet inexpensive method to screen for the contamination of soils based on flame ionization or photoionization of sampled air. Useful at a variety of sites including leaking underground tanks pits in spillage. TTP Match	This is a mature technology. Available at X-10, Y-12.	For quick screening and surveying, instruments are available commercially. Interfacing the instruments with an ion mobility mass spectrometer would allow detection of individual compounds (~\$30K).
H	Direct Sampling Ion Trap Mass Spectrometry (DSITMS) CHAR-90-OL <i>Ranking:*</i> H-5-2 (\$.2M;\$50/sample)	Predemonstration, method development needed. TTP Match	Methods need to be developed for specific applications. Available at X-10.	Hardware cost: \$100K; personnel are needed for development, training, and implementation costs; \$200K.
H	Gas Chromatography in the Field CHAR-262-OL <i>Ranking:*</i> H-5-0 (\$.25M;\$50/sample) H-3-0 (\$.25M;\$50/sample)	Accepted. Using flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, or thermionic detectors with gas chromatography can determine a variety of environmentally important analytes.	Technology needs are minimal. While improvements can be made, in general, the technology is ready to use. Available at all sites.	A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs. Various groups at ORNL have large sample handling capabilities.
M	Synchronous Fluorescence Screening for Polycyclic Aromatic Hydrocarbons CHAR-101-OL <i>Ranking:*</i> M-4-1 (\$.2M;<\$50/sample)	Demonstration, technology available; Predemonstration. When light of a specific wavelength is directed onto a sample, certain organic compounds (such as PAHs) absorb and re-emit that light (fluoresce) at a higher wavelength. In this technique, exciting and fluorescing wavelengths are scanned synchronously. Analytes can be differentiated because they absorb and fluoresce at different wavelengths. TTP Match	Technology needs to be validated in the EPA program. Numerous situations at X-10 have involved used oils and lubricants. Available at X-10.	Hardware cost: \$25K; Development cost: \$200K.
atory Methods				
M	Analytical Methods for Chelators and Decontamination Agents CHAR-206-OL <i>Ranking:*</i> M-3-1 (\$.25M;\$500-1000/sample)	Demonstration, an existing method shows the technology is promising, but further development is needed. TTP Match	Adapt current methods to the specific constituents and sample matrices at the ORNL site, conduct method performance validation, and prepare an analytical protocol.	Development cost: \$250K.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decon

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	Organics	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	M Capillary Zone Electrophoresis CHAR-207-OL <i>Ranking:*</i> M-3-1 (\$.25M;\$300/sample)	Demonstration, the technology is gaining widespread acceptance in biomedical applications, and appears useful for RA/WM applications.	Adaptation and validation for the specific target compounds and sample matrices at the ORNL site. Available at X-10.	Hardware cost: \$30K-\$60K; Development cost: \$250K.
	H On-line Supercritical Fluid Extraction-Multidetector Gas Chromatography (SPE-GC) CHAR-115-OL <i>Ranking:*</i> H-5-1 (\$.25M;\$300/sample)	Predemonstration, technology requires final development and demonstration. TTP Match	The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.	Capital cost: \$60K; Development cost: \$250K.
	M Gas Chromatography-Fourier Transform Infrared Spectroscopy (GC-FTIR) CHAR-66-OL <i>Ranking:*</i> M-4-2 (\$.5M;\$400/sample)	Demonstration, technology is available.	Specific methods for targeted analytes and general methods for unknown identification need to be developed. Available at X-10.	Hardware cost: \$200K; Development cost: \$400K. One instrument is available at ORNL.
	M Liquid Chromatography—Mass Spectroscopy (LC-MS) CHAR-89-OL <i>Ranking:*</i> M-4-1 (\$.3M;\$500/sample)	Demonstration, not yet available on-site for service work. TTP Match	Case-by-case development and demonstration for specific applications is needed. Available at X-10, Y-12.	Hardware cost: \$200K; Development cost: \$300K.
	E Gas Chromatography—Mass Spectroscopy (GC-MS) CHAR-88-OL <i>Ranking:*</i> E-5-0 (\$0M;\$200-800/sample)	Accepted, available on-site. TTP Match	Technology is applicable as is. Benefit would be derived from faster chromatography to shorten analysis time. Available at all sites.	Technology is available at ORNL.
	H Synchronous Fluorescence Screening for Polycyclic Aromatic Hydrocarbons (PAHs) CHAR-101-OL <i>Ranking:*</i> H-5-1 (\$.2M;\$10/sample)	Demonstration, technology available. When light of a specific wavelength is directed onto a sample, certain organic compounds (such as PAHs) absorb and re-emit that light (fluoresce) at a higher wavelength. In this technique, exciting and fluorescing wavelengths are scanned synchronously. Analytes can be differentiated because they absorb and fluoresce at different wavelengths.	Technology needs to be validated in the EPA program. Numerous situations at X-10 have involved used oils and lubricants. Available at X-10.	Hardware cost: \$25K; Development cost: \$200K.
	H Gas Chromatography CHAR-94-OL <i>Ranking:*</i> H-5-0 (\$0M;\$300/sample)	Accepted, technology available on-site. TTP Match	Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.	A variety of gas chromatography equipment exists already at ORNL.
	E Laser Ablation Organic Mass Spectrometry CHAR-93-OL <i>Ranking:*</i> E-5-1 (\$.3M;<\$500/sample)	Predemonstration, technology under development. TTP Match	Development of a sampling methodology (perhaps using a wipe of the surface) and test it on target compounds. Available at X-10.	Hardware cost: \$120K; Development cost: \$300K.
	E Surface Enhanced Raman Scattering (SERS) CHAR-265-OL <i>Ranking:*</i> E-4-1 (\$.15M;N)	Evolving. TTP Match	System development and validation for specific needs. Available at X-10.	Hardware cost: \$10K- \$250K; Development cost: \$150K.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems Including various subparts of the following facilities: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	Physical	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization	Field
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					Labo

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Methods	E Instrument Response Models for Remote Sensing CHAR-246-OL <i>Ranking:*</i> E-5-2 (\$0.6M;\$200Kam)	Accepted Instrument response models have been used for many years to evaluate satellite sensor, control, and communication systems.	Information necessary for developing models of the instrument subsystems and measurement processes must be provided.	Instrument response models are usually represented in software that executes on a computer, so implementation needs would be those of software developed for engineering and scientific applications.
	E Fiber-Optic Systems for Measuring Multiple Physical Variables CHAR-248-OL <i>Ranking:*</i> E-5-3 (\$1M;\$25/sample event)	Pre-demonstration Proof-of-principle of this technology can be demonstrated in devices suitable for use in underground waste storage tanks. TTP Match	A range of applications can be developed using this technology. Available at X-10.	This technology should lend itself well to economies of scale in the manufacture of rugged, replaceable devices that should require low (or no) maintenance.
Laboratory Methods	M Particle Size Analysis CHAR-26-OL <i>Ranking:*</i> M-4-0 (\$0M;\$1000/sample)	Accepted	None, this is a mature technology. Available at all sites.	In situ devices need to be implemented for more aggressive IH-HP protection of personnel and to ensure the control (spread) of radioactive contamination.
	M Optical Microscopy CHAR-32-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100-800/sample)	Accepted	A particle atlas of site-specific materials is needed to allow rapid identification. Available at all sites.	A centralized image collection system is needed to establish a site-specific database.
	M Magnetic Resonance Imaging CHAR-58-OL <i>Ranking:*</i> M-4-0 (\$2M;N)	Accepted TTP Match	Model studies are needed for waste forms and various equipment parts.	Instrumentation is needed.
	M Holographic Imaging CHAR-46-OL <i>Ranking:*</i> M-4-0 (N;N)	Accepted	This is a mature technology.	A holographic imaging laboratory with field-portable units is needed to allow holographic imaging of permanently-mounted
	M Inorganic Cementitious Matrix Composites Model CHAR-39-OL <i>Ranking:*</i> M-4-0 (N;N)	Demonstration TTP Match	Characterization of variations in the cement for the various structures of interest is needed; and matrix/contaminant interaction studies need to be performed.	
	M Nondestructive Testing for Concrete CHAR-38-OL <i>Ranking:*</i> M-4-0 (\$0M;\$100/sample)	Demonstration	Testing protocols for evaluating and characterizing large concrete structures are needed.	A testing plan for site buildings and a field testing kit for site-wide deployment are needed.
	H Modeling of Heterogenous Materials—Sampling CHAR-61-OL <i>Ranking:*</i> H-4-0 (\$3M;N)	Evolving technology (conceptual) TTP Match	An experimental design, models need to be established. A study needs to be performed.	

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decon

EM Goals	ORNL Problem	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>All Problems Including various subparts of the following facilities:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum</p>	Physical	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 	<p>• Painted sheet metal floor of coolant salt cell, Bldg. 9203-1 • 3,000-gallon stainless steel tank, Bldg. 9203-1 • Fission Products Development Laboratory Inactive Cells, Bldg. 3019</p>	Oils and Purex Chemicals	Refer to Vol. 1, Pt. C, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Characterization

Alternatives	Technology	Status	Science/Technology Needs	Implementation Needs
<p>Laboratory Methods</p> <p>H Model (RIS) CHA-42-OL Ranking: H-4-2 (\$5M,N)</p> <p>M Infrared Absorption (Laser Based Source) CHA-65-OL Ranking: M-3-2 (\$5M,N)</p> <p>H Portable Volatile Organic Compound Detectors CHA-5-OL Ranking: H-3-0 (\$25M,\$10/sample)</p> <p>H Direct Sampling Ion Trap Mass Spectrometry (DSIMS) CHA-90-OL Ranking: H-3-2 (\$1M,\$50/sample)</p> <p>H Sampling Interface System for Organics CHA-271-OL Ranking: H-4-3 (\$75M,N)</p> <p>H Fiber-Optic Chemical Sensors CHA-25-OL Ranking: H-3-1 (\$1M,\$10/sample)</p> <p>M Infrared Spectroscopy (Wavelength Dispersion) CHA-18-OL Ranking: M-3-1 (\$5M,\$100/sample)</p> <p>E Gas Chromatography—Mass Spectrometry (GC-MS) CHA-88-OL Ranking: E-3-0 (\$0M,\$200-800/sample)</p>	<p>Demonstration</p> <p>Accepted (for commercial units) Evolving technology (for laser-based) TTP Match</p> <p>Conceptual TTP Match</p> <p>Demonstration TTP Match</p> <p>Accepted TTP Match</p> <p>Accepted, available on-site TTP Match</p>	<p>Models need to be used to determine if, in reactor equipment, the high radiation fields and temperature combinations allow for an enhancement of defect sites, which may cause variability in decontamination or dismantlement.</p> <p>Laser source would enhance sensitivity, but cost and size would increase appreciably.</p> <p>Methods need to be developed for specific applications. Available at X-10.</p> <p>Hardware cost: \$100K. Personnel are needed for development, training, and implementation costs, \$200K.</p> <p>Development cost of \$775K over 3 years.</p> <p>Wavelengths that can withstand the harsh chemical environment that may be present in some of the sampling locations are needed.</p> <p>Centralized mounting areas would allow multiple site areas to be monitored with one unit.</p> <p>Available at all sites.</p> <p>Technology is applicable as is. Benefit would be derived from faster chromatography to shorten analysis time.</p>	<p>Same as Science/Technology needs.</p> <p>Inexpensive commercial units can be purchased; detection limits ppm-ppb. Laser-based systems need to be developed.</p> <p>This is a mature technology. For quick screening and surveying, instruments are available commercially. Interfacing the instruments with an ion mobility mass spectrometer would allow detection of individual compounds (~\$30K).</p> <p>Methods need to be developed for specific applications. Available at X-10.</p> <p>Hardware cost: \$100K. Personnel are needed for development, training, and implementation costs, \$200K.</p> <p>Development cost of \$775K over 3 years.</p> <p>Wavelengths that can withstand the harsh chemical environment that may be present in some of the sampling locations are needed.</p> <p>Centralized mounting areas would allow multiple site areas to be monitored with one unit.</p> <p>Available at all sites.</p> <p>Technology is applicable as is. Benefit would be derived from faster chromatography to shorten analysis time.</p>	<p>September 1993</p>

See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Characterization for Decontamin

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Laboratory Methods	H On-line Supercritical Fluid Extraction—Multidetector Gas Chromatography (SFE-GC) CHAR-115-OL <i>Ranking:*</i> H-3-1 (\$0.25M;\$300/sample)	Predemonstration , technology requires final development and demonstration. TTP Match	The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.	Capital cost: \$60K; Development cost: \$250K.
	H Laser Ablation Organic Mass Spectrometry CHAR-93-OL <i>Ranking:*</i> H-3-1 (\$0.3M; <\$500/sample)	Predemonstration , technology under development. TTP Match	Development of a sampling methodology (perhaps using a wipe of the surface) and test it on target compounds. Available at X-10.	Hardware cost: \$120K; Development cost: \$300K.
	H Analytical Methods for Chelators and Decontamination Agents CHAR-206-OL <i>Ranking:*</i> H-3-1 (\$0.25M;\$500–1000/sample)	Demonstration , an existing method shows the technology is promising, but further development is needed. TTP Match	Adapt current methods to the specific constituents and sample matrices at the ORNL site, conduct method performance validation, and prepare an analytical protocol.	Development cost: \$250K.
Methods	H Portable Gas Chromatograph /Electron Capture Detection for Analyzing PCBs CHAR-100-OL <i>Ranking:*</i> H-3-0 (\$0.25M;\$50/sample)	Accepted TTP Match	Available at Y-12.	We need to order GC/ECD devices (~\$15K each).
	H PCB Immunoassay Kit CHAR-99-OL <i>Ranking:*</i> H-3-0 (\$0.25M;\$80/sample)	Accepted	None Available at X-10, K-25.	The technology is ready to apply and should be used for routine analyses.
	H Direct Sampling Ion Trap Mass Spectrometry (DSITMS) CHAR-90-OL <i>Ranking:*</i> H-3-2 (\$0.2M;\$50/sample)	Predemonstration , method development needed. TTP Match	Methods need to be developed for specific applications. Available at X-10.	Hardware cost: \$100K; personnel are needed for development, training, and implementation costs: \$200K.
	Sampling Interface System for Surface Contamination by Organics CHAR-271-OL <i>Ranking:*</i> No Ranking	Conceptual TTP Match	Development of rapid heating interface and software for rapid contaminant identification by direct sampling ion trap mass spectrometry.	Development cost: of \$775K over 3 years.
Laboratory Methods	H Gas Chromatography CHAR-94-OL <i>Ranking:*</i> H-3-0 (\$0M;\$300/sample)	Accepted , technology available on-site. TTP Match	Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.	A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs.
	H On-line Supercritical Fluid Extraction—Multidetector Gas Chromatography (SFE-GC) CHAR-115-OL <i>Ranking:*</i> H-3-1 (\$0.25M;\$300/sample)	Predemonstration , technology requires final development and demonstration. TTP Match	The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.	Capital cost: \$60K; Development cost: \$250K.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decomtami

The Dismantlement section is written to address the massive concrete, structural steel, asbestos materials, majority of equipment, and the need for other "enabling technology" that dismantlement will not, in general, depend upon the worker protection are provided. Each section will explain the dismantlement problem list. Dismantlement has been assumed D&D efforts elsewhere.

There are some basic assumptions for dismantlement: (1) decontaminated as much as practical, (2) remaining, characterized before dismantlement is initiated, (3) the materials in forms suitable for disposal as recyclable scrap or waste, and (4) recycle of materials will be desirable and/or required.

ation and Decommissioning

the X-10 Site problems specific to dismantlement: major dismantlement (removal of equipment), disassembly technologies." Basic to this approach is the assumption of the type of contamination as long as containment and maintain the relationship of the subject to the dismantlement to follow a sequence similar to the current ongoing

ment including: (1) equipment exteriors will have been removed or vestigial, contamination will have been located and the products of dismantlement will be sorted materials for waste or for disposition to complete decontamination, required.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Massive Containment	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Cutti
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 					
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Ground Water and Surface Water 		Reactor Pools	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Cutti
<ul style="list-style-type: none"> • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
ng	H High-Pressure Abrasive Water Jet (Massive Containment) DISM-11-OL <i>Ranking:*</i> H-5-5 (\$5.5M;\$10/ft ²)	Status: Demonstration - Technology is a DOE sponsored development. Has not been demonstrated at X-10. Efficacy: High; robotics useful in high radiation areas. Waste: Contaminated water slurry. Amount would be minimal.	Technology Improvement Needs: 1: Need to develop a high efficiency fluid recovery system. 2: Need to address contaminated cracks in concrete.	Unusual Needs: Determine level of robotics technology available. Development Costs: \$5.5M Capital Costs: \$1M Operating Costs: \$700/yr ³
	M Diamond Wire Cutting (Massive Containment) DISM-12-OL <i>Ranking:*</i> M-5-5 (\$3.5M;\$100/ft ²)	Status: Demonstration - Has not been demonstrated at X-10. Efficacy: High; industry accepted standard. Waste: Contaminated water slurry. Amount would be minimal.	Technology Improvement Needs: 1: Method of cutting large rebar must be developed. 2: High efficiency fluid recovery system must be developed.	Unusual Needs: Determine robotics technology available. Development Costs: \$1.5M Capital Costs: \$1M Operating Costs: \$1200/yr ³
plition	M Microwave Demolition (Massive Containment) DISM-16-OL <i>Ranking:*</i> M-5-9 (\$5M;\$6/ft ²)	Status: Pre-demonstration - In final stage of development. Efficacy: Medium - will remove moderate amounts of material. Waste: No additional waste will be generated as a result of utilizing this technology.	Technology Improvement Needs: 1: Final phase of development. Available in Private Sector.	Unusual Needs: Need to develop a demonstration program. Need to develop track system. Development Costs: \$5M Capital Costs: \$2M Operating Costs: \$17/yr ³
g	M High-Pressure Abrasive Water Jet (Reactor Pools) DISM-21-OL <i>Ranking:*</i> M-4-7 (\$5.5M;\$15/ft ²)	Status: Demonstration - Technology is a DOE sponsored development. Has not been demonstrated at X-10. Efficacy: High; robotics useful in high radiation areas. Waste: Contaminated water slurry. Amount would be minimal.	Technology Improvement Needs: 1: Need to develop a high efficiency fluid recover system. 2: Need to address contaminated cracks in concrete.	Unusual Needs: Determine level of robotics technology available. Development Costs: \$5.5M Capital Costs: \$1M Operating Costs: \$700/yr ³

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <ul style="list-style-type: none"> Bldg. 3028 Bldg. 3028E Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete 	Reactor Pools	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Cutting	Diamond Wire Cutting (Reactor Pools) DISM-22-OL <i>Ranking:*</i> <i>not ranked</i>	<i>Status:</i> Demonstration - has not been demonstrated at X-10. <i>Efficacy:</i> High; industry accepted standard. <i>Waste:</i> Contaminated water slurry. Amount would be minimal.	<i>Technology Improvement Needs:</i> 1: Method of cutting large rebar must be developed. 2: High efficiency fluid recovery system must be developed.	<i>Unusual Needs:</i> Determine robotics technology available. <i>Development Costs:</i> \$3.5M <i>Capital Costs:</i> \$1M <i>Operating Costs:</i> \$1200/yd ³
	Explosive Cutting (Reactor Pools) DISM-23-OL <i>Ranking:*</i> <i>not ranked</i>	<i>Status:</i> Demonstration - not demonstrated at X-10. <i>Efficacy:</i> Low; not well suited for these types of structures. <i>Waste:</i> Contaminated water slurry used to hold down dust possible.	<i>Technology Improvement Needs:</i> 1: Crane system to remove large sections of concrete. 2: Remote method of cutting rebar in large amounts of debris is needed.	<i>Unusual Needs:</i> Need to witness an actual site being demolished. <i>Development Costs:</i> \$2.5M <i>Capital Costs:</i> \$0.75M <i>Operating Costs:</i> \$400/yd ³
Demolition	M Demolition Compounds (Reactor Pools) DISM-25-OL <i>Ranking:*</i> <i>M-4-6 (\$4M/\$90/ft³)</i>	<i>Status:</i> Demonstration - has not been demonstrated at X-10. <i>Efficacy:</i> Medium; can be used on lightly reinforced concrete only. <i>Waste:</i> No additional waste will be generated as a result of the use of this technology.	<i>Technology Improvement Needs:</i> 1: Demonstration is required using a lightly reinforced building. 2: Hole geometry needs to be determined.	<i>Unusual Needs:</i> Method of cutting rebar must be developed. <i>Development Costs:</i> \$40M <i>Capital Costs:</i> \$0.5M <i>Operating Costs:</i> \$900/yd ³
	Conventional Demolition (Reactor Pools) DISM-26-OL <i>Ranking:*</i> <i>No Ranking</i>	<i>Status:</i> Demonstration - has not been demonstrated at X-10. <i>Efficacy:</i> High; industry accepted standard. <i>Waste:</i> No additional waste will be generated as a result of utilizing this technology.	<i>Technology Improvement Needs:</i> 1: Vacuum system to handle dust must be created. 2: Crusher to down size concrete sections must be developed.	<i>Unusual Needs:</i> Need to determine level of robotic technology available. <i>Development Costs:</i> \$4.5M <i>Capital Costs:</i> \$0.5M <i>Operating Costs:</i> \$400/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete</p>	<p>Reactor Pools</p> <p>Buried Tanks</p>	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders; and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p> <p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Dismantlement</p> <p>Dismantlement</p>	<p>Demolition</p> <p>Cutting</p> <p>Demolition</p>
<p>EM Problems</p> <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					

tion and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
M	Microwave Demolition (Reactor Pools) DISM-28-OL	Status: Pre-demonstration - In final stage of development. Efficacy: Medium - will remove moderate amounts of material. Waste: No additional waste will be generated as a result of utilizing this technology.	Technology Improvement Needs: 1: Final phase of development.	Unusual Needs: Need to develop a demonstration program. Need to develop track system. Development Costs: \$5M Capital Costs: \$2M Operating Costs: TBD
	Ranking: M-4-10 (\$7M;\$60/ft ²)			
	H	Status: Demonstration - Technology is a DOE sponsored development. Has not been demonstrated at X-10. Efficacy: High; robotics useful in high radiation areas. Waste: Contaminated water slurry. Amount would be minimal.	Technology Improvement Needs: 1: Need to develop a high efficiency fluid recovery system. 2: Need to address contaminated cracks in concrete.	Unusual Needs: Determine level of robotics technology available. Development Costs: \$5.5M Capital Costs: \$1.5M Operating Costs: \$700/yr ³
	High-Pressure Abrasive Water Jet (Buried Tanks) DISM-31-OL			
M	Diamond Wire Cutting (Buried Tanks) DISM-32-OL	Status: Demonstration - has not been demonstrated at X-10. Efficacy: High; industry accepted standard. Waste: Contaminated water slurry. Amount would be minimal.	Technology Improvement Needs: 1: Method of cutting large rebar must be developed. 2: High efficiency fluid recovery system must be developed.	Unusual Needs: Determine robotics technology available. Development Costs: \$3.5M Capital Costs: \$1.5M Operating Costs: \$1200/yr ³
	Ranking: not ranked			
	M	Status: Demonstration - not demonstrated at X-10. Efficacy: Low; not well suited for these types of structures. Waste: Contaminated water slurry used to hold down dust possible.	Technology Improvement Needs: 1: Crane system to remove large sections of concrete. 2: Remote method of cutting rebar in large amounts of debris is needed.	Unusual Needs: Need to witness an actual site being demolished. Development Costs: \$2.5M Capital Costs: \$1M Operating Costs: \$400/yr ²
	Explosive Cutting (Buried Tanks) DISM-33-OL			
M	Demolition Compounds (Buried Tanks) DISM-35-OL	Status: Demonstration - has not been demonstrated at X-10. Efficacy: Medium; can be used on lightly reinforced concrete only. Waste: No additional waste will be generated as a result of the use of this technology.	Technology Improvement Needs: 1: Demonstration is required using a lightly reinforced building. 2: Hole geometry needs to be determined.	Unusual Needs: Method of cutting rebar must be developed. Development Costs: \$4M Capital Costs: \$0.75M Operating Costs: \$900/yr ³
	Ranking: M-4-8 (\$4M;\$90/ft ³)			

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <ul style="list-style-type: none"> Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete 	Buried Tanks	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
<p>EM Problems</p> <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) 		Structural-only-Concrete	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
<ul style="list-style-type: none"> Remedial Action (RA)—Soils, Ground Water and Surface Water 				
<ul style="list-style-type: none"> Waste Management (WM) 				

Amiation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Demolition	Conventional Demolition (Buried Tanks) DISM-36-OL <i>Ranking:*</i> <i>not ranked</i>	<i>Status:</i> Demonstration has not been demonstrated at X-10. <i>Efficacy:</i> High; industry accepted standard. <i>Waste:</i> No additional waste will be generated as a result of utilizing this technology.	<i>Technology Improvement Needs:</i> 1: Vacuum system to handle dust must be created. 2: Crusher to down size concrete sections must be developed.	<i>Unusual Needs:</i> Need to determine level of robotic technology available. <i>Development Needs:</i> \$4.5M <i>Capital Costs:</i> \$0.75M <i>Operating Costs:</i> \$400/ft ²
	Microwave Demolition (Buried Tanks) DISM-38-OL <i>Ranking:*</i> <i>not ranked</i>	<i>Status:</i> Pre-demonstration. In final stages of development. <i>Efficacy:</i> Medium; will remove moderate amounts of material. <i>Waste:</i> No additional waste will be generated as a result of utilizing this technology.	<i>Technology Improvement Needs:</i> 1: Final phase of development.	<i>Unusual Needs:</i> Need to develop a demonstration program. Need to develop track system. <i>Development Needs:</i> \$5M <i>Capital Costs:</i> \$3.0M <i>Operating Costs:</i> TBD
Cutting	M High-Pressure Abrasive Water Jet (Structural-Only Concrete) DISM-41-OL <i>Ranking:*</i> <i>M-2-1 (\$2M;\$10/ft³)</i>	<i>Status:</i> Demonstration Technology is a DOE sponsored development. Has not been demonstrated at X-10. <i>Efficacy:</i> High; industry accepted standard. <i>Waste:</i> None.	<i>Technology Improvement Needs:</i> 1: Need to develop a high efficiency fluid recovery system.	<i>Unusual Needs:</i> None <i>Development Costs:</i> \$1M <i>Capital Costs:</i> \$0.5M <i>Operating Costs:</i> \$500/yd ³
	H Diamond Wire Cutting (Structural-Only Concrete) DISM-42-OL <i>Ranking:*</i> <i>H-2-0.5 (\$1.5M;\$10/ft³)</i>	<i>Status:</i> Demonstration has not been demonstrated at X-10. <i>Efficacy:</i> High; industry accepted standard. <i>Waste:</i> None.	<i>Technology Improvement Needs:</i> 1: Method of cutting large rebar must be developed. 2: High efficiency fluid recovery system must be developed.	<i>Unusual Needs:</i> Determine robotics technology available. <i>Development Costs:</i> \$1.5M <i>Capital Costs:</i> \$0.5M <i>Operating Costs:</i> \$800/yd ³

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <ul style="list-style-type: none"> Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete 	<p>Structural-only Concrete</p>	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Dismantlement</p>	<p>Dem</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Demolition	<div>H</div> <p>Conventional—Jack Hammer, Headache Ball, etc. (Structural-Only Concrete) DISM-44-OL</p> <p>Ranking:* H-2-0 (\$0M;\$20/ft³)</p>	<p>Status: Demonstration - has not been demonstrated at X-10.</p> <p>Efficacy: High; industry accepted standard.</p> <p>Waste: None.</p>	<p>Technology Improvement Needs:</p> <p>1: Vacuum system to handle dust must be created.</p> <p>2: Crusher to down size concrete sections must be developed.</p>	<p>Unusual Needs: Need to determine level of robotic technology available.</p> <p>Development Costs: \$1.5M</p> <p>Capital Costs: \$0.4M</p> <p>Operating Costs: 200/ft²</p>
	<p>Explosive Cutting (Structural-Only Concrete) DISM-45-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Demonstration - not demonstrated at X-10.</p> <p>Efficacy: High; industry accepted standard.</p> <p>Waste: None.</p>	<p>Technology Improvement Needs:</p> <p>1: Crane system to remove large sections of concrete.</p> <p>2: Remote method of cutting rebar in large amounts of debris is needed.</p>	<p>Unusual Needs: Need to witness an actual site being demolished.</p> <p>Development Costs: \$1.5M</p> <p>Capital Costs: \$0.5M</p> <p>Operating Costs: \$200/yd³</p>
	<div>M</div> <p>Demolition Compounds (Structural-Only Concrete) DISM-46-OL</p> <p>Ranking:* M-2-2 (\$1.5M;\$25/ft³)</p>	<p>Status: Demonstration - has not been demonstrated at X-10.</p> <p>Efficacy: Medium; can be used on lightly reinforced concrete only.</p> <p>Waste: No additional waste will be generated as a result of the use of this technology.</p>	<p>Technology Improvement Needs:</p> <p>1: Demonstration is required using a lightly reinforced building.</p> <p>2: Hole geometry needs to be determined.</p>	<p>Unusual Needs: Method of cutting rebar must be developed.</p> <p>Development Costs: \$1.5M</p> <p>Capital Costs: \$0.4M</p> <p>Operating Costs: \$500/yd²</p>
	<p>Microwave Demolition (Structural-Only Concrete) DISM-47-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Pre-demonstration - in final stage of development.</p> <p>Efficacy: Medium - will remove moderate amounts of material.</p> <p>Waste: No additional waste will be generated as a result of utilizing this technology.</p>	<p>Technology Improvement Needs:</p> <p>1: Final phase of development.</p>	<p>Unusual Needs: Need to develop a demonstration program. Need to develop a track system.</p> <p>Development Costs: \$5M</p> <p>Capital Costs: \$1.5M</p> <p>Operating Costs: TBD</p>
	<div>H</div> <p>Grappler (Structural-Only Concrete) DISM-48-OL</p> <p>Ranking:* H-2-1 (\$1M;\$8/ft³)</p>	<p>Status: Demonstration - not demonstrated at X-10.</p> <p>Efficacy: High - relatively inexpensive technology.</p> <p>Waste: No additional waste would be generated as a result of the use of this technology.</p>	<p>Technology Improvement Needs:</p> <p>1: None</p>	<p>Unusual Needs: Need to verify applicability to X-10 structures.</p> <p>Development Costs: \$2M-\$2.5M</p> <p>Capital Costs: \$2.0M</p> <p>Operating Costs: \$100/yd³</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities including:</p> <ul style="list-style-type: none"> Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete 	<p>Steel Containment Structures (Highly Contaminated)</p>	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Dismantlement</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Cutting	<p>H</p> <p>Laser Cutting (Steel Structures, Highly Contaminated) DISM-51-OL</p> <p>Ranking:* H-4-6 (\$2.5M;\$1000/cut)</p>	<p>Predemonstration Efficacy: High; can cut any known material. Contamination could be alloyed to the process material. Waste: N/A; no waste generated by the process. Equipment will be decontaminated after use.</p>	<p>Science Development: The appropriate power level for the laser A fiber-optic delivery system Technology Improvement: A remote controlled manipulator</p>	<p>Personnel Training Development Cost: \$2M + \$2.5M Capital Cost: \$3M/system Operating Costs: \$1000/cut of 6 in. in diameter steel pipe</p>
	<p>H</p> <p>Abrasive Water Jet (Steel Structures, Highly Contaminated) DISM-53-OL</p> <p>Ranking:* H-4-3 (\$750K;\$100/h)</p>	<p>Demonstration Efficacy: High; can cut any known material, steel up to 9 in. thick. Does not alloy contaminants to the process material. Waste: 2 lb/min of garnet is used. 1.5 gal/min of liquid waste is generated. The water can be recycled, therefore, reducing waste. Decontamination of manipulator.</p>	<p>Science Development: Recyclable abrasives A recovery system for the abrasives and water Technology Improvement: A remote controlled manipulator Longer lasting nozzles, hoses and intensifier pumps</p>	<p>Personnel Training Development Cost: \$750K Capital Cost: \$850K/system Operating Costs: \$100/hour of cutting</p>
	<p>Cryogenic Liquid Cutting (Steel Structures, Highly Contaminated) DISM-55-OL</p> <p>Ranking:* not ranked</p>	<p>Evolving technology Efficacy: High; can cut any known material. Does not alloy contaminants to the process material. Effective on hazardous materials having a low vaporization temperature. Waste: N/A; Decontamination of manipulator.</p>	<p>Science Development: Cryogenic liquid cutting Technology Improvement: A remote controlled manipulator Long lasting nozzles and hoses</p>	<p>Personnel Training Development Cost: \$10M Capital Cost: \$3.5M/system Operating Costs: \$2000/cut</p>
	<p>M</p> <p>Plasma Arc Cutting (Steel Structures, Highly Contaminated) DISM-56-OL</p> <p>Ranking:* M-4-4 (\$1M;\$1300/cut)</p>	<p>Demonstration Efficacy: Medium; can cut only conductive materials. Alloys contaminants to the process material. Waste: Water at 1/2 gal/hr is used to cool the nozzle. Nozzles: Particulate generation occurs at 4-6 lb/hr. Decontamination of manipulator.</p>	<p>Science Development: Computer aided process Technology Improvement: A remote controlled manipulator Longer lasting nozzles</p>	<p>Personnel Training Development Cost: \$1M Capital Cost: \$450K/system Operating Costs: \$1300/cut</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Steel Containment Structures (Highly Contaminated)	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Cutting
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

tion and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
g	E Oxygen Cutting (Steel Structures, Highly Contaminated) DISM-57-OL <i>Ranking:*</i> E-4-2 (\$200K;\$100/cut)	Accepted Efficacy: High; cuts mostly ferrous metals. Alloys contaminants to the process material. Waste: N/A; Decontamination of manipulator.	Technology Improvement: A remote controlled manipulator to view the cutting and to manipulate the nozzle Remote control of the amount of oxygen and fuel gases being consumed Available at all sites.	Normal implementation needs: Development Cost: \$200K Capital Cost: \$300K/system Operating Costs: \$100/cut
	Plasma Arc Saw (Steel Structures, Highly Contaminated) DISM-58-OL <i>Ranking:*</i> not ranked	Demonstration Efficacy: Low; can cut any type of steel. Can cut geometrically complicated components. Alloys contaminants to the process material. Waste: Dust and aerosol from the process. The saw blade. Decontamination of manipulator.	Science Development: Computer aided process Technology Improvement: A remote controlled manipulator Different sizes of saw blades that are interchangeable	Personnel Training Development Cost: \$1M - \$1.5M Capital Cost: \$1.2M - \$1.4M/system Operating Costs: \$1100/cut
	Thermal Arc Water Jet (Steel Structures, Highly Contaminated) DISM-59-OL <i>Ranking:*</i> not ranked	Demonstration Efficacy: Low; can cut any type of steel. Can cut geometrically complicated components. Alloys contaminants to the process material. Waste: Dust and aerosol from the process. The water used to wash the material from the kerf. Decontamination of manipulator.	Science Development: Computer aided process Technology Improvement: A remote controlled manipulator	Personnel Training Development Cost: \$1M - \$1.5M Capital Cost: \$1M - \$1.2M/system Operating Costs: \$1000/cut
	E Conventional Disassembly (Steel Structures, Highly Contaminated) DISM-60-OL <i>Ranking:*</i> E-4-2 (\$800K;\$75/bolt & \$600/cut)	Accepted Efficacy: High; can cut or dismantle any material or component. Cutting is independent of geometry. Does not alloy contaminants to the process material. Waste: Saw blades. Decontamination of manipulator and associated equipment.	Science Development: The capability to capture the contaminants exiting the kerf Technology Improvement: A remote controlled manipulator Available at all sites.	Personnel Training Development Cost: \$600K - \$800K Capital Cost: \$900K/system Operating Costs: \$75/bolt & \$600/cut

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Steel Containment Structures (Highly Contaminated)	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 		Structural Steel	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement

mination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Cutting	<p>E</p> <p>Grappler Mobile Shearing (Steel Structures, Highly Contaminated) DISM-61-OL</p> <p>Ranking:* E-4-1.5 (\$250K;\$250/cut)</p>	<p>Demonstrated Efficacy: High; can shear and maneuver most any material or component. Cutting is independent of geometry. Does not alloy contaminants to the process material. Waste: N/A. Decontamination of manipulator and associated equipment.</p>	<p>Technology Improvement: A remote controlled manipulator</p>	<p>Personnel Training Development Cost: \$250K Capital Cost: \$400K/system Operating Costs: \$250/cut</p>
	<p>H</p> <p>Explosive Cutting (Steel Structures, Highly Contaminated) DISM-62-OL</p> <p>Ranking:* H-4-3 (\$1.3M;\$12000/cut)</p>	<p>Demonstrated Efficacy: High; can cut any known material in normal surroundings or under water. Used where other mechanical cutting methods are impractical. Waste: N/A. Decontamination of manipulator.</p>	<p>Science Development: A method of buttering the shock wave and its noise A method to contain the contamination that explodes of the material Technology Improvement: A remote controlled manipulator that will place the charges</p>	<p>Personnel Training Development Cost: \$1.3M Capital Cost: \$600K/system Operating Costs: \$12,000/cut</p>
Cutting	<p>H</p> <p>Laser Cutting (Structural Steel, Mild Contaminants) DISM-71-OL</p> <p>Ranking:* H-2-4 (\$2.5M;\$900/cut)</p>	<p>Predemonstration Efficacy: High; can cut any known material. Contamination will be alloyed to the process material. Waste: N/A; no waste generated by the process. Equipment will be decontaminated after use.</p>	<p>Science Development: The appropriate power level for the laser A fiber-optic delivery system</p>	<p>Personnel Training Development Cost: \$2M-\$2.5M Capital Cost: \$1.5M/system Operating Costs: \$900/cut of 6 in. in diameter steel pipe</p>
	<p>H</p> <p>Abrasive Water Jet (Structural Steel, Mild Contaminants) DISM-72-OL</p> <p>Ranking:* H-2-2 (\$250K;\$100/h)</p>	<p>Demonstration Efficacy: High; can cut any known material, steel up to 9 in. thick. Does not alloy contaminants to the process material. Waste: 2 lb/min of garnet is used. 1.5 gal/min of liquid waste is generated. The water can be recycled, therefore, reducing waste. Decontamination of manipulator.</p>	<p>Science Development: Recyclable abrasives A recovery system for the abrasives and water Technology Improvement: Longer lasting nozzles, hoses and intensifier pumps Available in Private Sector.</p>	<p>Personnel Training Development Cost: \$250K Capital Cost: \$700K/system Operating Costs: \$100/hour of cutting</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Structural Steel	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Cut
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					Dem

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
g	M Plasma Arc Cutting (Structural Steel, Mild Contaminants) DISM-74-OL <i>Ranking:*</i> M-2-4 (\$250K;\$600/cut)	Demonstration Efficacy: Medium; can cut only conductive materials. Alloys contaminants to the process material. Waste: Water at 1/2 gal/hr is used to cool the nozzle. Particulate generation occurs at 4-6 lb/hr. Decontamination of manipulator.	None Available at Y-12.	Normal implementation needs. Development Cost: \$250K Capital Cost: \$50K/system Operating Costs: \$600/cut
	E Oxygen Cutting (Structural Steel, Mild Contaminants) DISM-75-OL <i>Ranking:*</i> E-2-N/A (\$N/A;\$150/cut)	Accepted Efficacy: High; cuts mostly ferrous metals. Alloys contaminants to the process material. Waste: N/A. Decontamination of manipulator.	None Available at all sites and Private Sector.	Normal implementation needs. Development Cost: N/A Capital Cost: \$300K/system Operating Costs: \$150/cut
	Thermite Lance (Structural Steel, Mild Contaminants) DISM-79-OL <i>Ranking:*</i> not ranked	Predemonstrated Efficacy: Medium; can cut steel in normal surroundings or under water. Waste: N/A. Decontamination of manipulator.	Science Development: A method to contain the contamination Available in Private Sector.	Personnel Training Development Cost: \$75K Capital Cost: \$100K/system Operating Costs: \$150/cut
olition	E Conventional Disassembly (Structural Steel, Mild Contaminants) DISM-76-OL <i>Ranking:*</i> E-2-1 (\$200K;\$10/bolt & \$300/cut)	Accepted Efficacy: High; can cut or dismantle any material or component. Cutting is independent of geometry. Does not alloy contaminants to the process material. Waste: Airborne contaminants. Decontamination of manipulator and associated equipment.	Science Development: The capability to capture the contaminants exiting the kerf	Personnel Training Development Cost: \$200K Capital Cost: \$100K/system Operating Costs: \$10/bolt & \$300/cut
	E Grappler Mobile Shearing (Structural Steel, Mild Contaminants) DISM-77-OL <i>Ranking:*</i> E-2-1 (\$N/A;\$150/cut)	Demonstrated Efficacy: High; can shear and maneuver most any material or component. Cutting is independent of geometry. Does not alloy contaminants to the process material. Waste: N/A. Decontamination of manipulator and associated equipment.	None Available in Private Sector.	Normal implementation needs. Development Cost: N/A Capital Cost: \$400K/system Operating Costs: \$150/cut
	Explosive Cutting (Structural Steel, Mild Contaminants) DISM-78-OL <i>Ranking:*</i> not ranked	Demonstrated Efficacy: High; can cut any known material in normal surroundings or under water. Used where other mechanical cutting methods are impractical. Waste: N/A. Decontamination of manipulator.	Science Development: A method of buffering the shock wave and its noise A method to contain the contamination that explodes of the material Available in Private Sector.	Personnel Training Development Cost: \$200K Capital Cost: \$175K/system Operating Costs: \$10,000/cut

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Asbestos	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 				
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Ground Water and Surface Water 		Major Equipment Removal	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
<ul style="list-style-type: none"> • Waste Management (WM) 				

mination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Stripping	Conventional (Asbestos) DISM-81-OL <i>Ranking:*</i> <i>not ranked</i>	Available <i>Efficacy: low; very labor intensive</i> <i>Waste: protective clothing and plastic bags. Very large volume</i>	None required Available in Private Sector.	Unusual needs: none required Development Costs: none required Capital Costs: none required Operating Costs: \$20.00 sq/ft
	H Conventional/Automated with Vacuum System (Asbestos) DISM-82-OL <i>Ranking:*</i> <i>H-3-6 (\$200K;\$30/ft³)</i>	Available <i>Efficacy: medium; industry accepted</i> <i>Waste: Plastic bags and protective clothing. Amounts would decrease by 70% over conventional method.</i>	None required Available at Y-12.	Unusual needs: none required Development Costs: \$200k Capital Costs: \$100K Operating Costs: \$2.00 sq/ft
	M CO ₂ Blasting (Asbestos) DISM-83-OL <i>Ranking:*</i> <i>M-3-7 (\$3.5M;\$60/ft³)</i>	Demonstration—has not been demonstrated at x-10. <i>Efficacy: high; industry accepted</i> <i>Waste: plastic bags. Amount would be minimal compared to conventional method.</i>	Pipe hangers close to walls Pipes close to walls	Unusual needs: determine robotics Available Development Costs: \$3.5m Capital Costs: \$1.2m Operating Costs: \$20 sq/ft
	Glassification (Asbestos) DISM-86-OL <i>Ranking:*</i> <i>not ranked</i>	Demonstration—has not been demonstrated at X-10 <i>Efficacy: high; huge cost savings in disposal</i> <i>Waste: very minimal</i>	Study to determine size capacity for disposal System to process material into workable size	Unusual needs: determine available robotics implementations Development Costs: \$3.4m Capital Costs: \$1.2m Operating Costs: \$35 sq/ft
Cutting	H Laser Cutting (Asbestos) DISM-84-OL <i>Ranking:*</i> <i>H-3-3 (\$3.5M;\$50/ft³)</i>	Development <i>Efficacy: high; potentially useful in cutting other hazardous materials such as PCBs, volatile organic compounds, etc.</i> <i>Waste: disposal bags. Waste would be minimal</i>	Confirmation of negligible dispersement Confirmation of cut cauterization	Unusual needs: determine beam containment, laser safety, and optics protection from flaming Development Costs: \$3.5m Capital Costs: \$1.5m Operating Costs: \$25 sq/ft
	M Abrasive Water Jet (Asbestos) DISM-85-OL <i>Ranking:*</i> <i>M-3-6 (\$3.5M;\$50/ft³)</i>	Demonstration—has not been demonstrated at X-10. <i>Efficacy: medium; industry accepted</i> <i>Waste: contaminated water slurry. Could be substantial without recovery system.</i>	High efficiency water recovery and recycle system must be developed. Improvement of wear on nozzles, hoses, and pumps when abrasives are used	Unusual needs: determine robotics technology Available Development Costs: \$3.5m Capital Costs: \$1.1m Operating Costs: \$1.25 sq/ft
Demolition	Thermite Cutting (Major Equipment Removal) DISM-88-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Pre-Demonstration <i>Efficacy: Low. Messy operation, may cause alloying of contaminants with metals, gross cutting tool</i> <i>Waste: Metals alloyed with radioactive contaminants</i>	Technology Improvement: None Science Development: None	Incorporate remote operations capability Development Costs: \$500K Capital Costs: \$10K not incl. remote manipulation provisions. Operating Costs: \$10/ft ³ of waste generated

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Major Equipment Removal	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Derr Cuts
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>Oxyacetylene (Major Equipment Removal) DISM-89-OL</p> <p>Ranking:* not ranked</p>	<p>Oxyacetylene (Major Equipment Removal) DISM-89-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Accepted Efficacy: Medium, Commonly used in normal environments, could be easily adapted to remote operations; limited material cutting capability Waste: Metals alloyed with contaminants possible</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability. Development Costs: \$500K Capital Costs: \$10K not incl. remote manipulation provisions Operating Costs: \$5/ft³ of waste generated</p>
<p>Mechanical Saws (Major Equipment Removal) DISM-90-OL</p> <p>Ranking:* M-5-1 (\$250K;\$40/ft³)</p>	<p>Mechanical Saws (Major Equipment Removal) DISM-90-OL</p> <p>Ranking:* M-5-1 (\$250K;\$40/ft³)</p>	<p>Status: Accepted Efficacy: High, Commonly used in normal environments, could be easily adapted to remote operations; slow process Waste: None</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability. Development Costs: \$250K Capital Costs: \$10K not incl. remote manipulation provisions Operating Costs: \$20/ft³ of waste generated</p>
<p>Laser Cutting (Major Equipment Removal) DISM-91-OL</p> <p>Ranking:* not ranked</p>	<p>Laser Cutting (Major Equipment Removal) DISM-91-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Predemonstration Efficacy: Low, Commonly used in normal environments, probably expensive to adapt to remote operations Waste: Metals alloyed with contaminants possible</p>	<p>Technology Improvement: Waveguide improvements - fiberoptics Science Development: None</p>	<p>Incorporate remote operations capability. Development Costs: \$3-5M Capital Costs: \$200K not incl. remote manipulation provisions Operating Costs: \$50/ft³ of waste generated</p>
<p>H Plasma Arc Cutting (Major Equipment Removal) DISM-92-OL</p> <p>Ranking:* H-5-4 (\$2-3.5M;\$50/ft³)</p>	<p>H Plasma Arc Cutting (Major Equipment Removal) DISM-92-OL</p> <p>Ranking:* H-5-4 (\$2-3.5M;\$50/ft³)</p>	<p>Status: Demonstration Efficacy: High, Commonly used in normal environments, readily adaptable to remote operations Waste: Metals alloyed with contaminants possible</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability. Development Costs: \$2-3.5M Capital Costs: \$200K not incl. remote manipulation provisions Operating Costs: \$50/ft³ of waste generated</p>
<p>H High-Pressure Water Jet (Major Equipment Removal) DISM-93-OL</p> <p>Ranking:* H-5-4 (\$2-4M;\$40/ft³)</p>	<p>H High-Pressure Water Jet (Major Equipment Removal) DISM-93-OL</p> <p>Ranking:* H-5-4 (\$2-4M;\$40/ft³)</p>	<p>Status: Accepted Efficacy: Low, Commonly used in normal environments, readily adaptable to remote operations Waste: Liquids (water) containing suspended particulate</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability. Development Costs: \$2-4M Capital Costs: \$200K not incl. remote manipulation provisions Operating Costs: \$40/ft³ of waste generated</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

Amputation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Cutting	Diamond Wire Cutting (Major Equipment Removal) DISM-94-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Demonstration Efficacy: Medium, Commonly used in normal environments, readily adaptable to remote operations Waste: Liquids (water) containing suspended particulate	Technology Improvement: None Science Development: None Available at all sites.	Incorporate remote operations capability Development Costs: \$2-3M Capital Costs: \$150K not incl. remote manipulation provisions Operating Costs: \$40/ft ³ of waste generated
	H Advanced Laser Cutting (Major Equipment Removal) DISM-95-OL <i>Ranking:*</i> <i>H-5-5 (\$2.5-4M, \$50/ft³)</i>	Status: Predemonstration Efficacy: Low, Under development for use in normal environments, probably expensive to adapt to remote operations Waste: Metals alloyed with contaminants possible	Technology Improvement: Scaling laser system to required levels Science Development: None	Incorporate remote operations capability Development Costs: \$2-3M Capital Costs: \$250K not incl. remote manipulation provisions Operating Costs: \$50/ft ³ of waste generated
	Explosive Cutting (Major Equipment Removal) DISM-96-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Demonstration Efficacy: Low, Difficult to contain, not recommended for contaminated materials Waste: None	Technology Improvement: A means of beffering the associated shock wave. Science Development: None Available at all sites.	Incorporate remote operations capability Development Costs: \$TBD Capital Costs: <\$100K not incl. remote manipulation provisions Operating Costs: \$TBD/ft ³ of waste generated
	High-Pressure Abrasive Water Jet (Major Equipment Removal) DISM-97-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Demonstration Efficacy: High, Commonly used in normal environments, readily adaptable to remote operations Waste: Liquids (water) containing suspended particulate	Technology Improvement: None Science Development: None Available at all sites.	Incorporate remote operations capability Development Costs: \$2-3M Capital Costs: \$200K not incl. remote manipulation provisions Operating Costs: \$40/ft ³ of waste generated

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete</p>	Major Equipment Removal	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Cutting
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
	Plasma Arc Saw Cutting (Major Equipment Removal) DISM-98-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Demonstration Efficacy: Low; Commonly used in normal environments, readily adaptable to remote operations Waste: Metals alloyed with contaminants possible	Technology Improvement: Saw design for material thicknesses > 100mm will require development Science Development: None	Incorporate remote operations capability Development Costs: \$3-4M Capital Costs: \$250K not incl. remote manipulation provisions Operating Costs: \$50/ft ³ of waste generated
	Thermal Arc Water Jet Cutting (Major Equipment Removal) DISM-99-OL <i>Ranking:*</i> <i>not ranked</i>	Status: Demonstration Efficacy: Low; Primarily and under water tool, may be difficult to adapt for out of water operation Waste: Metals alloyed with contaminants possible	Technology Improvement: None Science Development: None	Incorporate remote operations capability Development Costs: \$2-3M Capital Costs: \$1M not incl. remote manipulation provisions Operating Costs: \$40/ft ³ of waste generated
H	Advanced Automatic Fixtures, Bug-O, etc. (Major Equipment Removal) DISM-100-OL <i>Ranking:*</i> H-5-3 (\$1.5-2.5M, \$30/ft ³)	Status: Accepted Efficacy: High; Commonly used in normal environments, readily adaptable to remote operations Waste: None	Technology Improvement: None Science Development: None Available at all sites.	Incorporate remote operations capability Development Costs: \$1-2M Capital Costs: \$200M not incl. remote manipulation provisions Operating Costs: \$30/ft ³ of waste generated
	Liquified Cryogenic Gas Cutting (Major Equipment Removal) DISM-101-OL <i>Ranking:*</i>	Status: Evolving Technology Efficacy: Low; Currently not ready for use Waste: None	Technology Improvement: Significant development effort required. Science Development:	Incorporate remote operations capability Development Costs: \$2-3M Capital Costs: ~\$10M not incl. remote manipulation provisions Operating Costs: \$60/ft ³ of waste generated

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Conventional	<p>Conventional Disassembly (Major Equipment Removal) DISM-102-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Accepted Efficacy: High, proven methods for remote environments, slow Waste: None</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability Development Costs: \$0.5-1M Capital Costs: \$250 not incl. remote manipulation provisions Operating Costs: \$40/ft³ of waste generated</p>
Automated Conventional	<p>Grabber/Gross Shearing and Lifting (Major Equipment Removal) DISM-103-OL</p> <p>Ranking:* not ranked</p>	<p>Status: Demonstration Efficacy: Medium, Commonly used in normal environments, readily adaptable to remote operations Waste: None</p>	<p>Technology Improvement: None Science Development: None Available at all sites.</p>	<p>Incorporate remote operations capability Development Costs: \$1-2M Capital Costs: \$250K not incl. remote manipulation provisions Operating Costs: \$30/ft³ of waste generated</p>
Entombment	<p>Thermoset Polymer/Thermal Plastic Stabilization (Entombment) DISM-109-OL</p> <p>Ranking:* not ranked</p>	<p>Demonstration Efficacy: Very useful particularly as compared to specialty grouts. Widely used at other sites. Leachability index of 11-12. Eliminates voids Waste Produced: None, unless excess promoter remains</p>	<p>Evaluation prior to use to insure compatibility with the waste being stabilized.</p>	<p>Develop process methodology to insure homogeneous mixing, maximum cost benefit, and elimination of excess promoter. Staff training. Solidification and transfer system needed. Overall Cost: \$11/ft³</p>
	<p>Ground Water Diversion (Entombment) DISM-110-OL</p> <p>Ranking:* not ranked</p>	<p>Accepted This technology's use is based on the need to divert groundwater away from the entombed area. Waste: Low Efficacy: High (French Drains)</p>	<p>None</p>	<p>Commercially available French drains are presumed to be adequate if designed properly. The cost of this technology is low, and the amount of waste generated is also low. Prototype testing of groundwater diversion techniques at the DOE X-10 Site will be required before acceptance by site D&D officials.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities including:</p> <ul style="list-style-type: none"> Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete 	Entombment	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR; radiation protection standards, DOE Orders; and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Entor
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Entombment	<p>Temporary Entombment/Clay Fill (Entombment) DISM-111-OL</p> <p>Ranking:* not ranked</p>	<p>Demonstration: This technology has been used at other sites and is proposed for the X-10 graphite reactor transfer trench for the purpose of temporary entombment. Efficacy considered high. The biggest limitation of this technology is leaching of contaminants because hydrologic isolation beneath the basement level is not addressed and hydrologic isolation.</p> <p>Waste Produced: Process itself - none. Decommissioning a filled site could result in increased waste.</p> <p>Overall Cost: \$0.3M - \$2M per 10^5 ft^3</p> <p>Efficacy: Medium</p>	<p>Definition of hydrologic isolation needs and moisturizing of clay to prevent drying and cracking need to be assessed.</p>	<p>Prototype testing at the DOE X-10 Site will be required prior to acceptance by site D&D officials.</p>
H	<p>Capping—Above Ground Environmental Barrier (Entombment) DISM-112-OL</p> <p>Ranking:* H-4-3 (\$0.5M; \$3/ft³)</p>	<p>Accepted: Used in both the public, commercial and government sectors. Capping technology has been demonstrated at other sites for the purpose of long-term protection of burial sites. In-situ grouting of low-level burial trenches has taken place at ORNL. Y-12 plant site has capped waste with asphalt matrixed over polyurethane sheets.</p> <p>Efficacy: of this technology is considered moderate. The biggest limitation of this technology is long-term stability and hydraulic isolation. Because this approach requires additional excavation, it is considered to be high in cost.</p> <p>Waste: Low</p>	<p>In order to ensure stable isolation of contaminated structures, application-specific hydraulic isolation caps must be developed. These barriers must include embedded sensors (discussed in another data sheet) to ensure structural and hydraulic isolation is maintained.</p>	<p>Overall Cost: \$5K-13K for 10,000 ft² (dependent on liner thickness requirement).</p>
H	<p>Encasement—Subsurface waste storage with void reduction (Entombment) DISM-113-OL</p> <p>Ranking:* H-4-3 (\$0.5M; \$10/ft³)</p>	<p>Evolving - Conceptual: Entombment of material and structures using existing structures should be a cost effective approach. Approach uses combination of existing accepted technologies.</p> <p>Waste Produced: None</p> <p>Overall Cost: Dependent on site and regulatory requirements</p> <p>Efficacy: High</p>	<p>Little or no development. Integration of hydraulic isolation, solidification, sensor technology, etc. needed.</p>	<p>Develop integration plan and demonstrate on small scale.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Entombment	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Termination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Entombment	<p>H</p> <p>Permanent Entombment (Entombment) DISM-114-OL</p> <p>Ranking:* H-4-3 (\$1M;\$15/ft³)</p>	<p>Conceptual. Utilizes numerous existing technologies to achieve a potentially cost effective means for dealing with low level waste and underground structures.</p> <p>Waste Produced: No additional waste from the entombment process.</p> <p>Efficacy: High. While concept is conceptual, it's implementation relies on the integration of accepted or demonstrated technologies. The commercial sector uses geosynthetic, high-density polyethylene liner and cap systems to environmentally safeguard sanitary landfills, leach pads, tailings dams, and the impounding of municipal incineration end products.</p>	<p>Application specific demonstration of capping, hydrologic isolation, sensors, etc. are needed.</p>	<p>Prototype testing of embedded sensors and engineering lining and cap barriers in a filled excavation application will be required prior to acceptance by site D&D officials.</p> <p>Overall Cost: To be determined by the site requirements and type of waste.</p>
	<p>H</p> <p>Engineered Storage—for very "hot" items, future disposal (Entombment) DISM-115-OL</p> <p>Ranking:* H-4-8 (\$7M;\$400/ft³)</p>	<p>Demonstrated for similar situation in Weapons Facilities.</p> <p>Waste: Waste can be significantly reduced.</p> <p>Efficacy: Certain to work; will require significant engineering and standards generation.</p>	<p>No new science and/or technology is needed.</p>	<p>Engineering of a prototype and licensing required to demonstrate process and lay ground work for other sizes and levels of radiation.</p> <p>Development Cost: Approximately \$6-9 million to get to the first usable and licensed cask.</p> <p>Capital Cost: Total facility D&D of a site such as the MSRE at ORNL would require \$20-30 million for all long term storage/shipping containers for high radiation level items. This may be off-set by a significant reduction in construction cost for roofed warehouses or other less durable concepts for interim storage.</p> <p>Operating Cost: Projected cost would be in the range of \$400/cu-ft of stored equipment components.</p>
	<p>Hydraulic Isolation (Entombment) DISM-116-OL</p> <p>Ranking:*</p>	<p>Demonstration</p> <p>Approaches vary with corresponding state of demonstrated usefulness. Isolation with high velocity jet grouting has been used at the White Oak Creek Enboynat, ORNL.</p> <p>Waste Produced:</p> <p>Overall Cost: \$2M - \$3M for ADPE test.</p> <p>Efficacy: Medium to high; dependant on the process in question.</p>	<p>Development and evaluations of great formulations. Demonstration of capabilities of other approaches are needed.</p>	<p>Tasting and demonstration of applicable technologies, so that selecting can be based on use requirements.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete</p>	Entombment	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement	Entombment
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

tion and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Entombment	Rubblization via Crushing and/or Shredding (Entombment) DISM-117-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration: Commercial products available which should meet requirements but neither detailed assessment or on site demonstration performed as yet. Waste Produced: Little to none. Efficacy: High: Greatly reduces the waste volume by reducing voids and permits easier incorporation.	Higher-torque, more durable shredders would be useful. Less labor intense systems are also needed.	Develop specifications, utilization plans, and user training. Overall Cost: \$50K to \$100K for large metal and cover.
	H Sensors for Monitoring Entombment Integrity (Entombment) DISM-118-OL <i>Ranking:*</i> H-4-3 (\$0.8M;\$1K/sensor)	Predemonstration: Use of integrated sensors in entombed structures and/or in capping etc. will provide information on integrity and stability. Waste Produced: None Efficacy: High	Development of application specific sensors, deployment approaches, and testing for survivability (and sensor projected life) are needed.	Implementation Needs: Develop requirements for sensors and deployment. Overall Cost: \$100K to \$500K fully instrumented site.
	Modular Entombment—with provisions for future removal (Entombment) DISM-119-OL <i>Ranking:*</i> <i>not ranked</i>	Demonstration: Use of preforms of metal or plastic to cast large blocks of material for temporary storage in entombed structures provides a cost effective means of dealing with waste. Waste Produced: Increases volume of waste to the percent of stabilizing material (grout, plastics, etc) added. Efficacy: High	Develop mixing requirements and test preforms for use with casting materials. Also assess cast block size for optimization of handling, storage, and relocation.	Develop application requirements, training needs, and handling requirements. Overall Cost: \$25/gallon (polymerization material) (See DISM-109-OL) <i>Ranking:*</i>
	Concrete-Based Solidification/Stabilization DISM-120-OL <i>Ranking:*</i> <i>not ranked</i>	Accepted: Currently has been used at K-25 Site as well as at other DOE sites. Use has surfaced several problems which would need to be dealt with if technology is elected. (Note that potentially increased waste volume if the entombed area is ever retrieved). Efficacy: High	Develop better understanding of needs for assuring validation of solidification and stabilization of the composite.	Mixing methodologies to avoid hot spots, installation of material to insure bonding and curing and pouring needs must be dealt with in implementation planning. Overall cost: \$2.5 to \$38/ft ³ depending on site requirements.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities Including:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE; Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete</p>	<p>Needed Enabling Technologies</p>	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Dismantlement</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Elimination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>Needed Enabling Technologies</p> <p>H</p>	<p>Bar Code/Laser Tooling Location (Needed Enabling Technologies) DISM-140-OL</p> <p>Ranking:* Not Ranked</p>	<p>Demonstration Technology exists to precisely position equipment such as warehouse stacker cranes using bar codes attached to permanent building features such as columns. The Caterpillar Company currently markets such a system. Assuming the philosophy of dismantlement is the automatic dismantlement of systems using robotic tool delivery platforms, when this technology will be directly applicable to our problem. This technology could save a large amount of funding depending upon the philosophy of dismantlement assumed.</p>	<p>No major development needed.</p>	<p>Major demonstration will be required to identify the detailed criteria for such a system. This demonstration would cost \$5-7M but could be a part of any integrated dismantlement demonstration. If integrated into another demonstration the cost would be minor (\$90 - 120 Thousand).</p>
	<p>Zoning for Containment—Three Zones (Needed Enabling Technologies) DISM-141-OL</p> <p>Ranking:* Not Ranked</p>	<p>Accepted Containment to prevent spread of exposed contamination to less contaminated areas has been demonstrated to be an effective cost reduction tool. At the Mound Laboratory facility a technique involving 3-Zones, "Cold, Buffer, and Hot" is being used to isolate contamination. Temporary containment has been shown to prevent increasing contamination in the surrounding building when removing gloveboxes. This technology will be necessary during dismantlement. It will allow an estimated 80-90% of the materials to be removed to be treated as low level waste. Commercial suppliers are available.</p>	<p>Lighter weight materials such as honeycomb construction may make panels easier to handle and cheaper. Inflatable panels may be applicable.</p>	<p>Panels need to be engineered to allow reuse of panels in the next dismantlement zone. Design for enhanced fire protection design. Flammable materials would be prohibited. Cost savings would result from reduction of disposal cost for 80-90% of the material in the diffusion facilities. Low level waste can be disposed at \$20/cu-ft. Material exceeding the limits for low level cost approximately \$100/cu-ft to dispose. Assuming all building materials can be disposed as low level waste the savings would be \$1-2 Billion for the older buildings.</p>
	<p>Point-and-Direct Tooling Positioning (Needed Enabling Technologies) DISM-142-OL</p> <p>Ranking:* Not Ranked</p>	<p>Evolving/Conceptual Pre-proof of principle stage. Efficacy: Reduced contact of worker with materials, low cost, easily adapted to multiple uses. Waste: None</p>	<p>Develop prototype and demonstrate efficacy. Cost to develop ~\$500K.</p>	<p>Overall cost - minimal (believed less than \$50K per unit). Field test prototype system. Test cost \$500K. Implementation cost per unit \$50K.</p>
	<p>Computer-Based D&D Information Retrieval (Needed Enabling Technologies) DISM-143-OL</p> <p>Ranking:* H-3-3 (\$3.5M; \$50/ft³)</p>	<p>Demonstration Status exists with FDDI networks being the primary nominee for this purpose. An FDDI network exists within Energy Systems and is being evaluated through the mathematics and physics group and C&TD. The application of this technology initially only requires customizing to meet the exact distribution requirements of the D&D program. Waste: None. Efficacy: High</p>	<p>Specific programs, technology development needs, and technology improvement needs.</p>	<p>Cost of proof of principle, amount of resources, equipment, hardware, software, facility, and educational needs. Reference requirements that are needed to deploy the technology successfully. Cost: Low.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<p>Various Facilities including:</p> <p>Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete</p>	<p>Needed Enabling Technologies</p>	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<p>Dismantlement</p>	<p>Need Tech</p>
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

ation and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Jed Enabling Technologies	<p>GIF Images to Augment As-Built Documentation (Needed Enabling Technologies) DISM-145-OL</p> <p>Ranking:* Not Ranked</p>	<p>Pre-demonstration Technology status is in the pre-demonstration stage of development. The concept is to take electronic images from digital cameras and camcorders as well as scanned images of common photographs and enter them into the computer. These images will be converted to GIF format for storage and viewing and utilize graphics programs for contrast enhancement to obtain scale measurements and allow design personnel to evolve designs around complicated assemblies without having to routinely travel back to the contaminated site for observation. The cost savings in accuracy and time will result in a large benefit.</p>	<p>There are some technology development needs that are required. Most of these stem from a systems integration set of requirements. The selection of the most advantageous suite of hardware and software that allow ease of use, high accuracy and definition, and the capability to select and view these images and display them in publications the needs that should be addressed in a prototype system prior to initiation of a program wide set of GIF image specifications.</p>	<p>These are vague at the present time. This technology is one of the fastest moving in the computer industry. Commercial products are literally being introduced every day. In addition, I&C at X-10 is currently doing a large amount of image storage and compression techniques for the Bureau of Engraving and Printing and the FBI that yield 10 to 1 factor of file size reduction with no discernable degradation in image quality.</p>
	<p>Laser Triangular Mapping of Facilities (Needed Enabling Technologies) DISM-146-OL</p> <p>Ranking:* Not Ranked</p>	<p>Pre-demonstration Laser scanning and distance mapping have been applied in many different disciplines. Actual integration into a computer 3-D database for remote manipulation is probably in the pre-development stages by commercial enterprises.</p>	<p>Specific detailed software that integrates the 3-D mapping to an existing database for use in robotic or remote manipulation applications will be required. Manipulation of the database and adjustment/calibration of the sensors in a real-time field mode of operation will be necessary to achieve success of this program.</p>	<ol style="list-style-type: none"> 1. A development effort between Energy Systems and commercial systems developers will be required. 2. A resource of programmers, workstation computers, lasers, I&C coordinators, commercial firms, and best efforts contracts will be required to demonstrate this technology. 3. After a 1-2 year development effort with individuals skilled in robotics, mechanical design, electronics design, software design, and optics and optical mapping/ a sufficient expertise should be available to initiate a design and procurement specification for procurement of multiple units to accomplish the optimum methods of D&D utilizing either/or remote or robotic methods.
	<p>Video Mapping (Needed Enabling Technologies) DISM-147-OL</p> <p>Ranking:* Not Ranked</p>	<p>Demonstration Video images can be an effective means of establishing configuration layouts for planning and executing work. Digitizing video (photographic) images for establishing baseline layouts and for computer-automated comparison of different positions with a baseline to characterize and establish equipment differences would facilitate planning and work direction. Comparison of multiple digitized images to highlight differences and conversion of images to line drawings is a well-established, demonstrated set of technologies.</p>	<p>Technology development needs include the assembly of an imaging/computer system, software development, procedure development, and personnel training.</p>	<p>Resource requirements and development needs are as follows:</p> <ol style="list-style-type: none"> 1. Imaging, computer, and related hardware (approx. \$40K-60K). 2. System integration and development (approx. \$300K-400K). 3. Development personnel: image technologist, software specialist, project manager. 4. System functional testing. 5. 9 to 15 months development. <p>Deployment Requirements:</p> <ol style="list-style-type: none"> 1. Procedure development and documentation (\$30K to 50K). 2. User training (\$10K - 20K). 3. System replication cost (if more than one system) (\$60K - 80K).

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

mination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Needed Enabling Technologies				
E	Project Information Access Services (Needed Enabling Technologies) DISM-151-OL <i>Ranking:*</i> E-2-1 (\$N/A;\$150/cut)	Demonstration The technology needs to be demonstrated because of the degree of integration of different host computers required to support effective information access across wide area networks.	Technology to implement such a system is commercially available and is found typically in financial services companies and some large corporations. Available at X-10.	Computer networks, especially Ethernet (cable, fiber), need to be extended throughout the X-10 Site to provide a basic foundation for information access and file transfers.
	Network Architecture with Integrated Workstations (Needed Enabling Technologies) DISM-152-OL <i>Ranking:*</i> Not Ranked	Demonstration Efficacy: Reduced time and cost to obtain or transfer information. Waste: N/A	None Available at X-10.	Software acquisition; user training.
E	Client/Server Access to Standards and Regulatory Guidelines (Needed Enabling Technologies) DISM-153-OL <i>Ranking:*</i> E-2-N/A (\$N/A;\$150/cut)	Demonstration Component technologies are well-established, commercially available, and affordable. They have not yet been integrated for use in a client/server environment.	A product is needed that provides network access to the databases on CD-ROM using the TCP/IP communications protocols between client and server. Available at X-10.	Automated, on-line access to basic reference documents is essential to reducing costs and increasing reliability of operations in a highly regulated work environment.
	Data Access Services (Needed Enabling Technologies) DISM-154-OL <i>Ranking:*</i> Not Ranked	Demonstration The particular network and communications configurations needed to support restoration activities may not exist, so would have to set up and their successful operation demonstrated.	Some software will be available commercially; some will have to be developed locally.	Requirements and specifications for such services must be identified and documented to serve as a common reference so that data can be accessed using a single set of services regardless of the type of computer at each node on the network.
E	Automated Scanning and Conversion of Engineering Drawings (Needed Enabling Technologies) DISM-155-OL <i>Ranking:*</i> E-2-1 (\$200K;\$10/bolt & \$300/cut)	Demonstration The basic technology is well established. Whether the current state of the art can adequately process the large number of drawings needed for reference and how effectively this technology can be integrated with other aspects of automated support needs to be demonstrated.	Improvements are needed in the speed and accuracy of converting scanned images to graphical representations that will meet the needs (e.g., ability to change scale to show more detail) of the environmental restoration program. Available at Y-12.	Considerable human intervention may be required to handle large drawings or drawings that cannot easily be laid flat on a scanning bed.
M	3-D CAD Data Base of Buildings and Structures (Needed Enabling Technologies) DISM-156-OL <i>Ranking:*</i> M-2-4 (\$250K;\$600/cut)	Accepted The basic technology is in wide use. A variety of commercial products is available for use on systems ranging from desktop computers to large mainframes.	Integration of this technology with the other supporting technologies that must work together with it to provide the high level of automation needed to assure proper compliance with environmental legislation governing restoration activities will be the main technology need.	Identification of all possible uses (e.g., "training" robots, visual "walkthroughs", tags for tracking activities) of this technology and development of database requirements to support them are very important foundations for effective use of this technology.
	Client/Server Architecture for Data Base Access (Needed Enabling Technologies) DISM-157-OL <i>Ranking:*</i> Not Ranked	Demonstration The effectiveness and appropriateness of a particular architecture design to meet the requirements of the restoration activities needs to be demonstrated.	This technology will benefit most from improvements in network technology (higher transmission speeds, improved transmission protocols and data access services) needed to support it.	Effectiveness depends strongly on the definition, design and implementation of the data dictionaries, data directories and data models that are the essential foundation for use of this technology.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decontamination

tion and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Enabling Technologies	Hypertext Information Systems (Needed Enabling Technologies) DISM-158-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration A range of products exists to support development of hypertext information systems having many capabilities such as mechanisms for linking related items, for starting execution and controlling other applications, and for navigating documents for faster access to information.	Authoring and design tools are needed. Available at X-10.	Hypertext information systems must be designed with great care to avoid problems with maintenance (e.g., modifying or replacing blocks of text from which or to which many links have been made to selected text strings within the block).
	H Electronic Catalog Descriptions and Source Locations of Site Historical Data (Needed Enabling Technologies) DISM-159-OL <i>Ranking:*</i> <i>H-2-4 (\$2.5M;\$900/cut)</i>	Accepted Standard database products can be used to create and maintain the inventory database.	Methods will be needed to evaluate and sort historical records according to their likely usefulness.	Initial implementation efforts must focus on locating the collections of records and documents of historical value.
	H Computer Aided Task Analysis and Procedure Preparation (Needed Enabling Technologies) DISM-172-OL <i>Ranking:*</i> <i>H-3-6 (\$200K;\$30/m²)</i>	Demonstration This technology is used extensively in planning by various federal agencies, most notably the Department of Defense in military operations planning.	More natural language analysis tools are needed to assist with analysis of information used for planning, much of which is provided in text form. Available at X-10.	Knowledge base development will require the largest effort, followed by development of expert systems and decision aids needed to make effective use of the information in the knowledge bases.
	Generalized Object-Oriented Simulation Software (Needed Enabling Technologies) DISM-173-OL <i>Ranking:*</i> <i>Not Ranked</i>	Demonstration The simulation environment is being used currently in ongoing studies associated with several different nuclear reactor design concepts. Modules would have to be written to model other types of systems.	Improvements are needed most in graphical display support systems. Available at X-10.	Successful deployment depends on availability of applications programmers who understand object-oriented design and programming principles and have experience applying this understanding to models of physical systems.
	Automated Engineering System Life Cycle Planning (Needed Enabling Technologies) DISM-174-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted A variety of commercial products developed to assist with managing large software development processes can be adapted for effective use in other engineering disciplines.	Improvements are needed to provide new types of support in order to satisfy regulatory requirements.	The usual life cycle planning methods must be modified to accommodate requirements of applicable environmental legislation which imposes constraints and requires additional elements to augment common practice.
	Automated System Reliability and Safety Analysis (Needed Enabling Technologies) DISM-175-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted/Demonstration Tools for some types of analysis are in common use in engineering development environments for things like software, aircraft, communications satellites, and medical diagnostic equipment.	Few automated analysis tools exist since much of the effort for these analysis requires checking for consistency, correctness, completeness, tolerance of designs to various kinds of system failures, and unintended function.	Detailed knowledge of the system being analyzed (its behavior and attributes), its intended use, operation, and constraints that apply is essential to being able to automate any such analysis.
	Geographic Information System for DOE Sites (Needed Enabling Technologies) DISM-181-OL <i>Ranking:*</i> <i>Not Ranked</i>	Accepted Most information, data, and computer system components for a basic geographic information system (GIS) for each DOE site already exists but must be integrated to meet the needs of the environmental restoration program.	Existing technology must be enhanced by adding a tagging mechanism to permit the system to be used for tracking activities and to link information in databases associated with a physical location to appropriate map and drawing displays on desktop computers. Available at X-10.	A large initial effort may be required to scan and digitize diagrams and drawings for electronic storage and quick retrieval or transfer across networks.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Dismantlement for Decont

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Various Facilities Including: Bldg. 3028 Bldg. 3028E Bldg. 3029 Bldg. 3030 Bldg. 3031 Bldg. 3032 Bldg. 3033 Bldg. 3036 Bldg. 3038 Bldg. 3517 Bldg. 7500 Bldg. 9219-1 MSRE, Bldg. 9201-3 Bldg. 9419-1 Process Piping and Tankage Drain Lines Pulsefeeder Pumps Pavement over 55-gal. Drum ORR Biological Shield HRT Structure ORR Hot Cell Liners Membrane Between HRT Concrete	Needed Enabling Technologies	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Dismantlement
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination and Decommissioning

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>Needed Enabling Technologies</p> <p>H</p>	<p>Computer-Based Training Systems (Needed Enabling Technologies) DISM-191-OL</p> <p>Ranking: H-2-2 (\$250K;\$100/h)</p>	<p>Demonstration Application software is available that permits rapid development of courses using many media (visual, audio), including support for a variety of testing strategies.</p>	<p>Further development is needed in the area of authoring support.</p>	<p>A well-defined course development life cycle does not yet exist. Currently used software engineering development life cycle methods should work well.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Decontam

The Decontamination section addresses co
contaminants from facilities and equipment. Be
contaminants and substrates, some simplification
This was accomplished by dividing problem areas
technologies.

ination

concepts and approaches for removing various
cause of the large number of combinations of
was necessary to limit the size of the diagram.
into different groups that had common treatment

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Slack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<ul style="list-style-type: none"> Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	<ul style="list-style-type: none"> Decontamination 	<ul style="list-style-type: none"> Mech Rem
<p>EM Problems</p> <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Preparation Methods	H Ultrahigh-Pressure Water DCON-35-OL Ranking:* H-5-1 (1.7; \$1/ft ²)	Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft ² concrete cleaned that contains ~0.01 ft ³ concrete residue, plus the contaminants removed.	Technology Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Technology Improvement: Automation, especially for walls and ceilings.	A water treatment system is needed to minimize liquid wastes from this technology. Development Cost: \$1.3M Capital Cost: ~\$500K Operating Cost: ~\$1/ft ²
	H Shot Blasting DCON-36-OL Ranking:* H-3-0 (<0.1; \$1/ft ²)	Accepted Commercial iron shot blasters are in use at the K-25 site. Efficacy: They are generally effective but leave some hot spots. Waste: Waste is ~0.01 ft ³ removed concrete (1/16" cut) containing removed contaminants plus 0.05 lb spent shot per ft ² of concrete decontaminated.	Technology Improvement: Automation, especially for walls and ceilings.	Normal implementation needs. Development Cost: None Capital Cost: ~\$50K Operating Cost: ~\$1/ft ²
	H Scabblers/Scarifiers DCON-37-OL Ranking:* H-4-2 (0.5; \$5/ft ²)	Accepted Mechanical scabblers are used for concrete decontamination at the K-25 Site and elsewhere. Efficacy: They are generally effective, but leave some hot spots. Waste: Waste is ~0.01 ft ³ removed substrate (1/16" cut) containing removed contaminants per ft ² of substrate decontaminated.	Technology Improvement: Automation, especially for walls and ceilings.	Normal implementation needs. Development Cost: None Capital Cost: ~\$500K (largest size) Operating Cost: ~\$5/ft ²
	H Grit Blasting DCON-38-OL Ranking:* H-4-0 (<0.1; \$5/ft ²)	Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste is ~0.01 ft ³ removed concrete (1/16" cut) containing removed contaminants per ft ² of concrete decontaminated plus spent grit.	Technology Improvement: automation, especially for walls and ceilings.	Normal implementation needs. Development Cost: None Capital Cost: ~\$500K (largest size) Operating Cost: ~\$5/ft ²
	H Centrifuge Cryogenic CO ₂ Pellet Blasting DCON-39-OL Ranking:* H-5-2 (1.0; <\$1/ft ²)	Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft repaint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.	Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Technology Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants, plus oxygen-depletion precautions. Development Cost: <\$1M Capital Cost: \$100K Operating Cost: <\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1 st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components	Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Ice Blasting DCON-40-OL</p> <p>Ranking:* H-5-1 (<1.0; \$1/ft²)</p>	<p>Demonstration Efficacy: Efficacy of commercial system for this application needs demonstration. Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.</p>	<p>Development: Demonstration of efficacy of commercial system. Technology Improvement: Automation/robotics, especially for walls, corners, etc.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development Cost: \$250K Capital Cost: \$100K-\$1M Operating Cost: <\$1/ft²</p>
	<p>H</p> <p>Supercritical CO₂ Blasting DCON-41-OL</p> <p>Ranking:* H-5-1 (0.75+; >\$1/ft²)</p>	<p>Predemonstration Efficacy: Likely to be effective with nearly infinite decontamination factors. Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.</p>	<p>Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions. Development Cost: \$250K-1M Capital Cost: ~\$500K Operating Cost: \$1+/ft²</p>
	<p>M</p> <p>Plastic Pellet Blasting DCON-42-OL</p> <p>Ranking:* M-4-0 (<0.1; \$1/ft²)</p>	<p>Accepted Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate. Efficacy: Technology should remove smearable, but not fixed contamination from concrete. Waste: Waste would be spent plastic pellets plus removed contamination.</p>	<p>Technology Improvement: Develop and demonstrate system for processing waste. Technology Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>A system for processing waste to an acceptable form is needed. Development Cost: Improvements \$5.5M+ Capital Cost: ~\$50K Operating Cost: \$0.20-\$2.15/ft²</p>
	<p>H</p> <p>Hand Grinding, Honing, Scraping DCON-43-OL</p> <p>Ranking:* H-2-0 (<<0.1; \$1/ft²)</p>	<p>Accepted Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>None Available at X-10, K-25.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development Costs: None Capital Cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation) Operating Cost: ~\$1/ft²</p>
	<p>H</p> <p>Automated Grinding DCON-44-OL</p> <p>Ranking:* H-2-1 (~ \$1; N)</p>	<p>Conceptual Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: The applicability of this technology to items with rad contamination should be demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$600K Capital cost: \$250K</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<ul style="list-style-type: none"> Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	<ul style="list-style-type: none"> Decontamination 	<ul style="list-style-type: none"> Mechanical Removal Thermal Removal
<ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) 					
<ul style="list-style-type: none"> Remedial Action (RA)—Soils, Ground Water and Surface Water 					
<ul style="list-style-type: none"> Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>M</p> <p>Concrete Milling DCON-47-OL</p> <p>Ranking:* M-1-2 (<1; \$0.75/ft²)</p>	<p>Accepted: The equipment is commercially available, but no reference to its use for decontamination has been found. This technology is suited for horizontal surfaces only.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Technology Improvement: The technology to operate this equipment remotely needs to be developed and demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology.</p> <p>Development cost: None</p> <p>Capital cost: \$400K</p> <p>Operating cost: \$0.75/ft²</p>
	<p>L</p> <p>Explosive DCON-48-OL</p> <p>Ranking:* L-2-5 (4; \$50/ft²)</p>	<p>Demonstration: Blasting has been used to decontaminate nuclear reactor shielding. Demonstration will be needed for other applications. Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: Improvements in the methods of applying explosives and in the uniformity of the detonation are needed. The explosion will generate toxic organic vapors. The technology to control toxic vapors formed by the explosion must be developed and demonstrated.</p>	<p>A certified blasting technician will be needed.</p> <p>Capital cost: \$50K</p> <p>Operating cost: \$50/ft²</p> <p>Development cost: \$1-4M</p>
	<p>H</p> <p>Microwave Scabbling DCON-71-OL</p> <p>Ranking:* H-3-2 (2.5+; >\$1/ft²)</p>	<p>Predemonstration: In FY 1991 ORNL demonstrated reliable removal of noncontaminated concrete surfaces using a stationary microwave device. A mobile device is under development.</p> <p>Efficacy: Since microwave scabbling removes the contaminated concrete surface, the decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: The waste generated is concrete rubble with particle diameters lying primarily in the range of 1 to 10 mm plus the contaminants. For a removal depth of 10 mm, 0.03 ft³ of concrete rubble is generated per ft² of concrete decontaminated.</p>	<p>Development: The development and testing of a mobile prototype microwave concrete removal machine needs to be completed.</p>	<p>Normal implementation needs.</p> <p>Development Cost: \$2.5M</p> <p>Capital Cost: ~\$250K</p> <p>Operating Cost: >\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<ul style="list-style-type: none"> Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	<ul style="list-style-type: none"> Decontamination
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 				
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Ground Water and Surface Water 				
<ul style="list-style-type: none"> • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Thermal Surface Removal Methods	H Plasma Torch DCON-72-OL Ranking:* H-4-1 (~ \$1/ft ²)	Evolving Technology Conceptual Plasma torches exist commercially to weld and cut materials that have very high melting temperatures or require an inert atmosphere. Efficacy: Its efficacy in removing various organic contaminants or to spall off layers of contaminated concrete has not been investigated. Waste: Wastes would consist of materials used to trap reaction products from the decomposition of organics and spalled concrete with contaminants.	Science: Laboratory tests are needed to evaluate the efficacy of vaporizing or decomposing organics, determine the decomposition reaction by-products, and suitable for trapping materials. Laboratory tests of thermal stress-induced spalling of concrete are also needed. Computer modeling of plasma-surface interactions and heat transfer in concrete are needed. Development: Plasma torches having geometries and conditions suitable for decontamination need to be developed along with suitable collection and gas treatment systems. Available at Y-12.	A collection system for the vaporized contaminants would be needed to implement this technology. Development Costs: ~\$500K Capital costs: ~\$100K Operating costs: \$0.01-\$1.00/ft ²
	M Laser Heating DCON-73-OL Ranking:* M-4-4 (3; \$1/ft ²)	Demonstration Currently being used to remove organic coatings from metal surfaces. Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft ² /hr. Effectiveness on contaminants and substrates of interest is uncertain. Waste: Waste will be prefilters and HEPA filters filled with contaminants.	Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.	A collection system for the vaporized contaminants would be needed to implement this technology. Development Costs: \$2M+ Capital Cost: \$500K-\$1M+/machine Operating Cost: ~\$1/ft ²
	M Laser Etching and Ablation DCON-74-OL Ranking:* M-4-4 (3.5; >\$1/ft ²)	Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed contaminants, some substrate material, and HEPA filters from the filtration system.	Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.	A collection system for the vaporized contaminants would be needed to implement this technology. Development Costs: \$2M+ Capital Cost: \$0.5-1M/machine Operating Cost: >\$1/ft ²
	H Flashlamp Cleaning DCON-77-OL Ranking:* H-3-3 (2.5; ~\$1/ft ²)	Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.	Development: Commercially available flashlamp systems need to be evaluated for radiological contamination	A collection system for the vaporized contaminants would be needed to implement this technology. Development Cost: ~\$2.5 M Capital Cost: \$50-100K/machine Operating Cost: ~1.00/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1 st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Slack Slab Supporting Low-Intensity Test Reactor Components	Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Surface
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Cleaning Methods	<p>H</p> <p>Compressed-Air Cryogenic CO₂ Pellet Blasting DCON-51-OL</p> <p>Ranking: H-4-1 (0.7; >\$1/ft²)</p>	<p>Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.</p>	<p>Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants. Development Costs: about \$0.50M Capital Cost: About \$200,000 Operating Cost: >\$1/ft²</p>
	<p>M</p> <p>High-Pressure Water DCON-52-OL</p> <p>Ranking: M-3-1 (1.3; <\$1/ft²)</p>	<p>Accepted High pressure water blasting has been used very successfully to decontaminate various large and complex surfaces at nuclear power plants. Efficacy: Technique is expected to be effective with a DF of about 50 for loosely adhering contamination on concrete. DFs will be higher if chemical cleaning agents are also used. Technique is expected to be ineffective for fixed contamination on concrete. Waste: Waste is 4 to >100 gpm of contaminated waste water.</p>	<p>Technology Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Technology Improvement: Remote operation will necessitate the adaptation of the high pressure water and vacuum collection systems to robotic system control.</p>	<p>A water treatment system is needed to minimize waste. Development Cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital Cost: \$50K-\$75K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>M</p> <p>Superheated Water DCON-53-OL</p> <p>Ranking: M-4-1 (1.4; <\$1/ft²)</p>	<p>Accepted Technology is available and has been used by industry. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has soaked into the concrete. On finished concrete, technology may drive contaminants deeper into substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Technology Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Technology Improvement: Remote operation will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.</p>	<p>A water treatment system is needed to minimize waste. Development Cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital Cost: About \$175K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>M</p> <p>Water Flushing DCON-54-OL</p> <p>Ranking: M-4-1 (1.3; <\$1/ft²)</p>	<p>Accepted Flushing with hot water is often used following scrubbing, especially on floors. Efficacy: The technique is not effective on fixed insoluble contamination. On finished concrete, technology may drive contaminants deeper into substrate. Waste: The waste generated is the contaminated water from the flushing operation.</p>	<p>Technology Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the hot water cleaning operation.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development Cost: About \$1.2M Capital Cost: <\$5K Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<ul style="list-style-type: none"> Decontamination
<p>EM Problems</p> <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning Methods	<p>M</p> <p>Steam Cleaning DCON-55-OL</p> <p>Ranking:* M-4-1 (1.3; ~\$1/ft²)</p>	<p>Accepted The technique has proven useful, especially on complex shapes and large surfaces. Efficacy: Technology should be effective except for fixed, insoluble contamination or contamination that has soaked into the concrete. On finished concrete, technology may drive contaminants deeper into substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Technology Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Remote operation will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.</p>	<p>A wastewater treatment / recycle system will be needed to use this technology. Development Cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital Cost: \$50K-\$75K (about \$250K with remote operation) Operating Cost: ~\$1.00/ft²</p>
	<p>H</p> <p>Hand Brushing Used to Remove Surface Contamination DCON-56-OL</p> <p>Ranking:* H-2-0 (0; \$1/ft²)</p>	<p>Accepted Brushing is a common decontamination technique. Efficacy: Brushing is effective for loose contamination only. Waste: Waste consists of removed contamination plus other loose debris.</p>	<p>None Available at K-25.</p>	<p>Normal implementation needs. Capital cost: negligible Operating cost: \$1.00/ft² Development cost: none</p>
	<p>M</p> <p>Automated Brushing DCON-57-OL</p> <p>Ranking:* M-3-2 (1; \$300/ft)</p>	<p>Demonstration This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.</p>	<p>Development: Tests to demonstrate that this technology is effective for the problems at ORNL.</p>	<p>Vacuum collection system Development costs: \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe</p>
	<p>M</p> <p>Sponge Blasting DCON-58-OL</p> <p>Ranking:* M-3-1 (1.3; \$2/ft²)</p>	<p>Accepted Although the technology is relatively new, it is currently being used by at least two sites including a nuclear power plant. Efficacy: Extensive data on decontamination factors are not available. With the aggressive sponges, which are impregnated with abrasives, this technology may be effective for the listed contaminants and substrates. Waste: Wastes consist of about 0.01 ft³ of blasting media and removed contaminants per ft² of area decontaminated plus any liquid cleaning agents that may have been added.</p>	<p>Technology Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the sponge blasting operation.</p>	<p>A wastewater treatment / recycle system will be needed to use this technology. Development Cost: About \$1.2M Capital Cost: Sponge blasting system: About \$20K (with sifter system) Operating Cost: About \$2/ft²</p>
	<p>M</p> <p>Solvent Washing to Remove Radiological Contamination DCON-61-OL</p> <p>Ranking:* M-3-2 (1; N)</p>	<p>Conceptual Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.</p>	<p>Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available in Private Sector.</p>	<p>Vapor collection system. Capital Cost: \$300K (1980 dollars) Development Cost: ~\$1M to identify and demonstrate the replacement solvent. Operating Cost: An average of 7.5 minutes per item was required when decontaminating small items.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<p>Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	<ul style="list-style-type: none"> Decontamination 	<ul style="list-style-type: none"> Surfa Chem Metho
<ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) 					
<ul style="list-style-type: none"> Remedial Action (RA)—Soils, Ground Water and Surface Water 					
<ul style="list-style-type: none"> Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Cleaning Methods	M Strippable Coatings DCON-63-OL Ranking:* M-3-0 (<0.1; >\$1/ft ²)	Accepted Technology has been used for decontamination applications involving hazardous and radioactive contaminants. Efficacy: Decontamination factors of one to several hundred can be expected with two applications. Waste: Waste is a solid polymer (volume = 1 mm x surface area decontaminated) containing the removed contaminants.	Technology Improvement: Develop coatings with lower material costs and greater ease of application.	Normal implementation needs. Capital cost: Negligible Operating cost: \$1-\$1.40/ft ²
	M Vacuum (Low Pressure) DCON-7-OL Ranking:* M-4-0 (<0.1; \$1/ft ²)	Accepted Vacuum cleaners have long been used to clean up loose contamination at the gaseous diffusion plants. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective in cleaning concrete floors at ORNL. Waste: The waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.	None	Normal implementation needs. Capital Cost: <\$10K Operating cost: >\$1/ft ²
	M Chemical Foams DCON-8-OL Ranking:* M-4-1 (3; \$.50-2/ft ²)	Demonstration Widely used throughout the nuclear industry. Foam is used as a carrier of chemical decontamination agents, not as the agent itself. It is sprayed onto component walls or the component is filled with the foam. It can be wiped, rinsed, or vacuumed off. Efficacy: Decontamination effectiveness was 63-92% with DF = 2.7 to 12.5 inside a hot cell in one study. Waste: Small amount of contaminated sulfonated detergents; synthetic wetting agents; coupling agents; rinse water, and drying cloth.	Development: Scale-up/development of the process to a size appropriate for ORNL use. The technology itself is inexpensive, but development and scale-up will probably require support. Technology Improvement: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.	Normal implementation needs. Development cost: \$1M-\$4M; Capital cost: \$50K Operating cost: \$0.50-\$2/ft ²
ical Surface Cleaning ds	M Fluoboric Acid Treatment DCON-11-OL Ranking:* M-4-2 (2; N)	Demonstration Technology was designed specifically for D&D. Efficacy: Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF). Fluoboric (or fluosilicic) acid can scabble and clean cement and brickwork if contaminated to a depth of only a few mm; concrete flooring and structures can be returned to unrestricted use.	Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.	Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital Cost: in 1990 to set up a plant for decontaminating 5 tons/day of steel cost \$774K, excluding development, planning, and buildings. Operating cost: Relatively low; this is a very simple process.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1 st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Slack Slab Supporting Low-Intensity Test Reactor Components	Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning Methods	L Biological Surface Cleaning DCON-3-OL Ranking:* L-2-3(1.0M; ~\$1/ft ²)	Evolving Technology / Pre-conceptual The knowledge base exists for biological treatments of various contaminants; however, there is not a data base for application of the technology for surface decontamination. Efficacy: This technology is quite likely to be successful for oil and PCBs. It could be successful for radionuclides of interest, but these contaminants would remain in the bacterial sludge. Waste: The waste generated would be the contaminated layer of microbes removed from the treated surface.	Science: Literature study and bench-scale tests of microbes on radionuclides of interest. Development: Develop methods for applying a layer of microbes, supplying needed nutrients, and removing the microbe layer from the decontaminated item. Available at X-10, K-25.	Facilities for cultivating the bacteria and disposing of the bacterial sludge would be needed. Development Cost: \$300K-\$600K Capital Cost: ~\$200K Operating Costs: \$0.10-\$3.00+/ft ²
	M Detergent Treatments DCON-13-OL Ranking:* M-4-0 (0; >\$1/ft ²)	Accepted Surface smearable decontamination with caustic chemicals (soap and water) is accepted technology and is used extensively at ORNL. The caustic hand scrubbing process was applied to cleaning small items. Efficacy: Soaps, carbonates, etc., will remove smearable, but not fixed contamination. Waste: Waste would be spent detergent solution containing removed contaminants (normally treated by neutralization and precipitation).	None for removal of smearable contamination with carbonates, soaps, etc. Available at X-10, K-25.	This is an established process that could be implemented at ORNL with no major changes. Capital Cost: <\$10K Operating costs: >\$1/ft
	M Electromigration DCON-20-OL Ranking:* M-3-3.5 (1.2; N)	Predemonstration Limited testing on a small scale. Efficacy: Initial data indicate 90+% removal of U & Tc from concrete. Applicable, in principle, to actinides & chromate. Removal of oil & PCBs possible, in principle, but not demonstrated. Waste: Wastes would be electrolytes containing removed contaminants and scrap cell components.	Development: Additional small-scale "proof of the principle" tests are needed followed by larger scale field demonstration. A treatment system that would permit recycle of the electrolyte is needed.	Normal implementation needs. Development Cost: \$1M Capital Cost: ~\$200K Operating Cost: ~\$5/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<ul style="list-style-type: none"> Oak Ridge Reactor Biological Shield Bldg. 3028 Hot Cell Interiors Bldg. 3029 Hot Cell Interiors Bldg. 3030 Hot Cell Interiors Bldg. 3031 Hot Cell Interiors Bldg. 3032 Hot Cell Interiors Bldg. 3036 Floor Homogeneous Reactor Test Structure Bldg. 3517 Hot Cell Interiors Bldg. 9419-1 floor, 1st Floor Molten Salt Cells Bldg. 3038 Cell Interiors Graphite Reactor Biological Shields Graphite Reactor Canal Graphite Reactor Ductwork Graphite Reactor Stack Slab Supporting Low-Intensity Test Reactor Components 	<ul style="list-style-type: none"> Concrete Fission Products, Corrosion Products Concrete Fission Products, Cm-244, Pm-147, Am-241 Concrete Cs-137, Sr-90, Co-60, Ir-192 Concrete 43 Beta/Gamma Emitters Concrete Gd-153, Am-241 Concrete P-32, Am-241 Concrete Cs-137, Sr-90 High-Density Concrete Fission Products, Corrosion Products, Induced Radiation Concrete C-137, Sr-90, Co-60 Concrete U, Th, Molten Salt Concrete Sr-90, Cs-137, Co-60, I-129 Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products Concrete Fission Products, Corrosion Products, Activation Products 	<ul style="list-style-type: none"> Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	Decontamination	Chemical Methods
<ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) 					
<ul style="list-style-type: none"> Remedial Action (RA)—Soils, Ground Water and Surface Water 					
<ul style="list-style-type: none"> Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Cal Surface Cleaning ds</p> <p>M</p>	<p>Chelation Treatment DCON-21-OL</p> <p>Ranking: M-4-2 (1.5; <\$1/ft²)</p>	<p>Demonstration The technology has been employed at various facility operations and nuclear power plant sites. Efficacy: Excellent DFEs achieving acceptable decontamination levels resulting in unconditional release. Easy to apply in-situ as agent acts at neutral pH and are non-hazardous; non-fuming, have no gas evolution and are biodegradable. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Interiors, Floors, Cell Faces Bldg. 3028 Hot Cell Interiors, Floors, Cell Faces Bldg. 3029 Cell Faces Bldg. 3030 Floors and Cell Faces Bldg. 3031 Floors and Cell Faces Bldg. 3032 Floors and Cell Faces Bldg. 3033 Cell Faces Bldg. 3036 Floors Bldg. 3517 High Bay Floors & Cell Faces Bldg. 9201-3 Coolant Salt Cell Bldg. 9201-3 Molten Salt Cell Bldg. 3038 Cell Floor & Surfaces Bldg. 3505 Floors and Cell Faces Bldg. 3506 Hot Cell Interiors Bldg. 3515 Floors and Cell Faces Bldg. 3047 Floors and Cell Faces Bldg. 7852 Floors and Cell Faces Bldg. 3019 Hot Cell Interiors, Floors, and Cell Faces Graphite Reactor Biological Shield Exterior	Painted Concrete Fission Products, TRU Painted Concrete Fission Products, Cm-147, Pm-241, Am Painted Concrete Cs-137, Sr-90, Co-60, Ir-192 Painted Concrete 43 Beta, Gamma Emitters Painted Concrete Gd-153, Am-241 Painted Concrete P-32, Am-241 Painted Concrete H-3, Kr-85 Painted Concrete Cs-137, Sr-90 Painted Concrete Cs-137, Sr-90, Co-60 Painted Concrete U, Th, Coolant Salt Painted Concrete U, Th, Molten Salt Painted Concrete Sr-90, Cs-137, Co-60, I-129 Painted Concrete Fission Products, TRU Painted Concrete Fission Products Painted Concrete Fission Products Painted Concrete Cs, Sr, Co, Cm, Eu, Am, Pu Painted Concrete Fission Products, Corrosion Products, Cs, Sr, TRU, Co, Cm, Eu, Am, Pu Painted Concrete U-233, Pu-239, Fission Products Painted Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products	Refer to Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems				
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Ultrahigh-Pressure Water DCON-35-OL</p> <p>Ranking:* H-5-1 (1.7; \$1/ft²)</p>	<p>Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft² concrete cleaned that contains ~0.01 ft³ concrete residue, plus the contaminants removed.</p>	<p>Technology Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Technology Improvement: Automation, especially for walls and ceilings.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$1.3M Capital cost: ~\$500K Operating Cost: ~\$1/ft²</p>
	<p>H</p> <p>Shot Blasting DCON-36-OL</p> <p>Ranking:* H-3-0 (<0.1; ~\$1/ft²)</p>	<p>Accepted Commercial iron shot blasters are in use at the K-25 site. Efficacy: They are generally effective but leave some hot spots. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants plus 0.05lb spent shot per ft² of concrete decontaminated.</p>	<p>Technology Improvement: Automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$50K Operating Cost: ~\$1/ft²</p>
	<p>H</p> <p>Scabblers/Scarifiers DCON-37-OL</p> <p>Ranking:* H-4-2 (0.5; \$5/ft²)</p>	<p>Accepted Mechanical scabblers are used for concrete decontamination at the K-25 Site and elsewhere. Efficacy: They are generally effective, but leave some hot spots. Waste: Waste is ~0.01 ft³ removed substrate (1/16" cut) containing removed contaminants per ft² of substrate decontaminated.</p>	<p>Technology Improvement: Automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating Cost: <\$5/ft² (More than shot blasting)</p>
	<p>H</p> <p>Grit Blasting DCON-38-OL</p> <p>Ranking:* H-4-0 (<0.1 \$5/ft²)</p>	<p>Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants per ft² of concrete decontaminated plus spent grit.</p>	<p>Technology Improvement: automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$50K Operating Cost: \$~5/ft²</p>
	<p>H</p> <p>Centrifuge Cryogenic CO₂ Pellet Blasting DCON-39-OL</p> <p>Ranking:* H-5-2 (1.0; <\$1/ft²)</p>	<p>Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft de paint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.</p>	<p>Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Technology Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen-depletion precautions. Development cost: <\$1M Capital cost: \$100K Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Interiors, Floors, Cell Faces Bldg. 3028 Hot Cell Interiors, Floors; Cell Faces Bldg. 3029 Cell Faces Bldg. 3030 Floors and Cell Faces Bldg. 3031 Floors and Cell Faces Bldg. 3032 Floors and Cell Faces Bldg. 3033 Cell Faces Bldg. 3036 Floors Bldg. 3517 High Bay Floors & Cell Faces Bldg. 9201-3 Coolant Salt Cell Bldg. 9201-3 Molten Salt Cell Bldg. 3038 Cell Floor & Surfaces Bldg. 3505 Floors and Cell Faces Bldg. 3506 Hot Cell Interiors Bldg. 3515 Floors and Cell Faces Bldg. 3047 Floors and Cell Faces Bldg. 7852 Floors and Cell Faces Bldg. 3019 Hot Cell Interiors, Floors, and Cell Faces Graphite Reactor Biological Shield Exterior	Painted Concrete Fission Products, TRU Painted Concrete Fission Products, Cm-147, Pm-241, Am Painted Concrete Cs-137, Sr-90, Co-60, Ir-192 Painted Concrete 43 Beta, Gamma Emitters Painted Concrete Gd-153, Am-241 Painted Concrete P-32, Am-241 Painted Concrete H-3, Kr-85 Painted Concrete Cs-137, Sr-90 Painted Concrete Cs-137, Sr-90, Co-60 Painted Concrete U, Th, Coolant Salt Painted Concrete U, Th, Molten Salt Painted Concrete Sr-90, Cs-137, Co-60, I-129 Painted Concrete Fission Products, TRU Painted Concrete Fission Products Painted Concrete Fission Products Painted Concrete Cs, Sr, Co, Cm, Eu, Am, Pu Painted Concrete Fission Products, Corrosion Products, Cs, Sr, TRU, Co, Cm, Eu, Am, Pu Painted Concrete U-233, Pu-239, Fission Products Painted Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech. Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Preparation Methods	<p>H</p> <p>Ice Blasting DCON-40-OL</p> <p>Ranking:* H-5-1 (<1.0; \$1/ft²)</p>	<p>Demonstration</p> <p>Efficacy: Efficacy of commercial system for this application needs demonstration.</p> <p>Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.</p>	<p>Development: Demonstration of efficacy of commercial system.</p> <p>Technology Improvement: Automation/robotics, especially for walls, corners, etc.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology.</p> <p>Development cost: \$250K</p> <p>Capital cost: \$100K-\$1M</p> <p>Operating Cost: \$1/ft²</p>
	<p>H</p> <p>Supercritical CO₂ Blasting DCON-41-OL</p> <p>Ranking:* H-5-1 (0.75+; >\$1/ft²)</p>	<p>Predemonstration</p> <p>Efficacy: Likely to be effective with nearly infinite decontamination factors.</p> <p>Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.</p>	<p>Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: \$250K-1M</p> <p>Capital cost: ~\$500K</p> <p>Operating Cost: \$1+/ft²</p>
	<p>M</p> <p>Plastic Pellet Blasting DCON-42-OL</p> <p>Ranking:* M-4-0 (<0.1; ~\$1/ft²)</p>	<p>Accepted</p> <p>Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate.</p> <p>Efficacy: Technology should remove smearable, but not fixed contamination, from concrete. May have trouble removing paint to reach contamination underneath.</p> <p>Waste: Waste would be spent plastic pellets plus removed contamination.</p>	<p>Technology Improvement: Develop and demonstrate system for processing waste.</p> <p>Technology Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>A system for processing waste to an acceptable form is needed.</p> <p>Development Cost (Improvements): \$5.5M+</p> <p>Capital cost: ~\$50K</p> <p>Operating Cost: \$0.20-\$2.15/ft²</p>
	<p>H</p> <p>Hand Grinding, Honing, Scraping DCON-43-OL</p> <p>Ranking:* H-2-0 (<0.1; ~\$1/ft²)</p>	<p>Accepted</p> <p>Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>None</p> <p>Available at X-10, K-25.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology.</p> <p>Development cost: None</p> <p>Capital cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation)</p> <p>Operating Cost: ~\$1/ft²</p>
	<p>H</p> <p>Automated Grinding DCON-44-OL</p> <p>Ranking:* H-2-1 (\$1; N)</p>	<p>Conceptual</p> <p>Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: The applicability of this technology to items with rad contamination should be demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology.</p> <p>Development cost: \$600K</p> <p>Capital cost: \$250K-500K</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<ul style="list-style-type: none"> • ORR Hot Cell Interiors, Floors, Cell Faces • Bldg. 3028 Hot Cell Interiors, Floors, Cell Faces • Bldg. 3029 Cell Faces • Bldg. 3030 Floors and Cell Faces • Bldg. 3031 Floors and Cell Faces • Bldg. 3032 Floors and Cell Faces • Bldg. 3033 Cell Faces • Bldg. 3036 Floors • Bldg. 3517 High Bay Floors & Cell Faces • Bldg. 9201-3 Coolant Salt Cell • Bldg. 9201-3 Molten Salt Cell • Bldg. 3038 Cell Floor & Surfaces • Bldg. 3505 Floors and Cell Faces • Bldg. 3506 Hot Cell Interiors • Bldg. 3515 Floors and Cell Faces • Bldg. 3047 Floors and Cell Faces • Bldg. 7852 Floors and Cell Faces • Bldg. 3019 Hot Cell Interiors, Floors, and Cell Faces • Graphite Reactor Biological Shield Exterior 	<ul style="list-style-type: none"> • Painted Concrete Fission Products, TRU • Painted Concrete Fission Products, Cm-147, Pm-241, Am • Painted Concrete Cs-137, Sr-90, Co-60, Ir-192 • Painted Concrete 43 Beta, Gamma Emitters • Painted Concrete Gd-153, Am-241 • Painted Concrete P-32, Am-241 • Painted Concrete H-3, Kr-85 • Painted Concrete Cs-137, Sr-90 • Painted Concrete Cs-137, Sr-90, Co-60 • Painted Concrete U, Th, Coolant Salt • Painted Concrete U, Th, Molten Salt • Painted Concrete Sr-90, Cs-137, Co-60, I-129 • Painted Concrete Fission Products, TRU • Painted Concrete Fission Products • Painted Concrete Cs, Sr, Co, Cm, Eu, Am, Pu • Painted Concrete Fission Products, Corrosion Products, Cs, Sr, TRU, Co, Cm, Eu, Am, Pu • Painted Concrete U-233, Pu-239, Fission Products • Painted Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products 	<ul style="list-style-type: none"> • Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	<ul style="list-style-type: none"> • Decontamination
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>M</p> <p>Concrete Milling DCON-47-OL</p> <p>Ranking:* M-1-2 (<1; \$0.75/ft²)</p>	<p>Accepted: The equipment is commercially available, but no reference to its use for decontamination has been found. This technology is suited for horizontal surfaces only.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Technology Improvement: The technology to operate this equipment remotely needs to be developed and demonstrated.</p>	<p>A collection system for the contaminated dust would be needed to implement this technology. Development cost: None Capital cost: \$400K Operating Cost: \$0.75/ft²</p>
	<p>L</p> <p>Explosive DCON-48-OL</p> <p>Ranking:* L-2-5 (4; \$50/ft²)</p>	<p>Demonstration: Blasting has been used to decontaminate nuclear reactor shielding. Demonstration will be needed for other applications. Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: Improvements in the methods of applying explosives and in the uniformity of the detonation are needed. The explosion will generate toxic organic vapors. The technology to control toxic vapors formed by the explosion must be developed and demonstrated.</p>	<p>A certified blasting technician will be needed. Capital cost: \$50K Operating Cost: \$50/ft² Development cost: \$1-4M</p>
Thermal Surface Removal Methods	<p>H</p> <p>Microwave Scabbling DCON-71-OL</p> <p>Ranking:* H-3-2 (2.5+; >\$1/ft²)</p>	<p>Predemonstration: In FY 1991 OFNL demonstrated reliable removal of noncontaminated concrete surfaces using a stationary microwave device. A mobile device is under development.</p> <p>Efficacy: Since microwave scabbling removes the contaminated concrete surface, the decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: The waste generated is concrete rubble with particle diameters lying primarily in the range of 1 to 10 mm plus the contaminants. For a removal depth of 10 mm, 0.03 ft³ of concrete rubble is generated per ft² of concrete decontaminated.</p>	<p>Development: The development and testing of a mobile prototype microwave concrete removal machine needs to be completed.</p>	<p>Normal implementation needs. Development cost: \$2.5M Capital cost: ~\$250K Operating Cost: >\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Interiors, Floors, Cell Faces Bldg. 3028 Hot Cell Interiors, Floors, Cell Faces Bldg. 3029 Cell Faces Bldg. 3030 Floors and Cell Faces Bldg. 3031 Floors and Cell Faces Bldg. 3032 Floors and Cell Faces Bldg. 3033 Cell Faces Bldg. 3036 Floors Bldg. 3517 High Bay Floors & Cell Faces Bldg. 9201-3 Coolant Salt Cell Bldg. 9201-3 Molten Salt Cell Bldg. 3038 Cell Floor & Surfaces Bldg. 3505 Floors and Cell Faces Bldg. 3506 Hot Cell Interiors Bldg. 3515 Floors and Cell Faces Bldg. 3047 Floors and Cell Faces Bldg. 7852 Floors and Cell Faces Bldg. 3019 Hot Cell Interiors, Floors, and Cell Faces Graphite Reactor Biological Shield Exterior	Painted Concrete Fission Products, TRU Painted Concrete Fission Products, Cm-147, Pm-241, Am Painted Concrete Cs-137, Sr-90, Co-60, Ir-192 Painted Concrete 43 Beta, Gamma Emitters Painted Concrete Gd-153, Am-241 Painted Concrete P-32, Am-241 Painted Concrete H-3, Kr-85 Painted Concrete Cs-137, Sr-90 Painted Concrete Cs-137, Sr-90, Co-60 Painted Concrete U, Th, Coolant Salt Painted Concrete U, Th, Molten Salt Painted Concrete Sr-90, Cs-137, Co-60, I-129 Painted Concrete Fission Products, TRU Painted Concrete Fission Products Painted Concrete Fission Products Painted Concrete Cs, Sr, Co, Cm, Eu, Am, Pu Painted Concrete Fission Products, Corrosion Products, Cs, Sr, TRU, Co, Cm, Eu, Am, Pu Painted Concrete U-233, Pu-239, Fission Products Painted Concrete Fission Products, Pu, C-14, Fe-55, Cs-137, Sr-90, Co-60, Activation Products	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Therm Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>ial Surface val Methods</p> <p>H</p> <p>M</p> <p>M</p> <p>H</p>	<p>Plasma Torch DCON-72-OL</p> <p>Ranking:* H-4-1 (0.5; \$1/ft²)</p>	<p>Evolving Technology Conceptual Plasma torches exist commercially to weld and cut materials that have very high melting temperatures or require an inert atmosphere. Efficacy: Its efficacy in removing various organic contaminants or to spall off layers of contaminated concrete has not been investigated. Waste: Wastes would consist of materials used to trap reaction products from the decomposition of organics and spalled concrete with contaminants.</p>	<p>Science: Laboratory tests are needed to evaluate the efficacy of vaporizing or decomposing organics, determine the decomposition reaction by-products, and suitable for trapping materials. Laboratory tests of thermal stress-induced spalling of concrete are also needed. Computer modeling of plasma-surface interactions and heat transfer in concrete are needed. Development: Plasma torches having geometries and conditions suitable for decontamination need to be developed along with suitable collection and gas treatment systems. Available at Y-12.</p>	<p>A collection system for the vaporized materials would be needed to implement this technology. Development cost: ~\$500K Capital Costs: ~\$100K Operating Costs: \$1.00/ft²</p>
	<p>Laser Heating DCON-73-OL</p> <p>Ranking:* M-4-4 (3; \$1/ft²)</p>	<p>Demonstration Currently being used to remove organic coatings from metal surfaces. Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft²/hr. Effectiveness on contaminants and substrates of interest is uncertain. Waste: Waste will be prefilters and HEPA filters filled with contaminants.</p>	<p>Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.</p>	<p>A collection system for the vaporized contaminants would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$500K- \$1M+/machine Operating Cost: ~\$1/ft²</p>
	<p>Laser Etching and Ablation DCON-74-OL</p> <p>Ranking:* M-4-4 (3.5; >\$1/ft²)</p>	<p>Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.</p>	<p>Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$0.5- 1M+/machine Operating Cost: >\$1/ft²</p>
	<p>Flashlamp Cleaning DCON-77-OL</p> <p>Ranking:* H-3-3 (2.5; \$1/ft²)</p>	<p>Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.</p>	<p>Development: Commercially available flashlamp systems need to be evaluated for deposit removal.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: ~\$2.5 M Capital cost: \$50- 100K/machine Operating Cost: ~1.00/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Subelements	Reference Requirements	Problem Areas/Constituents	ORNL Problems	EM Goals
-------------	------------------------	----------------------------	---------------	----------

Refer to Vol. 1, P.1A
Chap. 7, for potentially
applicable proposed and
promulgated environmental
laws, signed and pending
agreements for ORR; radiation
protection standards, DOE
Orders, and nonregulatory
guidance. As site- and waste-
specific characteristics are
provided for each technology,
specific regulatory
requirements will be specified.

Painted Concrete
Fission Products, TRU
Painted Concrete
Fission Products, Cm-147,
Pm-241, Am
Painted Concrete
Cell Faces
Bldg. 3028 Hot Cell
Interiors, Floors, Cell Faces
Bldg. 3029 Cell Faces
Bldg. 3030 Floors and
Cell Faces
Bldg. 3031 Floors
and Cell Faces
Bldg. 3032 Floors
and Cell Faces
Bldg. 3033 Cell Faces
Bldg. 3036 Floors
Bldg. 3517 High Bay
Floors & Cell Faces
Bldg. 9201-3 Coolant
Salt Cell
Bldg. 9201-3
Molten Salt Cell
Bldg. 3038 Cell Floor
& Surfaces
Bldg. 3505 Floors and
Cell Faces
Bldg. 3506 Hot Cell
Interiors
Bldg. 3515 Floors and
Cell Faces
Bldg. 3047 Floors and
Cell Faces
Bldg. 7852 Floors and
Cell Faces
Bldg. 3019 Hot Cell Interiors,
Floors, and Cell Faces
Graphite Reactor Biological
Shield Exterior
Painted Concrete
Fission Products, Pu, C-14,
Fe-55, Cs-137, Sr-90,
Co-60, Activation Products
Painted Concrete
Fission Products, TRU,
Co, Cm, Eu, Am, Pu
Products, Cs, Sr, TRU,
Fission Products, Comosion
Painted Concrete
Cs, Sr, Co, Cm, Eu, Am, Pu
Painted Concrete
Fission Products
Painted Concrete
Fission Products
Painted Concrete
Fission Products, TRU
Painted Concrete
Sr-90, Cs-137, Co-60, I-129
Painted Concrete
U, Th, Molten Salt
Painted Concrete
U, Th, Coolant Salt
Painted Concrete
Cs-137, Sr-90, Co-60
Painted Concrete
Cs-137, Sr-90
Painted Concrete
H-3, Kr-85
Painted Concrete
P-32, Am-241
Painted Concrete
Gd-153, Am-241
Painted Concrete
43 Beta, Gamma Emitters
Painted Concrete
Cs-137, Sr-90, Co-60, Ir-192
Painted Concrete
Pm-241, Am

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods	<p>H</p> <p>Compressed-Air Cryogenic CO₂ Pellet Blasting DCON-51-OL</p> <p>Ranking: * H-4-1 (0.7; >\$1/ft²)</p>	<p>Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.</p>	<p>Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants plus oxygen depletion precautions. Development cost: about \$0.50M Capital cost: About \$200,000 Operating Cost: >\$1/ft²</p>
Chemical Surface Cleaning Methods	<p>H</p> <p>Fluoboric Acid Treatment DCON-11-OL</p> <p>Ranking: * H-4-2 (2; N)</p>	<p>Demonstration Technology was designed specifically for D&D. Efficacy: Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF). Fluoboric (or fluosilicic) acid can scabble and clean cement and brickwork. If contaminated to a depth of only a few mm, concrete flooring and structures can be returned to unrestricted use.</p>	<p>Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.</p>	<p>Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital cost: \$774K (1990 plant cost for decontaminating 5 tons/day of steel, excluding development, planning, and buildings.) Operating Cost: Relatively low; this is a very simple process.</p>
	<p>M</p> <p>Chelation Treatment DCON-21-OL</p> <p>Ranking: * M-4-2 (1.5; <\$1/ft²)</p>	<p>Demonstration The technology has been employed at various facility operations and nuclear power plant sites. Efficacy: Excellent DFs achieving acceptable decontamination levels resulting in unconditional release. Easy to apply in-situ as agent acts at neutral pH and are non-hazardous, non-fuming, have no gas evolution and are biodegradable. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none">• Clean Up Legacy Waste• Prevent Future Insult• Develop Environmental Stewardship	<ul style="list-style-type: none">• ORR Hot Cell Liners• Bldg. 3028 Hot Cell Liners• Bldg. 3029 Hot Cell Liners• Bldg. 3030 Hot Cell Liners• Bldg. 3031 Hot Cell Liners• Bldg. 3032 Hot Cell Liners• Bldg. 3033 Process Piping• Membrane Between HRT Concrete• Bldg. 3029 Cell 2 Wall• Bldg. 7500 High Bay Area• MSRE Exterior Siding• ORR Building Siding• Bldg. 3028E Charging Area• Bldg. 3029 Exterior Walls• Bldg. 3030 Siding/Interior Walls• Bldg. 3031 Siding/Interior Walls• Bldg. 3032 Siding/Interior Walls• Bldg. 3033 Siding/Interior Walls• Bldg. 3036 Siding/Interior Walls• MSRE Bldg. Structure• ORR Steel Bldg. Structure• Bldg. 3028E Steel Structure• Bldg. 3029 Structure• Bldg. 3030 Steel Bldg. Structure• Bldg. 3517 Hot Cell Liners• Bldg. 3038 Glove Boxes• Bldg. 3038 Glove Boxes & Cell Interior• Bldg. 3517 Interior/Exterior Walls• Bldg. 9201-3-3 Walls & Upper Floors Molten Salt Cells• Bldg. 9201-3 Walls & Roof Coolant Salt Cells• Bldg. 3031 Structure• Bldg. 3032 Structure• Bldg. 9419-1 Handrail• MSRE Piping• ORR Primary Coolant Piping• Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3• HRT Process Piping• MSRE Off-Gas System• ORR Demineralizer Piping (Outside Pool)• Graphite Reactor Process Piping	<ul style="list-style-type: none">• Stainless Steel Fission Products, Corrosion Products• Stainless Steel Fission Products, Cm-147, Pm-241, Am• Stainless Steel Cs-137, Sr-90, Co-60, Ir-192• Stainless Steel 43 Beta, Gamma Emitters• Stainless Steel Gd-153, Am-241• Stainless Steel P-32, Am-241• Stainless Steel H-3, Kr-85• Steel Plate Fission Products, Corrosion Products• Steel Plate Cs-137, Sr-90, Co-60, Ir-192• Sheet Steel Cs, Sr, TRU, Co-60• Sheet Steel Cs, Sr, TRU, Co-60• Sheet Steel Fission Products• Sheet Steel Fission Products, TRU• Sheet Steel Cs-137, Sr-90, Co-60, Ir-192• Sheet Steel 43 Beta, Gamma Emitters• Sheet Steel Gd-153, Am-241• Sheet Steel P-32, Am-241• Sheet Steel H-3, Kr-85• Sheet Steel Cs-137, Sr-90• Structural Steel Cs, Sr, TRU, Co-60• Structural Steel Fission Products• Structural Steel Fission Products, TRU• Structural Steel Cs-137, Sr-90, Co-60, Ir-92• Structural Steel 43 Beta, Gamma Emitters• Stainless Steel Cs-137, Sr-90, Co-60• Stainless Steel Pu-238, Am-241, Cm-244• Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I• Stainless Steel Cs-137, Sr-90, Co-60• Sheet Steel U, Th, Molten Salt• Sheet Steel U, Th, Coolant Salt• Structural Steel Gd-153, Am-241• Structural Steel P-32, Am-241• Painted Steel Pipe Exterior U, Th, Molten Salt• INOR-8 Pipe Exterior U, Be, LiF, TiF₃• Al Piping Exterior Fission Products, Corrosion Products• Cu Tubing Exterior U, Th, H-3, Molten Salt• Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products• Stainless Steel Pipe Exterior Fission Products, Corrosion Products• Stainless Steel Pipe Exterior Fission Products, Corrosion Products• Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	<ul style="list-style-type: none">• Refer to the Vol. 1, P.L.A. Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	<ul style="list-style-type: none">• Decontamination	<ul style="list-style-type: none">• Mech Rem

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Ultrahigh-Pressure Water DCON-35-OL</p> <p>Ranking:* H-5-1 (1.7M; \$1/ft²)</p>	<p>Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused into the metal. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft² cleaned that contains ~0.01 ft³ metal residue, plus the contaminants removed.</p>	<p>Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Improvement: Automation, especially for walls and ceilings.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$1.3M Capital cost: ~\$500K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Shot Blasting DCON-36-OL</p> <p>Ranking:* H-3-0 (<0.1M; \$1/ft²)</p>	<p>Accepted Commercial iron shot blasters are in use at the K-25 site. Efficacy: They are generally effective but leave some hot spots. Waste: Waste would be spent shot, abraded substrate, and removed contaminants in filters and HEPA filters.</p>	<p>Improvement: Automation, especially for walls and ceilings.</p>	<p>A collection system with adequate filtration Development cost: None Capital cost: ~\$50K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Grit Blasting DCON-38-OL</p> <p>Ranking:* H-4-0 (<0.1\$5/ft²)</p>	<p>Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste would be spent grit, abraded substrate, and removed contaminants in filters and HEPA filters.</p>	<p>Improvement: automation, especially for walls and ceilings. Better vacuum system demonstration.</p>	<p>A collection system with adequate filtration Development cost: None Capital cost: ~\$50K Operating cost: ~\$-5/ft²</p>
	<p>H</p> <p>Centrifuge Cryogenic CO₂ Pellet Blasting DCON-39-OL</p> <p>Ranking:* H-5-2 (1.0M; <\$1/ft²)</p>	<p>Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently, as an aircraft repaint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.</p>	<p>Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Improvement: 1) Demonstration of an on line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen-depletion precautions. Development cost: <\$1M Capital cost: \$100K Operating cost: <\$1/ft²</p>
	<p>H</p> <p>Ice Blasting DCON-40-OL</p> <p>Ranking:* H-5-1 (<1.0M; \$1/ft²)</p>	<p>Demonstration Efficacy: Efficacy of commercial system for this application needs demonstration. Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.</p>	<p>Development: Demonstration of efficacy of commercial system. Improvement: Automation/robotics, especially for walls, corners, etc.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$250K Capital cost: \$100K-\$1M Operating cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
ORNL Hot Cell Liners	Stainless Steel Fission Products, Corrosion Products	Refer to the Vol. 1, PTA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORNL radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste- specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
Bldg. 3028 Hot Cell Liners	Stainless Steel Fission Products, Cm-147, Pm-241, Am		
Bldg. 3029 Hot Cell Liners	Stainless Steel Cs-137, Sr-90, Co-60, Ir-192		
Bldg. 3030 Hot Cell Liners	Stainless Steel 43 Beta, Gamma Emitters		
Bldg. 3031 Hot Cell Liners	Stainless Steel Cd-153, Am-241		
Bldg. 3032 Hot Cell Liners	Stainless Steel P-32, Am-241		
Bldg. 3033 Process Piping	Stainless Steel H-3, Ir-85		
Membrane Between HRT Concrete	Steel Plate Fission Products, Corrosion Products		
Bldg. 3029, Cell 2 Wall	Steel Plate Cs-137, Sr-90, Co-60, Ir-192		
Bldg. 7500 High Bay Area	Steel Plate Cs, Sr, THU, Co-60		
MSRE Exterior Siding	Steel Plate Cs, Sr, THU, Co-60		
ORNL Building Siding	Steel Plate Fission Products		
Bldg. 3028E Charing Area	Steel Plate Fission Products, TRU		
Bldg. 3029 Exterior Walls	Steel Plate Cs-137, Sr-90, Co-60, Ir-192		
Bldg. 3030 Siding/Inletor Walls	Steel Plate 43 Beta, Gamma Emitters		
Bldg. 3031 Siding/Inletor Walls	Steel Plate Cd-153, Am-241		
Bldg. 3032 Siding/Inletor Walls	Steel Plate P-32, Am-241		
Bldg. 3033 Siding/Inletor Walls	Steel Plate H-3, Ir-85		
Bldg. 3036 Siding/Inletor Walls	Steel Plate Cs-137, Sr-90		
MSRE Bldg. Structure	Structural Steel Cs, Sr, THU, Co-60		
ORNL Steel Bldg. Structure	Structural Steel Fission Products		
Bldg. 3028E Steel Structure	Structural Steel Fission Products, TRU		
Bldg. 3029 Structure	Structural Steel Cs-137, Sr-90, Co-60, Ir-92		
Bldg. 3030 Steel Bldg. Structure	Structural Steel 43 Beta, Gamma Emitters		
Bldg. 3517 Hot Cell Liners	Stainless Steel Cs-137, Sr-90, Co-60		
Bldg. 3038 Glove Boxes	Stainless Steel Pu-238, Am-241, Cm-244		
Bldg. 3038 Glove Boxes & Cell Interior	Co. I Pu, Cf, Cm, Np, Pa, U, Sr, Cs,		
Bldg. 3517 Inletor/Extensor Walls	Stainless Steel Cs-137, Sr-90, Co-60		
Bldg. 9201-3 Walls & Upper Floors Inletor Siding Cells	Sheet Steel U, Th, Molten Salt		
Bldg. 9201-3 Walls & Roof	Sheet Steel U, Th, Molten Salt		
Bldg. 9201-3 Walls & Roof	Sheet Steel U, Th, Molten Salt		
Bldg. 3031 Structure	Structural Steel Cd-153, Am-241		
Bldg. 3032 Structure	Structural Steel P-32, Am-241		
Bldg. 9419-1 Handrail	Painted Steel Pipe Extensor U, Th, Molten Salt		
MSRE Piping	Al Piping Extensor U, Be, Li, H ₂		
ORNL Primary Coolant Piping	Al Piping Extensor Fission Products, Corrosion Products		
Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3	Cu Tubing Extensor Stainless Steel Pipe Extensor U, Th, H-3, Molten Salt		
HRT Process Piping	Stainless Steel Pipe Extensor Fission Products, Corrosion Products		
MSRE Off-Gas System	Stainless Steel Pipe Extensor Fission Products, Corrosion Products		
ORNL Demineralizer Piping (Outside Pool)	Stainless Steel Pipe Extensor Fission Products, Corrosion Products		
Graphite Reactor Process Piping	Stainless Steel Pipe Extensor Fission Products, Co-14, Fe-55, Cs-137, Pu, Sr-90, Co-60		

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Supercritical CO₂ Blasting DCON-41-OL</p> <p>Ranking:* H-5-1 (0.75+M; >\$1/ft²)</p>	<p>Predemonstration</p> <p>Efficacy: Likely to be effective with nearly infinite decontamination factors.</p> <p>Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.</p>	<p>Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: \$250K-1M</p> <p>Capital cost: ~\$500K</p> <p>Operating cost: ~\$2/ft²</p>
	<p>M</p> <p>Plastic Pellet Blasting DCON-42-OL</p> <p>Ranking:* M-4-0 (<0.1M; \$1/ft²)</p>	<p>Accepted</p> <p>Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate.</p> <p>Efficacy: Technology should remove smearable, but not fixed contamination.</p> <p>Waste: Waste would be spent plastic pellets plus removed contamination.</p>	<p>Improvement: Develop and demonstrate system for processing waste.</p> <p>Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>A system for processing waste to an acceptable form is needed.</p> <p>Development cost: (improvements) \$5.5M+</p> <p>Capital cost: ~\$50K</p> <p>Operating cost: \$0.20-\$2.15/ft²</p>
	<p>H</p> <p>Hand Grinding, Honing, Scraping DCON-43-OL</p> <p>Ranking:* H-2-0 (<<0.1M; \$1/ft²)</p>	<p>Accepted</p> <p>Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>None</p> <p>Available at X-10, K-25.</p>	<p>A collection system for the vaporized contaminants would be needed to implement this technology.</p> <p>Development cost: None</p> <p>Capital cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation)</p> <p>Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Automated Grinding DCON-44-OL</p> <p>Ranking:* H-2-1 (\$1M; \$1M; N)</p>	<p>Conceptual</p> <p>Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the metal.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development:</p> <p>The applicability of this technology to items with rad contamination should be demonstrated.</p>	<p>A collection system for the vaporized contaminants would be needed to implement this technology.</p> <p>Development cost: \$600K</p> <p>Capital cost: \$250-500K</p>
	<p>M</p> <p>Metal Milling DCON-45-OL</p> <p>Ranking:* M-2-1 (\$0.15M; \$17.50/ft²)</p>	<p>Accepted</p> <p>Efficacy: Milling has been used to decontaminate metal items.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Improvement:</p> <p>The technology to operate this equipment remotely needs to be developed and demonstrated.</p> <p>Available at K-25.</p>	<p>The contaminated equipment must be removed and disassembled before this technology can be used.</p> <p>Capital cost: ~\$150K</p> <p>Operating cost: ~\$17.50/ft²</p> <p>Development cost: \$3M for remote operation.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3:3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, PEA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Therm Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Metal Surface Removal Methods	H Plasma Torch DCON-72-OL Ranking:* H-4-1 (0.5M,\$1/ft ²)	Evolving Technology Conceptual Plasma torches exist commercially to weld and cut materials that have very high melting temperatures or require an inert atmosphere. Efficacy: Its efficacy in removing various organic contaminants or to remove layers of contaminated metal has not been investigated. Waste: Wastes would consist of materials used to trap reaction products from the decomposition of organics, vaporized substrate, and removed contaminants.	Science: Laboratory tests are needed to evaluate the efficacy of vaporizing or decomposing organics, determine the decomposition reaction by-products, and suitable trapping materials. Computer modeling of plasma-surface interactions and heat transfer are needed. Development: Plasma torches having geometries and conditions suitable for decontamination need to be developed along with suitable collection and gas treatment systems. Available at Y-12.	A collection system for the vaporized deposits would be needed to implement this technology. Development costs: ~\$500K Capital costs: ~\$100K Operating costs: \$0.01-\$1.00/ft ²
	M Laser Heating DCON-73-OL Ranking:* M-4-4 (3M,\$1/ft ²)	Demonstration Currently being used to remove organic coatings from metal surfaces. Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft ² /hr. Effectiveness on contaminants and substrates of interest is uncertain. Waste: Waste will be prefillers and HEPA filters filled with contaminants.	Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.	A collection system for the vaporized deposits would be needed to implement this technology. An electric power supply would be needed. Development cost: \$2M+ Capital cost: \$500K-\$1M/machine Operating cost: ~\$1/ft ²
	M Laser Etching and Ablation DCON-74-OL Ranking:* M-4-4 (3.5M,>\$1/ft ²)	Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.	Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.	A collection system for the vaporized deposits would be needed to implement this technology. Development costs: \$2M+ Capital cost: \$0.5-1M/machine Operating cost: >\$1/ft ²
	H Plasma Surface Cleaning DCON-75-OL Ranking:* H-4-2 (1.0M,>\$1/ft ²)	Predemonstration Plasma surface cleaning by glow discharges are commonly and effectively utilized for cleaning high bonding energy contaminants from surfaces of metals prior to the operation of fusion devices. Efficacy: Technology is expected to be effective for removing deposits from listed substrates, but whether the plasma can follow the irregular shapes involved is uncertain. Waste: Wastes would be the vaporized deposits plus filters and HEPA filters from the collection system.	Science: Data on cleaning rates for contaminants and substrates of interest are needed. Development: The capability of plasma generation and cleaning on complex internal surfaces of contaminated equipment with large surface areas needs to be established. Available at Y-12.	A collection system with appropriate filters for the vaporized deposits would be needed to use this technology. An electric power supply would be needed. Development cost: About \$2M+ Capital cost: \$0.5-1M/machine Operating cost: >\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3/3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, P.L.A. Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 				
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Ground Water and Surface Water 				
<ul style="list-style-type: none"> • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Thermal Surface Removal Methods	Flashlamp Cleaning DCON-77-OL <i>Ranking:*</i>	Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed contaminants some substrate material, and HEPA filters from the filtration system.	Development: Commercially available flashlamp systems need to be evaluated for deposit removal.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: ~\$2.5 M Capital cost: \$50-100K/machine Operating cost: ~1.00/ft ²
Surface Cleaning Methods	Compressed-Air Cryogenic CO ₂ Pellet Blasting DCON-51-OL <i>Ranking:*</i> H-4-1 (0.7M, >\$1/ft ²)	Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.	Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants plus oxygen depletion precautions. Development Costs: about \$0.50M Capital cost: About \$200,000 Operating cost: >\$1/ft ²
	High-Pressure Water DCON-52-OL <i>Ranking:*</i> M-3-1 (1.3M, <\$1/ft ²)	Accepted High pressure water blasting has been used very successfully to decontaminate various large and complex surfaces at nuclear power plants. Efficacy: Technique is expected to be effective with a DF of about 50 for loosely adhering contamination on concrete. DFs will be higher if chemical cleaning agents are also used. Technique is expected to be ineffective for fixed contamination. Waste: Waste is 4 to >100 gpm of contaminated waste water.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the high pressure water and vacuum collection systems to robotic system control.	A water treatment system is needed to minimize waste. Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating cost: <\$1.00/ft ²
	Superheated Water DCON-53-OL <i>Ranking:*</i> M-4-1 (1.4M, \$1/ft ²)	Accepted Technology is available and has been used by industry. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has penetrated into the substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.	A water treatment system is needed to minimize waste. Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: About \$175K (about \$250K with remote operation) Operating cost: ~\$1.00/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3-3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Surface
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods	M Water Flushing DCON-54-OL Ranking:* M-4-1 (1.3M; <\$1/ft ²)	Accepted Flushing with hot water is often used following scrubbing. Efficacy: The technique is not effective on fixed insoluble contamination. Waste: The waste generated is the contaminated water from the flushing operation.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the hot water cleaning operation.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: About \$1.2M Capital cost: <\$5K Operating cost: <\$1/ft ²
	M Steam Cleaning DCON-55-OL Ranking:* M-4-1 (1.3M; \$1/ft ²)	Accepted The technique has proven useful, especially on complex shapes and large surfaces. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has penetrated into the metal. On finished concrete, technology may drive contaminants deeper into substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement - To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Remote operation will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating cost: \$0.03-\$1.00/ft ²
	H Hand Brushing Used to Remove Surface Contamination DCON-56-OL Ranking:* H-2-0 (0M; \$1/ft ²)	Accepted Brushing is a common decontamination technique. Efficacy: Brushing is effective for loose contamination only. Waste: Waste consists of removed contamination plus other loose debris.	None Available at K-25.	Vacuum collection system. Capital cost: negligible Operating cost: \$1.00/ft ² Development cost: none
	M Automated Brushing DCON-57-OL Ranking:* M-3-2 (1M; \$300/ft)	Demonstration This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.	Development: Tests to demonstrate that this technology is effective for the problems at ORNL.	Vacuum collection system. Development costs: \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe
	M Sponge Blasting DCON-58-OL Ranking:* M-3-1 (1.3M; \$2/ft ²)	Accepted Although the technology is relatively new, it is currently being used by at least two sites including a nuclear power plant. Efficacy: Extensive data on decontamination factors are not available. With the aggressive sponges, which are impregnated with abrasives, this technology may be effective for the listed contaminants and substrates. Waste: Wastes consist of about 0.01 ft ³ of blasting media and removed contaminants per ft ² of area decontaminated plus any liquid cleaning agents that may have been added.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the sponge blasting operation.	A wastewater treatment / recycle system will be needed to use this technology. Development cost: About \$1.2M Capital cost: Sponge blasting system: About \$20K (with sifter system) Operating cost: About \$2/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029; Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3-3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods	<p>Solvent Washing to Remove Radiological Contamination DCON-61-OL</p> <p><i>Ranking:*</i></p>	<p>Conceptual Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.</p>	<p>Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available in Private Sector.</p>	<p>Vapor collection system Capital cost: \$300K (1980 dollars) Development cost: <\$1M to identify and demonstrate the replacement solvent. Operating cost: an average of 7.5 minutes per item was required when decontaminating small items.</p>
H	<p>Solvent Washing to Remove Organics DCON-62-OL</p> <p><i>Ranking:*</i> H-2-2 (?M;N)</p>	<p>Conceptual Solvent degreasing was used successfully, but its use was stopped to avoid exposing the workers and the environment to the hazardous solvents. This equipment is produced by a number of manufacturers and its use for removing organic surface contamination is common in a variety of industries. Efficacy: The technique is effective for most organics. Waste: Waste would be spent solvent containing removed contamination.</p>	<p>Science: Solvents that are less damaging to the environment need to be identified and demonstrated.</p>	<p>Capital cost: \$400K (1992 dollars) for a 4,000-lb capacity unit. Labor cost: One operator for one hour to load, clean, and unload 4,000 lb of metal.</p>
M	<p>Strippable Coatings DCON-63-OL</p> <p><i>Ranking:*</i> M-3-0 (<0.1M;>\$1/ft²)</p>	<p>Accepted Technology has been used for decontamination applications involving hazardous and radioactive contaminants. Efficacy: Decontamination factors of one to several hundred can be expected with two applications. Waste: Waste is a solid polymer (volume = 1 mm x surface area decontaminated) containing the removed contaminants.</p>	<p>Improvement: Develop coatings with lower material costs and greater ease of application.</p>	<p>Normal implementation needs. Capital cost: Negligible Operating cost: \$1-\$1.40/ft²</p>
M	<p>Vacuum (Low Pressure) DCON-64-OL</p> <p><i>Ranking:*</i> M-4-0 (<0.1M;\$1/ft²)</p>	<p>Accepted Vacuum cleaners have long been used to clean up loose contamination. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective. Waste: the waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.</p>	<p>None</p>	<p>Normal implementation needs. Capital cost: <\$10K Operating cost: >\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3-3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Surface Metal
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Cleaning Methods</p> <p>M</p>	<p>Ultrasonic Cleaning DCON-65-OL</p> <p>Ranking:* M-2-1 (0.1M; >\$2/ft²)</p>	<p>Accepted Ultrasonic cleaning has been used for many years in the private sector and in government installations for removing surface contamination from relatively small metal parts which can fit into an ultrasonic bath. Efficacy: Technology will work well for loosely bound surface deposits, but not for tightly bound materials. Waste: Wastes would be spent ultrasonic bath solutions containing any removed contaminants; these may be mixed wastes that are difficult to manage.</p>	<p>Improvement: Definition of acceptable cleaning liquids which (1) are not hazardous, (2) can be separated from the contaminants, and (3) can be reused to minimize secondary wastes. Improvement: More aggressive cleaning action.</p>	<p>Requires removal, disassembly, and size reduction of contaminated equipment. Development cost: (Improvements) \$1M Capital cost: \$10K-\$100K Operating cost: \$2 - \$10/ft² or more.</p>
<p>Refining Methods</p> <p>H</p>	<p>Smelt Purification DCON-31-OL</p> <p>Ranking:* H-3-3 (100M; \$1/lb)</p>	<p>Demonstration Smelt purification of radioactive metals has been performed by a large number of investigators on a lab-scale and by some investigators on a large scale. The metals include mild steel, stainless steel, nickel, copper, monel, aluminum, and others. Efficacy: Metal purification has been demonstrated except for aluminum. U is removed to 0.01-4ppm. Tc is not removed. Waste: Waste are slags, scrubber solutions, chemical trap materials, and HEPA filters.</p>	<p>Development: Attempt to demonstrate fluxing agent for removing radionuclides of interest. If possible, demonstrate removal of radionuclides of interest on a larger scale.</p>	<p>Scientific Ecology Group (SEG) personnel estimate the costs of metal smelting at roughly \$0.93/lb of metal in 1992 dollars, depending on the type metal and configuration of the metal. Kellogg et al. estimated that the capital and operating costs of smelting the 90,000 tons of DOE scrap metal presently on hand at K-25 could be recovered through sale of the metal if a <i>de minimis</i> were established. The quantity of metals at ORNL is probably not sufficient to be cost effective unless added to this. The technology development needs will require further lab and pilot-scale evaluation. The development costs are roughly estimated at \$3M - \$5M.</p>
	<p>Electrorefining DCON-32-OL</p> <p>Ranking:*</p>	<p>Predemonstration Electrorefining is a well-established commercial technology. However, this technology cannot be considered mature concerning its use for decontaminating radioactive metal because this application is much less established. Efficacy: Technology is likely to be effective for the listed contaminants and substrates. Waste: Waste would be solid mixed waste from assumed treatment of electrolyte solutions for recycle.</p>	<p>Development: Demonstrate (1) separation for radionuclides and substrates of interest and (2) recycle electrolyte solutions.</p>	<p>An electrorefining plant would also require a smelting and anode forming facility to form the impure metal into anodes of proper configuration. The capital costs altogether are estimated at \$200M. The cost of an operating facility with a 10 million-pound/year capacity is estimated at \$2M capital and \$6/lb operating costs, which exceed the present value of virtually any metal because commercial companies operate on a much larger scale. Development costs are estimated at \$3M. To allow sale of the purified metal, either a <i>de minimis</i> level must be established in the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> level exists.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3:3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems				
<ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Metal Refining Methods M	Leach/Electrowinning DCON-34-OL <i>Ranking:*</i> M-2-5 (200M;\$3.80/lb)	Predemonstration Leach/Electrowinning is a well-established commercial method for producing nickel from nickel ore, but is not used commercially to refine impure nickel metal. Efficacy: Scientific Ecology Group, Inc. (SEG), has purified nickel to ≥ 1 Bq/g of Tc on a small scale. The Tc must be removed from the electrolytic solutions by ion exchange or some other method. The method has not been evaluated for treatment of metals other than nickel. At ORNL, nickel was not used extensively. Waste: Recycle of electrolytic solutions will result in a solid mixed waste bearing the contaminants and traces of the purified metal amounting to roughly 2% by weight of the metal purified.	Development: Pilot-scale testing of this method is needed with special attention to the leaching process, decontamination efficiency, and recycle of the electrolytic solutions. The development work by SEG may satisfy some of this requirement.	A leach/electrowinning plant would require a size-reduction facility, a leaching facility, and a tankhouse for the electrolytic cells. The costs of an operating facility with a 10-million-pound-per-year capacity are estimated by INCO at \$200M capital and \$3.80/lb operating costs. The operating costs exceed the present value of most all metals because commercial nickel companies operate on a much larger scale. The development costs are estimated by INCO at \$440K if the work were done at their facilities. To allow sale of the resulting purified metal, either a <i>de minimis</i> must be established for the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> standard exists.
Chemical Surface Cleaning Methods M	Chemical Foams DCON-8-OL <i>Ranking:*</i> M-4-1 (3M;\$0.50-\$2/ft ²)	Demonstration Widely used throughout the nuclear industry. Foam is used as a carrier of chemical decontamination agents; not as the agent itself. It can be sprayed on and wiped, rinsed, or vacuumed off. Efficacy: Effectiveness for listed contaminants and substrates has not been demonstrated. Waste: Small amount of contaminated sulfonated detergents, synthetic wetting agents, coupling agents, rinse water, and drying cloth.	Development: Scale-up/development of the process to a size appropriate for ORNL use. The technology itself is inexpensive, but development and scale-up will probably require support. Improvement: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.	These estimated costs are: Development cost: \$1M-\$4M; Capital cost: \$50K Operating cost: \$0.50-\$2/ft ²
M	Chemical Gels DCON-9-OL <i>Ranking:*</i> M-4-2 (3M;N)	Demonstration The use of chemical gels is most suited to in situ decontamination of large surfaces. Gel is used as a carrier of chemical decontamination agents; not as the agent itself. It is sprayed on component walls; allowed to work; and then scrubbed, wiped, rinsed, or peeled off. Steps include scraping and vacuuming of solid waste material, preliminary hot water rinsing, and gel spraying throughout the cell. Efficacy: Expected to be effective only for smearable contamination. Waste: Wastes would be carboxymethylcellulose gelling agent, aluminum nitrate chelating agent, wash water, acidic chemical agent (possibly nitric-hydrofluoric-oxalic acid), and the removed contaminants. Wastes are reportedly 4-5 times less compared to chemical solutions.	Development: Complex gel formulation with a number of compounds may be required, depending on the objectives. Laboratory optimization will be necessary, with any change in variables.	Normal implementation needs: Development cost: \$1M-\$4M Capital cost: ~\$50K Operating cost: \$0.50-\$2.00/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-33 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-3 Pipe Exterior U, Be, LiF, Hf Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, PLA Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR radiation protection standards; DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Chem Meth
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 					
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Ground Water and Surface Water 					
<ul style="list-style-type: none"> • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning ds	Organic Acid Treatments DCON-10-OL <i>Ranking:*</i> H-4-2 (2M;N)	Demonstration The technology is currently in use by BNFL at Capenhurst gaseous diffusion plant. BNFL uses citric and sulfuric acids in sequence for removal of U and Tc, respectively, from metal surfaces (mostly wrought aluminum). Efficacy: DF of 300 for U alpha and 40 for Tc beta are reported (11.1 Bq/g alpha, 0.04 Bq/g beta). Has not been demonstrated to remove other radionuclides. Waste: Wastes include citric and sulfuric acids containing uranium and other metal ions and ion exchange media containing the metals. Uranium is difficult to precipitate.	Development: Pilot plant development for waste treatments (ion exchange columns) to verify that we can meet our standards and regulations. More fundamental studies are needed in secondary waste disposal.	Purchase of technology, regulatory compliance for pilot-scale decontamination, and waste treatment demonstrations. BNFL's expertise may reduce the amount of original research, etc. necessary to begin implementation. Cost \$400K-\$1M. No present ORNL facility could be adapted for citric acid cleaning, but decontamination with BNFL's citric acid process should pose no undue difficulties. It may well be less costly to implement than the more familiar nitric acid process would be due to the relative nontoxicity and ease of treating secondary waste stream. Development cost: \$400K-\$1M (rough estimate) Capital cost: \$4M-\$10M if new equipment is required Operating cost: \$300/Mg (BNFL estimate)
	Fluoboric Acid Treatment DCON-11-OL <i>Ranking:*</i> H-4-2 (2M;N)	Demonstration Technology was designed specifically for D&D. Efficacy: Attacks nearly every metal surface and metallic oxide. Removes oxide and contaminated outer layer in controllable, uniform and efficient manner. High decontamination factor (DF); however, high corrosion.	Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.	Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital cost in 1990 to set up a plant for decontaminating 5 tons/day of steel was \$774K, excluding development, planning, and buildings. Operating cost will be relatively low; this is a very simple process.
	Inorganic Acid Treatments DCON-12-OL <i>Ranking:*</i> M-3-0 (4M;N)	Accepted Nitric acid decontamination has been the preferred method at ORNL for cleaning items in various facility operations since the 1940s. In addition, the technique has been widely used at K-25 and Portsmouth. Efficacy: DFs are in the 100 range. Waste: Wastes consist of large quantities of corrosive wastes containing the removed contaminants and require treatment and disposal as mixed waste.	Improvements: Adaptation of modifications to system (i.e., scrubbers, filters, treatment for nitrates and heavy metals) in order to meet regulatory requirements. Possible development of HNO ₃ /HF decontamination methods, with or without ultrasonic agitation. Continuing research and development, waste treatment, and volume reduction. Possible research and development in control of base metal dissolution. Available at X-10, K-25.	Nitrate treatment facility either on site or accessible to decontamination facility. Operating costs may be relatively high. Nitric acid decontamination was used extensively at most DOE plants, but data is not available regarding costs. Currently, Portsmouth plant is developing a data base to track costs, but it will not contain historical data. Development cost: (improvements) \$400K-1M (rough estimate) Capital cost: <\$4M-\$10M (rough estimate)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3.3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TIF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, P.L.A. Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR; radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning Methods	<p>M</p> <p>Detergent Treatments DCON-13-OL</p> <p>Ranking: M-4-0 (0M;>\$1/ft²)</p>	<p>Accepted Surface smearable decontamination with caustic chemicals (soap and water) is accepted technology and is used extensively at ORNL. The caustic hand-scrubbing process was applied to cleaning small items.</p> <p>Efficacy: Since many of the listed contaminants are expected to be fixed, caustic scrubbing is expected to only partially decontaminate the contaminated surfaces.</p> <p>Waste: Wastes would consist of used caustic solution containing the removed contaminants.</p>	<p>None for removal of smearable contamination with carbonates, soaps, etc.</p> <p>Available at X-10, K-25.</p>	<p>This is an established process that could be implemented at ORNL with no major changes.</p> <p>Capital cost: <\$10K</p> <p>Operating costs: >\$1/ft²</p>
	<p>M</p> <p>REDOX Treatments DCON-14-OL</p> <p>Ranking: M-4-1 (3M;<\$1/ft²)</p>	<p>Demonstration REDOX treatments have been demonstrated for nuclear power plant decontamination, but not for the contaminants of interest.</p> <p>Efficacy: DFs of 10-100 can be expected based on experience in nuclear power plants.</p> <p>Waste: With recycle, waste is spent ion exchange media containing removed contaminants. With neutralization and evaporation, waste is a solid mixed waste containing the removed contaminants and chemicals from the REDOX reagents.</p>	<p>Development: All REDOX techniques will require demonstration to determine their usefulness to decontamination of ORNL operations and applicability to various contaminant films.</p>	<p>A system for treating the REDOX reagents to permit recycling these reagents will be needed to use this technology.</p> <p>Development costs: \$1M to bring a REDOX decontamination development through bench-scale and demonstration phases.</p> <p>Capital cost: >\$1M</p> <p>Operating cost: <\$1/ft²</p>
	<p>L</p> <p>Biological DCON-3-OL</p> <p>Ranking: L-2-Unknown</p>	<p>Evolving Technology / Pre-conceptual The knowledge base exists for biological treatments of various contaminants; however, there is not a data base for application of the technology for surface decontamination.</p> <p>Efficacy: This technology is quite likely to be successful for oil and PCBs. It could be successful for other radionuclides, but these contaminants would remain in the bacterial sludge.</p> <p>Waste: The waste generated would be the contaminated layer of microbes removed from the treated surface.</p>	<p>Science: Literature study and bench-scale tests of microbes on contaminants of interest.</p> <p>Development - Develop methods for applying a layer of microbes, supplying needed nutrients, and removing the microbe layer from the decontaminated item.</p>	<p>Facilities for cultivating the bacteria and disposing of the bacterial sludge would be needed.</p> <p>Development cost: \$300K-\$600K</p> <p>Capital cost: ~\$200K</p> <p>Operating cost: ~\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	ORR Hot Cell Liners Bldg. 3028 Hot Cell Liners Bldg. 3029 Hot Cell Liners Bldg. 3030 Hot Cell Liners Bldg. 3031 Hot Cell Liners Bldg. 3032 Hot Cell Liners Bldg. 3033 Process Piping Membrane Between HRT Concrete Bldg. 3029, Cell 2 Wall Bldg. 7500 High Bay Area MSRE Exterior Siding ORR Building Siding Bldg. 3028E Charging Area Bldg. 3029 Exterior Walls Bldg. 3030 Siding/Interior Walls Bldg. 3031 Siding/Interior Walls Bldg. 3032 Siding/Interior Walls Bldg. 3033 Siding/Interior Walls Bldg. 3036 Siding/Interior Walls MSRE Bldg. Structure ORR Steel Bldg. Structure Bldg. 3028E Steel Structure Bldg. 3029 Structure Bldg. 3030 Steel Bldg. Structure Bldg. 3517 Hot Cell Liners Bldg. 3038 Glove Boxes Bldg. 3038 Glove Boxes & Cell Interior Bldg. 3517 Interior/Exterior Walls Bldg. 9201-3-3 Walls & Upper Floors Molten Salt Cells Bldg. 9201-3 Walls & Roof Coolant Salt Cells Bldg. 3031 Structure Bldg. 3032 Structure Bldg. 9419-1 Handrail MSRE Piping ORR Primary Coolant Piping Instrument & Air Lines in Coolant Salt Cell, Bldg. 9201-3 HRT Process Piping MSRE Off-Gas System ORR Demineralizer Piping (Outside Pool) Graphite Reactor Process Piping	Stainless Steel Fission Products, Corrosion Products Stainless Steel Fission Products, Cm-147, Pm-241, Am Stainless Steel Cs-137, Sr-90, Co-60, Ir-192 Stainless Steel 43 Beta, Gamma Emitters Stainless Steel Gd-153, Am-241 Stainless Steel P-32, Am-241 Stainless Steel H-3, Kr-85 Steel Plate Fission Products, Corrosion Products Steel Plate Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Cs, Sr, TRU, Co-60 Sheet Steel Fission Products Sheet Steel Fission Products, TRU Sheet Steel Cs-137, Sr-90, Co-60, Ir-192 Sheet Steel 43 Beta, Gamma Emitters Sheet Steel Gd-153, Am-241 Sheet Steel P-32, Am-241 Sheet Steel H-3, Kr-85 Sheet Steel Cs-137, Sr-90 Structural Steel Cs, Sr, TRU, Co-60 Structural Steel Fission Products Structural Steel Fission Products, TRU Structural Steel Cs-137, Sr-90, Co-60, Ir-92 Structural Steel 43 Beta, Gamma Emitters Stainless Steel Cs-137, Sr-90, Co-60 Stainless Steel Pu-238, Am-241, Cm-244 Stainless Steel Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I Stainless Steel Cs-137, Sr-90, Co-60 Sheet Steel U, Th, Molten Salt Sheet Steel U, Th, Coolant Salt Structural Steel Gd-153, Am-241 Structural Steel P-32, Am-241 Painted Steel Pipe Exterior U, Th, Molten Salt INOR-8 Pipe Exterior U, Be, LiF, TiF ₃ Al Piping Exterior Fission Products, Corrosion Products Cu Tubing Exterior U, Th, H-3, Molten Salt Stainless Steel Pipe Exterior Uranyl Sulfate, Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, Corrosion Products Stainless Steel Pipe Exterior Fission Products, C-14, Fe-55, Cs-137, Pu, Sr-90, Co-60	Refer to the Vol. 1, P.T.A. Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR; radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Chem Meth
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Chemical Surface Cleaning Methods</p> <p>M</p> <p>H</p>	<p>Chelation Treatment DCON-21-OL</p> <p>Ranking:* M-4-2 (1.5M; <\$1/ft²)</p>	<p>Demonstration The technology has been employed at various facility operations and nuclear power plant sites. Efficacy: Excellent DFs achieving acceptable decontamination levels resulting in unconditional release. Easy to apply in-situ as agent acts at neutral pH and are non-hazardous, non-fuming, have no gas evolution and are biodegradable. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating cost: <\$1/ft²</p>
	<p>Catalytic Extraction Process DCON-6-OL</p> <p>Ranking:* H-5-4 (20M; \$1/lb)</p>	<p>Predemonstration Has not been used to process scrap bearing radioactivity. However, the method is virtually the same as smelt purification when applied to metals. Efficacy: High reduction of U is expected. Removal effectiveness on fission products, etc., is not known. Waste: Wastes would be slag containing contaminants plus contaminants in scrubber solution or chemical trapping materials.</p>	<p>Science: Evaluate effectiveness on fission products, etc. Development: Demonstrate effectiveness of removal of fission products, etc.</p>	<p>"Off the shelf" induction or arc furnace. Development cost: \$3M - \$5M Capital cost: ~\$16 million Operating cost: \$1/lb.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems				
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Ultrahigh-Pressure Water DCON-35-OL</p> <p>Ranking:* H-5-1 (1.7M; \$1/ft²)</p>	<p>Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft² concrete cleaned that contains ~0.01 ft³ concrete residue, plus the contaminants removed.</p>	<p>Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Improvement: Automation, especially for walls and ceilings.</p>	<p>A water treatment/recycle system is needed to minimize liquid wastes from this technology. Development cost: \$1.3M Capital cost: ~\$500K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Shot Blasting DCON-36-OL</p> <p>Ranking:* H-3-0 (<0.1M; \$1/ft²)</p>	<p>Accepted Commercial iron shot blasters are in use at the K-25 site. Efficacy: They are generally effective but leave some hot spots. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants plus 0.05lb spent shot per ft² of concrete decontaminated.</p>	<p>Improvement: Automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Scabblers/Scarifiers DCON-37-OL</p> <p>Ranking:* H-4-2 (0.5M; \$5/ft²)</p>	<p>Accepted Mechanical scabblers are used for concrete decontamination at the K-25 Site and elsewhere. Efficacy: They are generally effective, but leave some hot spots. Waste: Waste is ~0.01 ft³ removed substrate (1/16" cut) containing removed contaminants per ft² of substrate decontaminated.</p>	<p>Improvement: Automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating cost: ~\$5/ft²</p>
	<p>H</p> <p>Grit Blasting DCON-38-OL</p> <p>Ranking:* H-4-0 (<0.1M; \$5/ft²)</p>	<p>Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants per ft² of concrete decontaminated plus spent grit.</p>	<p>Improvement: automation, especially for walls and ceilings.</p>	<p>Normal implementation needs. Development cost: none Capital cost: ~\$500K Operating cost: ~\$5/ft²</p>
	<p>H</p> <p>Centrifuge Cryogenic CO₂ Pellet Blasting DCON-39-OL</p> <p>Ranking:* H-5-2 (1.0M; <\$1/ft²)</p>	<p>Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft depaint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.</p>	<p>Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants plus oxygen-depletion precautions. Development cost: <\$1M Capital cost: \$100K Operating cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Remediation Methods	H Ice Blasting DCON-40-OL <i>Ranking:*</i> H-5-1 (<1.0M;\$1/ft ²)	Demonstration Efficacy: Efficacy of commercial system for this application needs demonstration. Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.	Development: Demonstration of efficacy of commercial system. Improvement: Automation/robotics, especially for walls, corners, etc.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$250K Capital cost: \$100K-\$1M Operating cost: <\$1/ft ²
	H Supercritical CO ₂ Blasting DCON-41-OL <i>Ranking:*</i> H-5-1 (0.75+M;>\$1/ft ²)	Predemonstration Efficacy: Likely to be effective with nearly infinite decontamination factors. Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.	Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants, plus oxygen depletion precautions. Development cost: \$250K-1M Capital cost: ~\$500K Operating cost: \$1+/ft ²
	M Plastic Pellet Blasting DCON-42-OL <i>Ranking:*</i> M-4-0 (<0.1M;\$1/ft ²)	Accepted Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate. Efficacy: Technology should remove smearable, but not fixed contamination, from concrete. Waste: Waste would be spent plastic pellets plus removed contamination.	Improvement: Develop and demonstrate system for processing waste. Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.	A system for processing waste to an acceptable form is needed. Improvements: Development cost: (Improvements) \$5.5M+ Capital cost: ~\$50K Operating cost: \$0.20-\$2.15/ft ²
	H Hand Grinding, Honing, Scraping DCON-43-OL <i>Ranking:*</i> H-2-0 (<<0.1M;\$1/ft ²)	Accepted Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	None Available at X-10, K-25.	A collection system for the vaporized contaminants would be needed to implement this technology. Development costs: None Capital cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation) Operating cost: ~\$1/ft ²
	H Automated Grinding DCON-44-OL <i>Ranking:*</i> H-2-1 (\$1M;\$1M;N)	Conceptual Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	Development: The applicability of this technology to items with rad contamination should be demonstrated.	A collection system for the vaporized contaminants would be needed to implement this technology. Development cost: \$600K Capital cost: \$250-500K

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<ul style="list-style-type: none"> • Bldg. 7500 Interior/Exterior Walls • MSRE Bldg. Interior/Exterior Walls • ORR Bldg. Interior/Exterior Walls • Bldg. 3028 Interior/Exterior Walls • Bldg. 3029 Interior/Exterior Walls • Bldg. 3031 Stacked Shielding • Bldg. 3032 Interior/Exterior Walls • Bldg. 3036 Interior Walls • Bldg. 3038 Interior Walls • Bldg. 3517 Interior/Exterior Walls • Bldg. 7500 Floors • MSRE Bldg. Floors • ORR Bldg. Floors • Bldg. 3028 Floors • Bldg. 3029 Floors • Bldg. 3030 Floors • Bldg. 3031 Floors • Bldg. 3032 Floors • Bldg. 3033 Floors • Bldg. 3036 Floors • Bldg. 3517 Floors • Bldg. 9201-3 Molten Salt Cells, Floor • Bldg. 9201-3 Coolant Salt Cell, Floor • Bldg. 3038 Floors 	<ul style="list-style-type: none"> • Concrete Block • Cs, Sr, TRU, Co-60 • Concrete Block • Fission Products, Corrosion Products • Concrete Block • Fission Products • Concrete Block • Fission Products, TRU • Concrete Block • Cs-137, Sr-90, Co-60, Ir-192 • Concrete Block • Gd-153, Am-241 • Concrete Block • P-32, Am-241 • Concrete Block • Cs-137, Sr-90 • Concrete Block • Sr-90, Cs-137, Co-60, I-129 • Concrete Block • Cs-137, Sr-90, Co-60 • Tiled Concrete • Cs, Sr, TRU, Co-60 • Tiled Concrete • Fission Products, Corrosion Products • Tiled Concrete • Fission Products • Tiled Concrete • Fission Products, TRU • Tiled Concrete • Cs-137, Sr-90, Co-60, Ir-192 • Tiled Concrete • 43 Beta, Gamma Emitters • Tiled Concrete • Gd-153, Am-241 • Tiled Concrete • P-32, Am-241 • Tiled Concrete • H-3, Kr-85 • Tiled Concrete • Cs-137, Sr-90 • Tiled Concrete • Cs-137, Sr-90, Co-60 • Tiled Concrete • U, Th, Molten Salt • Tiled Concrete • U, Th, Coolant Salt • Tiled Concrete • Sr-90, Cs-137, Co-60, I-129 	<ul style="list-style-type: none"> • Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. 	<ul style="list-style-type: none"> • Decontamination
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) 				
<ul style="list-style-type: none"> • Remedial Action (RA)—Soils, Groundwater and Surface Water 				
<ul style="list-style-type: none"> • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>M</p> <p>Concrete Milling DCON-47-OL</p> <p>Ranking: M-1-2 (<1M; \$0.75/ft²)</p>	<p>Accepted The equipment is commercially available, but no reference to its use for decontamination has been found. This technology is suited for horizontal surfaces only. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Improvement: The technology to operate this equipment remotely needs to be developed and demonstrated.</p>	<p>A collection system for the contaminated dust that is generated would be needed to implement this technology. Development cost: None Capital cost: \$400K Operating cost: \$0.75/ft²</p>
	<p>L</p> <p>Explosive DCON-48-OL</p> <p>Ranking: L-2-5 (4M; \$50/ft²)</p>	<p>Demonstration Blasting has been used to decontaminate nuclear reactor shielding. Demonstration will be needed for other applications. Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: Improvements in the methods of applying explosives and in the uniformity of the detonation are needed. The explosion will generate toxic organic vapors. The technology to control toxic vapors formed by the explosion must be developed and demonstrated.</p>	<p>A certified blasting technician will be needed. Capital cost: \$50K Operating cost: \$50/ft² Development cost: \$1-4M</p>
Thermal Surface Removal Methods	<p>H</p> <p>Microwave Scabbling DCON-71-OL</p> <p>Ranking: H-3-2 (2.5+M; >\$1/ft²)</p>	<p>Predemonstration In FY 1991 ORNL demonstrated reliable removal of noncontaminated concrete surfaces using a stationary microwave device. A mobile device is under development. Efficacy: Since microwave scabbling removes the contaminated concrete surface, the decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: The waste generated is concrete rubble with particle diameters lying primarily in the range of 1 to 10 mm plus the contaminants. For a removal depth of 10 mm, 0.03 ft³ of concrete rubble is generated per ft² of concrete decontaminated.</p>	<p>Development: The development and testing of a mobile prototype microwave concrete removal machine needs to be completed.</p>	<p>Normal implementation needs. Development cost: \$2.5M Capital cost: ~\$250K Operating cost: >\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Therm Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
al Surface al Methods	H Plasma Torch DCON-72-OL <i>Ranking:*</i> H-4-1 (0.5M,\$1/ft ²)	Evolving Technology Conceptual Plasma torches exist commercially to weld and cut materials that have very high melting temperatures or require an inert atmosphere. Efficacy: Its efficacy in removing various organic contaminants or to spall off layers of contaminated concrete has not been investigated. Waste: Wastes would consist of materials used to trap reaction products from the decomposition of organics and spalled concrete with contaminants.	Science: Laboratory tests are needed to evaluate the efficacy of vaporizing or decomposing organics, determine the decomposition reaction by-products, and suitable for trapping materials. Laboratory tests of thermal stress-induced spalling of concrete are also needed. Computer modeling of plasma-surface interactions and heat transfer in concrete are needed. Development: Plasma torches having geometries and conditions suitable for decontamination need to be developed along with suitable collection and gas treatment systems. Available at Y-12.	A collection system for the vaporized deposits would be needed to implement this technology. Development costs: ~\$500K Capital costs: ~\$100K Operating costs: \$0.01-\$1.00/ft ² (170K/hr.)
	M Laser Heating DCON-73-OL <i>Ranking:*</i> M-4-4 (3M,\$1/ft ²)	Demonstration Currently being used to remove organic coatings from metal surfaces. Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft ² /hr. Effectiveness on contaminants and substrates of interest is uncertain. Waste: Waste will be prefilters and HEPA filters filled with contaminants.	Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$500K- \$1M+/machine Operating cost: ~\$1/ft ²
	M Laser Etching and Ablation DCON-74-OL <i>Ranking:*</i> M-4-4 (3.5M,>\$1/ft ²)	Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed contamination, some substrate material, and HEPA filters from the filtration system.	Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.	A collection system for the vaporized deposits would be needed to implement this technology. Development costs: \$2M+ Capital cost: \$0.5-1M/machine Operating cost: >\$1/ft ²
	H Flashlamp Cleaning DCON-77-OL <i>Ranking:*</i> H-3-3 (2.5M,\$1/ft ²)	Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford-Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.	Development: Commercially available flashlamp systems need to be evaluated for decontamination.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: ~\$2.5 M Capital cost: \$50-100K/machine Operating cost: ~1.00/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, P.T.A. Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods				
H	Compressed-Air Cryogenic CO ₂ Pellet Blasting DCON-51-OL <i>Ranking:*</i> H-4-1 (0.7M; >\$1/ft ²)	Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.	Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants plus oxygen depletion precautions. Development cost: about \$0.50M Capital cost: About \$200,000 Operating cost: >\$1/ft ²
M	High-Pressure Water DCON-52-OL <i>Ranking:*</i> M-3-1 (1.3M; <\$1/ft ²)	Accepted High pressure water blasting has been used very successfully to decontaminate various large and complex surfaces at nuclear power plants. Efficacy: Technique is expected to be effective with a DF of about 50 for loosely adhering contamination on concrete. DFs will be higher if chemical cleaning agents are also used. Technique is expected to be ineffective for fixed contamination on concrete. Waste: Waste is 4 to >100 gpm of contaminated waste water.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the high pressure water and vacuum collection systems to robotic system control.	A water treatment system is needed to minimize waste. Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating cost: <\$1.00/ft ²
M	Superheated Water DCON-53-OL <i>Ranking:*</i> M-4-1 (1.4M; \$1/ft ²)	Accepted Technology is available and has been used by industry. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has soaked into the concrete. On finished concrete, technology may drive contaminants deeper into substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.	A water treatment system is needed to minimize waste. Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: About \$175K (about \$250K with remote operation) Operating cost: ~\$1.00/ft ²
M	Water Flushing DCON-54-OL <i>Ranking:*</i> M-4-1 (1.3M; <\$1/ft ²)	Accepted Flushing with hot water is often used following scrubbing, especially on floors. Efficacy: The technique is not effective on fixed insoluble contamination. On finished concrete, technology may drive contaminants deeper into substrate. Waste: The waste generated is the contaminated water from the flushing operation.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the hot water cleaning operation.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: About \$1.2M Capital cost: <\$5K Operating cost: <\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, PTA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Chemical Methods
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
al Surface Cleaning s	M Steam Cleaning DCON-55-OL Ranking:* M-4-1 (1.3M;\$1/ft ²)	Accepted The technique has proven useful, especially on complex shapes and large surfaces. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has soaked into the concrete. On finished concrete, technology may drive contaminants deeper into substrate. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Remote operation will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.	Normal implementation needs. Development cost: (improvements) Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating cost: \$0.03-\$1.00/ft ²
	H Hand Brushing Used to Remove Surface Contamination DCON-56-OL Ranking:* H-2-0 (0M;\$1/ft ²)	Accepted Brushing is a common decontamination technique. Efficacy: Brushing is effective for loose contamination only. Waste: Waste consists of removed contamination plus other loose debris.	None Available at K-25.	Normal implementation needs. Capital cost: negligible Operating cost: \$1.00/ft ² Development cost: none
	M Automated Brushing DCON-57-OL Ranking:* M-3-2 (1M;\$300/ft)	Demonstration This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.	Development: Tests to demonstrate that this technology is effective for the problems at ORNL.	Vacuum Collection system. Development costs: \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe.
	M Sponge Blasting DCON-58-OL Ranking:* M-3-1 (1.3M;\$2/ft ²)	Accepted Although the technology is relatively new, it is currently being used by at least two sites including a nuclear power plant. Efficacy: Extensive data on decontamination factors are not available. With the aggressive sponges, which are impregnated with abrasives, this technology may be effective for the listed contaminants and substrates. Waste: Wastes consist of about 0.01 ft ³ of blasting media and removed contaminants per ft ² of area decontaminated plus any liquid cleaning agents that may have been added.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the sponge blasting operation.	A wastewater treatment / recycle system will be needed to use this technology. Development cost: About \$1.2M Capital cost: Sponge blasting system: About \$20K (with sifter system) Operating cost: About \$2/ft ²
	M Solvent Washing to Remove Radiological Contamination DCON-61-OL Ranking:* M-3-2 (1M;N)	Conceptual Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.	Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available at all sites.	Vapor collection system. Capital cost: \$300K (1980 dollars) Development cost: ~\$1M to identify and demonstrate the replacement solvent. Operating cost: an average of 7.5 minutes per item was required when decontaminating small items.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Cs-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems				
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods	M Strippable Coatings DCON-63-OL <i>Ranking:*</i> M-3-0 (<0.1M; >\$1/ft ²)	Accepted Technology has been used for decontamination applications involving hazardous and radioactive contaminants. Efficacy: Decontamination factors of one to several hundred can be expected with two applications. Waste: Waste is a solid polymer (volume = 1 mm x surface area decontaminated) containing the removed contaminants.	Improvement: Develop coatings with lower material costs and greater ease of application.	Normal implementation needs. Capital cost: Negligible Operating cost: \$1-\$1.40/ft ²
	L Vacuum (Low Pressure) DCON-7-OL <i>Ranking:*</i> L-1-2 (2M;N)	Accepted Vacuum cleaners have long been used to clean up loose contamination at the gaseous diffusion plants. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective in cleaning concrete floors at ORNL. Waste: The waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.	None	Normal implementation needs. Capital cost: <\$10K Operating cost: >\$1/ft ²
Chemical Surface Cleaning Methods	M Chemical Foams DCON-8-OL <i>Ranking:*</i> M-4-1 (3M; \$0.50-\$2/ft ²)	Demonstration Widely used throughout the nuclear industry. Foam is used as a carrier of chemical decontamination agents, not as the agent itself. It is sprayed on to component walls or the component is filled with the foam. It can be wiped, rinsed, or vacuumed off. Efficacy: Decontamination effectiveness was 63-92% with DF = 2.7 to 12.5 inside a hot cell in one study. Waste: Small amount of contaminated sulfonated detergents, synthetic wetting agents, coupling agents, rinse water, and drying cloth.	Development: Scale-up/development of the process to a size appropriate for ORNL use. The technology itself is inexpensive, but development and scale-up will probably require support. Improvement: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.	These estimated costs are Development cost: \$1M-\$4M; Capital cost: \$50K Operating cost: \$0.50-\$2/ft ²
	H Fluoboric Acid Treatment DCON-11-OL <i>Ranking:*</i> H-4-2 (2M;N)	Demonstration Technology was designed specifically for D&D. Efficacy: Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF). Fluoboric (or fluosilicic) acid can scabble and clean cement and brickwork. If contaminated to a depth of only a few mm, concrete flooring and structures can be returned to unrestricted use.	Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.	Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital cost: in 1990 to set up a plant for decontaminating 5 tons/day of steel was \$774K, excluding development, planning, and buildings. Operating cost: Relatively low; this is a very simple process.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Chemical Methods
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Groundwater and Surface Water Waste Management (WM) 					

*Assumes tile has been removed

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
cal Surface Cleaning ds*	<p>L</p> <p>Biological DCON-3-OL</p> <p>Ranking:* L-2-Unknown</p>	<p>Evolving Technology / Pre-conceptual The knowledge base exists for biological treatments of various contaminants; however, there is not a data base for application of the technology for surface decontamination. Efficacy: This technology is quite likely to be successful for oil and PCBs. It could be successful for radionuclides, but these contaminants would remain in the bacterial sludge. Waste: The waste generated would be the contaminated layer of microbes removed from the treated surface.</p>	<p>Science: Literature study and bench-scale tests of microbes on radionuclides of interest. Development: Develop methods for applying a layer of microbes, supplying needed nutrients, and removing the microbe layer from the decontaminated item.</p>	<p>Facilities for cultivating the bacteria and disposing of the bacterial sludge would be needed. Development cost: \$300K-\$600K Capital cost: ~\$200K Operating cost: \$0.10-\$3.00+/ft²</p>
	<p>M</p> <p>Detergent Treatments DCON-13-OL</p> <p>Ranking:* M-4-0 (0M;>\$1/ft²)</p>	<p>Accepted Surface smearable decontamination with caustic chemicals (soap and water) is accepted technology and is used extensively at ORNL. The caustic hand-scrubbing process was applied to cleaning small items. Efficacy: Soaps, carbonates, etc., will remove smearable, but not fixed contamination. Waste: Waste would be spent detergent solution containing removed contaminants (normally treated by neutralization and precipitation).</p>	<p>None for removal of smearable contamination with carbonates, soaps, etc. Available at X-10, K-25.</p>	<p>This is an established process that could be implemented at ORNL with no major changes. Capital cost: <\$10K Operating cost: >\$1/ft²</p>
	<p>M</p> <p>Chelation Treatment DCON-21-OL</p> <p>Ranking:* M-4-2 (1.5M;<\$1/ft²)</p>	<p>Demonstration The technology has been employed at various facility operations and nuclear power plant sites. Efficacy: Excellent DFs achieving acceptable decontamination levels resulting in unconditional release. Easy to apply in-situ as agent acts at neutral pH and are non-hazardous, non-fuming, have no gas evolution and are biodegradable. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, PTA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems				
<ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning Methods	Electromigration DCON-20-OL Ranking:* M-3-3.5 (1.2M; ?/ft2)	Predemonstration Limited testing on a small scale. Efficacy: Initial data indicate 90+% removal of U & Tc from concrete. Applicable, in principle, to actinides & chromate. Removal of oil & PCBs possible, in principle, but not demonstrated. Waste: Wastes would be electrolytes containing removed contaminants and scrap cell components.	Development : Additional small-scale "proof of the principle" tests are needed followed by larger scale field demonstration. A treatment system that would permit recycle of the electrolyte is needed.	Normal implementation needs. Development cost: \$1.0M Capital cost: ~\$200K Operating Cost: ~\$5/ft
Bulk Decontamination Methods	Solvent Extraction DCON-1-OL Ranking:* M-2-? (<2M;N)	Solvent extraction is a mature technical field but specific extractants have not been identified for all radionuclides. PCB extraction from concrete etc. Efficacy: An attractive solvent, triethylamine, has been evaluated for organic extraction from sludge and found to be a very effective solvent and one for which industrial processing equipment is available commercially. Has been demonstrated remotely but not for waste materials. Waste: Solvent containing removed contaminants.	Development: Survey and tests of specific extractants applicable to PCB-contaminated concrete, transite and metal are needed. A portable "spot" remover can be developed or adapted from commercial devices. Applicability of rotary contractor, solvent recycle and, if appropriate because of solvent selection, an off-gas treatment system.	Development cost - \$1750K assuming availability of lab scale and pilot-scale extraction units from ORNL, and industrial participation in demo. Development (pilot-scale) equipment may be used in production. Operating Cost: \$5 to \$50/lb.
	Incineration DCON-2-OL Ranking:* M-2-12 (30M;\$10/lb)	Accepted The incineration of contaminated combustible building materials is common in the nuclear industry. Waste: Depends on the design of the incinerator and the ash content of the waste being burned. During a test, the K1435 incinerator generated 1.1 gallons of wastewater and 27 pounds of ash per 100 pounds of waste fed.	None Available at K-25.	Capital cost: \$26M Operating cost: \$10/lb About 8-10 years may be required for writing an environmental impact statement, holding public hearings, and obtaining the necessary permits-TSCA permit, RCRA permit, NESHAP permit, and Clean Air Act permit.
	Biological DCON-3-OL Ranking:* L-2-Unknown	Preconceptual Efficacy: unknown Waste: Unknown	Development: This technology would have to be developed and scaled-up.	Development cost: >\$4M Capital cost: unknown Operating Cost: unknown
	Dry Heat (Bulk Roasting) DCON-4-OL Ranking:* L-1-1 (2M;N)	Evolving technology The technology is available, but has not been demonstrated or accepted for decontamination at the X-10 Site. It is not known what the technology can do. Waste: Unknown	Science: The characteristics of the specific materials and their contaminants must be defined before a decontamination plan can be formulated. The characteristics of the specific contaminants must be matched to the decontaminating advantages of roasting. Development: After a sound technical basis is shown, the primary process could be optimized for worker safety and efficiency. Secondary waste logistics need to be defined.	Off-gas treatment is needed for this technology. Overall Cost: ~\$10/lb is typical for this process.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior/Exterior Walls MSRE Bldg. Interior/Exterior Walls ORR Bldg. Interior/Exterior Walls Bldg. 3028 Interior/Exterior Walls Bldg. 3029 Interior/Exterior Walls Bldg. 3031 Stacked Shielding Bldg. 3032 Interior/Exterior Walls Bldg. 3036 Interior Walls Bldg. 3038 Interior Walls Bldg. 3517 Interior/Exterior Walls Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Concrete Block Cs, Sr, TRU, Co-60 Concrete Block Fission Products, Corrosion Products Concrete Block Fission Products Concrete Block Fission Products, TRU Concrete Block Cs-137, Sr-90, Co-60, Ir-192 Concrete Block Gd-153, Am-241 Concrete Block P-32, Am-241 Concrete Block Cs-137, Sr-90 Concrete Block Sr-90, Cs-137, Co-60, I-129 Concrete Block Cs-137, Sr-90, Co-60 Tiled Concrete Cs, Sr, TRU, Co-60 Tiled Concrete Fission Products, Corrosion Products Tiled Concrete Fission Products Tiled Concrete Fission Products, TRU Tiled Concrete Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete 43 Beta, Gamma Emitters Tiled Concrete Gd-153, Am-241 Tiled Concrete P-32, Am-241 Tiled Concrete H-3, Kr-85 Tiled Concrete Cs-137, Sr-90 Tiled Concrete Cs-137, Sr-90, Co-60 Tiled Concrete U, Th, Molten Salt Tiled Concrete U, Th, Coolant Salt Tiled Concrete Sr-90, Cs-137, Co-60, I-129	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Bulk Meth
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Groundwater and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Decontamination ds	<div>M</div> Chemical Leaching DCON-5-OL <i>Ranking:*</i> <i>M-3-2 (1M; <\$1/ft²)</i>	Predemonstration Although chemical leaching is an accepted technique for some applications, bench scale tests are needed to determine which chemical would be effective. Waste: Waste would be original materials contaminated with chemical leachates plus chemical leachates containing removed contaminants or sludges, filter cakes, and ion exchange resin from recycle system containing removed contaminants.	Development: Bench scale tests are needed to determine which chemicals would be effective and what secondary waste treatment would be necessary to recycle chemicals.	Extensive chemical processing system for chemical leaching with a waste treatment system for treatment or recycle of spent chemical leaching solution. Development cost: Efficacy demo: \$350K Waste treatment: \$400K Capital cost: \$350 - 1000K Waste treatment: \$1M Operating cost: <\$1/ft ² or \$5-\$50/lb
	Catalytic Extraction Process DCON-6-OL <i>Ranking:*</i>	Predemonstration Efficacy: Has not been used for these materials or for scrap having radioactivity. Waste: Slag containing metallic contaminants plus contaminated scrubber solution or chemical trap materials.	Science: Lab evaluation effectiveness on the radionuclides of interest and on the materials of interest. Development: Demonstrate effectiveness for materials and contaminants of interest.	"Off-the-shelf" induction or arc furnace with off-gas treatment system. Development cost: \$3M-\$5M Capital cost: 1/2 of an incinerator of equal capacity - \$16M Operating Cost: 1/3 of an incinerator \$2 - \$3/lb
	Vacuum (Low Pressure) DCON-7-OL <i>Ranking:*</i>	Demonstration Proprietary vacuum process to remove Cr ⁶⁺ from transits. Efficacy: Technique should work for volatile contaminants only. Waste: Caustic scrubber solution containing removed contaminants and other volatiles.	Development: The characteristics of the specific contaminants must be matched to the advantages of decontamination by volatilization under vacuum conditions.	Large blower systems are needed to draw a vacuum on the building; sprayer systems are needed to spray acid on the material; capital and operating costs are considered proprietary. Rough guesses follow. Capital cost: \$1 to \$10M Operating cost: \$2 to \$8/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/schema.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Tiled Concrete ^a Cs, Sr, TRU, Co-60 Tiled Concrete ^a Fission Products, Corrosion Products Tiled Concrete ^a Fission Products Tiled Concrete ^a Fission Products, TRU Tiled Concrete ^a Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete ^a 43 Beta, Gamma Emitters Tiled Concrete ^a Gd-153, Am-241 Tiled Concrete ^a P-32, Am-241 Tiled Concrete ^a H-3, Kr-85 Tiled Concrete ^a Cs-137, Sr-90 Tiled Concrete ^a Cs-137, Sr-90, Co-60 Tiled Concrete ^a U, Th, Molten Salt Tiled Concrete ^a U, Th, Coolant Salt Tiled Concrete ^a Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Ultrahigh-Pressure Water DCON-35-OL</p> <p>Ranking:* H-5-1 (1.7M;\$1/ft²)</p>	<p>Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft² concrete cleaned that contains ~0.01 ft³ concrete residue, plus the contaminants removed.</p>	<p>Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Improvement: Automation.</p>	<p>A water treatment/recycle system is needed to minimize liquid wastes from this technology. Development cost: \$1.3M Capital cost: ~\$500K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Shot Blasting DCON-36-OL</p> <p>Ranking:* H-3-0 (<0.1M;\$1/ft²)</p>	<p>Accepted Commercial iron shot blasters are in use at the K-25 site. Efficacy: They are generally effective but leave some hot spots. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants plus 0.05lb spent shot per ft² of concrete decontaminated.</p>	<p>Improvement: Automation.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$50K Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Scabblers/Scarifiers DCON-37-OL</p> <p>Ranking:* H-4-2 (0.5M;\$5/ft²)</p>	<p>Accepted Mechanical scabblers are used for concrete decontamination at the K-25 Site and elsewhere. Efficacy: They are generally effective, but leave some hot spots. Waste: Waste is ~0.01 ft³ removed substrate (1/16" cut) containing removed contaminants per ft² of substrate decontaminated.</p>	<p>Improvement: Automation.</p>	<p>Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating cost: < \$1/ft² (More than shot blasting)</p>
	<p>H</p> <p>Grit Blasting DCON-38-OL</p> <p>Ranking:* H-4-0 (<0.1M;\$5/ft²)</p>	<p>Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste is ~0.01 ft³ removed concrete (1/16" cut) containing removed contaminants per ft² of concrete decontaminated plus spent grit.</p>	<p>Improvement: Automation.</p>	<p>A vacuum collection system with pre-filters and HEPA filters would be needed to use this technology. Development cost: None Capital cost: ~\$500K Operating cost: \$-2/ft²</p>
	<p>H</p> <p>Centrifuge Cryogenic CO₂ Pellet Blasting DCON-39-OL</p> <p>Ranking:* H-5-2 (1.0M;<\$1/ft²)</p>	<p>Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft de paint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.</p>	<p>Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precaution. Development cost: <\$1M Capital cost: \$100K Operating cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Tiled Concrete ^a Cs, Sr, TRU, Co-60 Tiled Concrete ^a Fission Products, Corrosion Products Tiled Concrete ^a Fission Products Tiled Concrete ^a Fission Products, TRU Tiled Concrete ^a Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete ^a 43 Beta, Gamma Emitters Tiled Concrete ^a Gd-153, Am-241 Tiled Concrete ^a P-32, Am-241 Tiled Concrete ^a H-3, Kr-85 Tiled Concrete ^a Cs-137, Sr-90 Tiled Concrete ^a Cs-137, Sr-90, Co-60 Tiled Concrete ^a U, Th, Molten Salt Tiled Concrete ^a U, Th, Coolant Salt Tiled Concrete ^a Sr-90, Cs-137, Co-60, I-129	Refer to the Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech Meth
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

^aAssumes tile decontaminated in situ

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	Supercritical CO ₂ DCON-41-OL <i>Ranking:*</i>	Predemonstration This technology is being developed by a private company. Efficacy: Likely to be effective with nearly infinite decontamination factors. Waste: Waste would be removed substrate and contaminants contained in a cyclone and a HEPA filter.	Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrated efficacy for contaminants of interest.	Normal implementation needs plus oxygen depletion precautions. Development cost: \$1 - 4M Capital cost: \$500K - \$1M Operating cost: \$1+/sq. ft.
	H Hand Grinding, Honing, Scraping DCON-43-OL <i>Ranking:*</i> H-2-0 (<0.1M; \$1/ft ²)	Accepted Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	None Available at X-10, K-25.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: None Capital cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation) Operating Cost: ~\$1/ft ²
	H Automated Grinding DCON-44-OL <i>Ranking:*</i> H-2-1 (\$1M; \$1M; N)	Conceptual Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	Development: The applicability of this technology to items with rad contamination should be demonstrated.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$600K Capital cost: \$250K
	M Concrete Milling DCON-47-OL <i>Ranking:*</i> M-1-2 (<1M; \$0.75/ft ²)	Conceptual The equipment is commercially available, but no reference to its use for decontamination has been found. This technology is suited for horizontal surfaces only. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	Improvement: The technology to operate this equipment remotely needs to be developed and demonstrated.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: None Capital cost: \$400K Operating cost: \$1.50/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Floors MSRE Bldg. Floors ORR Bldg. Floors Bldg. 3028 Floors Bldg. 3029 Floors Bldg. 3030 Floors Bldg. 3031 Floors Bldg. 3032 Floors Bldg. 3033 Floors Bldg. 3036 Floors Bldg. 3517 Floors Bldg. 9201-3 Molten Salt Cells, Floor Bldg. 9201-3 Coolant Salt Cell, Floor Bldg. 3038 Floors	Tiled Concrete ^a Cs, Sr, TRU, Co-60 Tiled Concrete ^a Fission Products, Corrosion Products Tiled Concrete ^a Fission Products Tiled Concrete ^a Fission Products, TRU Tiled Concrete ^a Cs-137, Sr-90, Co-60, Ir-192 Tiled Concrete ^a 43 Beta, Gamma Emitters Tiled Concrete ^a Gd-153, Am-241 Tiled Concrete ^a P-32, Am-241 Tiled Concrete ^a H-3, Kr-85 Tiled Concrete ^a Cs-137, Sr-90 Tiled Concrete ^a Cs-137, Sr-90, Co-60 Tiled Concrete ^a U, Th, Molten Salt Tiled Concrete ^a U, Th, Coolant Salt Tiled Concrete ^a Sr-90, Cs-137, Co-60, I-129	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>Mechanical Surface Removal Methods</p> <p>L</p>	<p>Explosive DCON-48-OL</p> <p>Ranking:* L-2-5 (4M;\$50/ft²)</p>	<p>Demonstration Blasting has been used to decontaminate nuclear reactor shielding. Demonstration will be needed for other applications. Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the concrete.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: Improvements in the methods of applying explosives and in the uniformity of the detonation are needed. The explosion will generate toxic organic vapors. The technology to control toxic vapors formed by the explosion must be developed and demonstrated.</p>	<p>A certified blasting technician will be needed. Capital cost-\$50K Operating cost-\$50/ft² Development cost-\$1-4M</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior Walls MSRE Bldg. Interior Walls ORR Bldg. Interior Walls Bldg. 3028 Interior Walls Bldg. 3029 Interior Walls Bldg. 3030 Interior Walls Bldg. 3031 Interior Walls Bldg. 3032 Interior Walls Bldg. 3036 Interior Walls Bldg. 3517 Interior Walls Bldg. 7500 Roof MSRE Bldg. Roof ORR Bldg. Roof Bldg. 3028 Roof Bldg. 3029 Roof Bldg. 3030 Roof Bldg. 3031 Roof Bldg. 3032 Roof Bldg. 3033 Roof Bldg. 3036 Roof Bldg. 3038 Roof Bldg. 3517 Roof Floor Under and Shield Around Evaporator in Bldg.	<u>Wood/Sheetrock</u> Cs, Sr, TRU, Co-60 <u>Wood/Sheetrock</u> Cs, Sr, TRU, Co-60 <u>Wood/Sheetrock</u> Fission Products <u>Wood/Sheetrock</u> Fission Products, TRU <u>Wood/Sheetrock</u> Cs-137, Sr-90, Co-60, Ir-192 <u>Wood/Sheetrock</u> 43 Beta, Gamma Emitters <u>Wood/Sheetrock</u> Gd-153, Am-241 <u>Wood/Sheetrock</u> P-32, Am-241 <u>Wood/Sheetrock</u> Cs-137, Sr-90 <u>Wood/Sheetrock</u> Cs-137, Sr-90, Co-60 <u>Tar and Felt Roofing</u> Cs, Sr, TRU, Co-60 <u>Tar and Felt Roofing</u> Cs, Sr, TRU, Co-60 <u>Tar and Felt Roofing</u> Fission Products <u>Tar and Felt Roofing</u> Fission Products, TRU <u>Tar and Felt Roofing</u> Cs-137, Sr-90, Co-60, Ir-192 <u>Tar and Felt Roofing</u> 43 Beta, Gamma Emitters <u>Tar and Felt Roofing</u> Gd-153, Am-241 <u>Tar and Felt Roofing</u> P-32, Am-241 <u>Tar and Felt Roofing</u> H-3, Kr-85 <u>Tar and Felt Roofing</u> Cs-137, Sr-90 <u>Tar and Felt Roofing</u> Sr-90, Cs-137, Co-60, I-129 <u>Tar and Felt Roofing</u> Cs-137, Sr-90, Co-60 <u>Concrete</u> Uranyl Sulfate, Fission Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws; signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Bulk Methods
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Decontamination ds	M Solvent Extraction DCON-1-OL Ranking:* M-2-? (<2M;N)	Demonstration Solvent extraction is a mature technical field but specific extractants have not been identified for all radionuclides. PCB extraction from concrete etc. Efficacy: An attractive solvent, triethylamine, has been evaluated for organic extraction from sludge and found to be very effective solvent and one for which industrial processing equipment is available commercially. Has been demonstrated remotely but not for waste materials. Waste: Solvent containing removed contaminants.	Development: Survey and tests of specific extractants applicable to PCB-contaminated concrete, transite and metal are needed. A portable "spot" remover can be developed or adapted from commercial devices. Applicability of rotary contractor, solvent recycle and, if appropriate because of solvent selection, an off-gas treatment system.	Development cost: \$1750K assuming availability of lab scale and pilot-scale extraction units from ORNL, and industrial participation in demo. Development (pilot-scale) equipment may be used in production. Operating cost: \$5 to \$50/lb.
	M Incineration DCON-2-OL Ranking:* M-2-12 (30M;\$10/lb)	Accepted The incineration of contaminated combustible building materials is common in the nuclear industry. Waste: Depends on the design of the incinerator and the ash content of the waste being burned. During a test, the K1435 incinerator generated 11.1 gallons of wastewater and 27 pounds of ash per 100 pounds of waste fed.	None Available at K-25.	Capital cost: \$26M Operating cost: \$10/lb About 8-10 years may be required for writing an environmental impact statement, holding public hearings, and obtaining the necessary permits-TSCA permit, RCRA permit, NESHAP permit, and Clean Air Act permit.
	L Dry Heat (Bulk Roasting) DCON-4-OL Ranking:* L-1-1 (2M;N)	Evolving technology The technology is available, but has not been demonstrated or accepted for decontamination at the X-10 Site. Efficacy: It is not known what the technology can do. Waste: Unknown.	Science: The characteristics of the specific materials and their contaminants must be defined before a decontamination plan can be formulated. The characteristics of the specific contaminants must be matched to the decontaminating advantages of roasting. Development: After a sound technical basis is shown, the primary process could be optimized for worker safety and efficiency. Secondary waste logistics need to be defined.	Off-gas treatment is needed for this technology. Overall Cost: ~\$10/lb is typical for this process.
	M Chemical Leaching DCON-5-OL Ranking:* M-3-2 (1M;<\$1/ft ²)	Predemonstration Although chemical leaching is an accepted technique for some applications, bench scale tests are needed to determine which chemical would be effective. Waste: Waste would be original materials contaminated with chemical leachates plus chemical leachates containing removed contaminants or sludges, filter cakes, and ion exchange resin from recycle system containing removed contaminants.	Science: Bench scale tests are needed to determine which chemicals would be effective and what secondary waste treatment would be necessary to recycle chemicals.	Extensive chemical processing system for chemical leaching with a waste treatment system for treatment or recycle of spent chemical leaching solution. Development cost: Efficacy demo: \$350K Waste treatment: \$400K Capital cost: \$2M Chemical leaching: \$350K to \$1000K Waste treatment: \$1M Operating cost: <\$1/ft ² or \$5-\$50/lb.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Bldg. 7500 Interior Walls MSRE Bldg. Interior Walls ORR Bldg. Interior Walls Bldg. 3028 Interior Walls Bldg. 3029 Interior Walls Bldg. 3030 Interior Walls Bldg. 3031 Interior Walls Bldg. 3032 Interior Walls Bldg. 3036 Interior Walls Bldg. 3517 Interior Walls Bldg. 7500 Roof MSRE Bldg. Roof ORR Bldg. Roof Bldg. 3028 Roof Bldg. 3029 Roof Bldg. 3030 Roof Bldg. 3031 Roof Bldg. 3032 Roof Bldg. 3033 Roof Bldg. 3036 Roof Bldg. 3038 Roof Bldg. 3517 Roof Floor Under and Shield Around Evaporator in Bldg.	<u>Wood/Sheetrock</u> Cs, Sr, TRU, Co-60 <u>Wood/Sheetrock</u> Cs, Sr, TRU, Co-60 <u>Wood/Sheetrock</u> Fission Products <u>Wood/Sheetrock</u> Fission Products, TRU <u>Wood/Sheetrock</u> Cs-137, Sr-90, Co-60, Ir-192 <u>Wood/Sheetrock</u> 43 Beta, Gamma Emitters <u>Wood/Sheetrock</u> Gd-153, Am-241 <u>Wood/Sheetrock</u> P-32, Am-241 <u>Wood/Sheetrock</u> Cs-137, Sr-90 <u>Wood/Sheetrock</u> Cs-137, Sr-90, Co-60 <u>Tar and Felt Roofing</u> Cs, Sr, TRU, Co-60 <u>Tar and Felt Roofing</u> Cs, Sr, TRU, Co-60 <u>Tar and Felt Roofing</u> Fission Products <u>Tar and Felt Roofing</u> Fission Products, TRU <u>Tar and Felt Roofing</u> Cs-137, Sr-90, Co-60, Ir-192 <u>Tar and Felt Roofing</u> 43 Beta, Gamma Emitters <u>Tar and Felt Roofing</u> Gd-153, Am-241 <u>Tar and Felt Roofing</u> P-32, Am-241 <u>Tar and Felt Roofing</u> H-3, Kr-85 <u>Tar and Felt Roofing</u> Cs-137, Sr-90 <u>Tar and Felt Roofing</u> Sr-90, Cs-137, Co-60, I-129 <u>Tar and Felt Roofing</u> Cs-137, Sr-90, Co-60 <u>Concrete</u> Uranyl Sulfate, Fission Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Bulk Decontamination Methods	H Catalytic Extraction Process DCON-6-OL <i>Ranking:*</i> H-5-4 (20M;\$1/lb)	Pre-demonstration Efficacy: Has not been used for these materials or for scrap having radioactivity. Waste: Slag containing metallic contaminants plus contaminated scrubber solution or chemical trap materials.	Science: Lab evaluation effectiveness on the radionuclides of interest and on the materials of interest. Development: Demonstrate effectiveness for materials and contaminants of interest.	"Off-the-shelf" induction or arc furnace with off-gas treatment system. Development cost: \$3M-\$5M Capital cost: 1/2 of an incinerator of equal capacity - \$16M Operating cost: 1/3 of an incinerator \$2 - \$3/lb
	L Vacuum (Low Pressure) DCON-7-OL <i>Ranking:*</i> L-1-2 (2M;N)	Preconceptual Efficacy: The basis for the technology does not currently exist. Proprietary vacuum process to remove Cr ⁶⁺ from transite. Technique should work for volatile contaminants only. Waste: Caustic scrubber solution containing removed contaminants and other volatiles.	Development: The characteristics of the specific contaminants must be matched to the advantages of decontamination by volatilization under vacuum conditions.	Large blower systems are needed to draw a vacuum on the building, sprayer systems are needed to spray acid on the material, capital and operating cost are considered proprietary. Rough guesses follow. Capital cost: \$1 to \$10M Operating cost: \$2 to \$8/ft ²
Chemical Surface Cleaning Methods	M Chelation Treatment DCON-21-OL <i>Ranking:*</i> M-4-2 (1.5M;<\$1/ft ²)	Demonstration Efficacy: Excellent DFs. Easy to apply in-situ as agent acts at neutral pH and is non-hazardous, non-fuming, have no gas evolution and is biodegradable. The technology has been employed at various facility operations and nuclear power plant sites achieving acceptable decontamination levels resulting in unconditional release. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.	Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.	Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating cost: <\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TiF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech Rem
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Cleaning Methods	H Ultrahigh-Pressure Water DCON-35-OL Ranking:* H-5-1 (1.7M; \$1/ft ²)	Accepted Technology has been used by industry to decontaminate metal parts. Efficacy: Should work for listed contaminants and substrates. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft ² concrete cleaned containing contaminants removed plus, perhaps, some metal substrate.	Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Improvement: Vacuum systems with nozzles designed to match commonly decontaminated parts are needed to minimize the spread of contamination.	Whenever necessary, prior removal and disassembly of contaminated equipment plus an enclosed glove box and/or room that is easily decontaminated on the inside is needed in which the Ultrahigh-pressure water (UHPW) system will be used. Development cost: \$1.3M (Recycle system); \$200K-\$1M (Vacuum system for each nozzle design) Capital cost: >\$500K (with vacuum system) Glove box: <\$50K Work room: ~\$250K Operating cost: ~\$2/ft ²
	H Centrifuge Cryogenic CO ₂ Pellet Blasting DCON-39-OL Ranking:* H-5-2 (1.0M; <\$1/ft ²)	Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft depanel mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.	Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants, plus oxygen-depletion precaution. Development cost: ~\$1M Capital cost: \$100K Operating cost: <\$1/ft ²
	H Ice Blasting DCON-40-OL Ranking:* H-5-1 (<1.0M; \$1/ft ²)	Demonstration Efficacy: Efficacy of commercial system for this application needs demonstration. Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.	Development: Demonstration of efficacy of commercial system. Improvement: Automation/robotics.	Whenever necessary, prior removal and disassembly of contaminated equipment plus an enclosed glove box and/or room that is easily decontaminated in which the decontamination will be accomplished are needed to use this technology. Capital cost: Evaporator for wastewater treatment: ~\$60K Ice blasting system: ~\$280K (Add about \$240K for automatic control) Glove box: <\$50K Work room: ~\$250K Operating cost: ~\$1/ft ²
	H Supercritical CO ₂ Blasting DCON-41-OL Ranking:* H-5-1 (0.75+M; >\$1/ft ²)	Predemonstration Efficacy: Likely to be effective with nearly infinite decontamination factors. Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.	Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.	Whenever necessary, prior removal and disassembly of contaminated equipment plus an enclosed glove box and/or room that is easily decontaminated in which the decontamination will be accomplished plus oxygen depletion precautions are needed to use this technology. Development cost: \$250K-1M Capital cost: Supercritical CO ₂ System: \$500-1M Glove box: <\$50K Work room: ~\$250K Operating cost: ~\$2/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TiF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	M Plastic Pellet Blasting DCON-42-OL Ranking:* M-4-0 (<0.1M; \$1/ft ²)	Accepted Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate. Efficacy: Technology is not likely to remove listed contaminants from listed substrates. Waste: Waste would be spent plastic pellets plus removed contamination.	Improvement: Develop and demonstrate system for processing waste. Improvement: Minimize blast media erosion to minimize waste; automation/robotics improve containment of waste and removed contaminants.	Whenever necessary, prior removal and disassembly of contaminated equipment plus an enclosed glove box and/or room that is easily decontaminated in which the decontamination will be accomplished plus a system for processing wastes to an acceptable form are needed to use this technology. Development cost: \$250K-1M Capital cost: Plastic pellet blasting system: ~\$50K Glove box: <\$50K Work room: ~\$250K Operating cost: ~\$0.75-2.25/ft ²
	H Automated Grinding DCON-44-OL Ranking:* H-2-1 (\$1M; \$1M; N)	Conceptual Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the metal. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.	Development: The applicability of this technology to items with rad contamination should be demonstrated.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$600K Capital cost: \$250K
Thermal Surface Removal Methods	M Laser Heating ^a DCON-73-OL Ranking:* M-4-4 (3M; \$1/ft ²)	Demonstration Currently being used to remove organic coatings from metal surfaces. Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft ² /hr. Effectiveness on contaminants and substrates of interest is uncertain. Waste: Waste will be prefilters and HEPA filters filled with contaminants.	Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$500K-1M+/machine Operating cost: ~\$1/ft ²
	M Laser Etching and Ablation ^a DCON-74-OL Ranking:* M-4-4 (3.5M; >\$1/ft ²)	Pre-demonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.	Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$0.5-1M/machine Operating cost: >\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TIF3 <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Therm. Remo
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
al Surface val Methods	H Plasma Surface Cleaning ^a DCON-75-OL Ranking: [*] H-4-2 (1.0M,>\$1/ft ²)	Predemonstration Plasma surface cleaning by glow discharges are commonly and effectively utilized for cleaning high bonding energy contaminants from surfaces of metals prior to the operation of fusion devices. Efficacy: Technology is expected to be effective for removing deposits from listed substrates, but whether the plasma can follow the irregular shapes involved is uncertain. Waste: Wastes would be the vaporized deposits plus filters and HEPA filters from the collection system.	Science: Data on cleaning rates for contaminants and substrates of interest are needed. Development: The capability of plasma generation and cleaning on complex internal surfaces of contaminated equipment with large surface areas needs to be established. Available at Y-12.	A collection system with appropriate filters for the vaporized deposits would be needed to use this technology. An electric power supply would be needed. Development cost: About \$1M+ Capital cost: \$0.5-M/machine Operating cost: > \$1/ft ²
	M Plasma Etching/Fluorination DCON-76-OL Ranking: [*] M-3-3 (5M,>\$2/ft ²)	Predemonstration Plasma etching processes are used in material processing and microelectronic manufacturing. Efficacy: Extrapolating these plasma processes for vaporizing and recovering radionuclide deposits is considered feasible. Reactive plasma decontamination rates should be higher than unassisted gas-phase decontamination rates. Waste: Wastes would be the vaporized deposits plus filters and HEPA filters from the collection system.	Science: Data on cleaning rates for contaminants and substrates of interest are needed. Development: The capability of plasma etching on deposits in complex equipment with large surface areas needs to be established.	A collection system with appropriate filters for the vaporized deposits would be needed to use this technology. An electric power supply would be needed. Development cost: ~\$5M Capital cost: ~\$1M Operating cost: \$0.70-\$7.00/ft ²
	H Flashlamp Cleaning DCON-77-OL Ranking: [*] H-3-3 (2.5M,\$1/ft ²)	Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford-Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.	Development: Commercially available flashlamp systems need to be evaluated for deposit removal.	A collection system for the vaporized deposits would be needed to implement this technology. Development cost: ~\$2.5 M Capital cost: \$50-100K/machine Operating cost: ~1.00/ft ²

^{*} See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells; Bldg. 9201-3 Drain Lines from Coolant Salt Cell; Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell; Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TlF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards; DOE Orders; and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods				
H	Compressed-Air Cryogenic CO ₂ Pellet Blasting DCON-51-OL <i>Ranking:*</i> H-4-1 (0.7M;>\$1/ft ²)	Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.	Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.	Prior removal and disassembly of contaminated equipment and a glove box that is easily decontaminated in which the decontamination will be accomplished plus design and construction of a vacuum waste-handling system with filters and HEPA filters to handle the vaporized CO ₂ containing the removed deposits are needed to use this technology. Development cost: \$500K Capital cost: CO ₂ System: ~\$200K Glove box: ~\$50K Operating cost: \$2-10/ft ²
M	Superheated Water DCON-53-OL <i>Ranking:*</i> M-4-1 (1.4M;\$1/ft ²)	Accepted Technology is available and has been used by industry. Efficacy: The removal of tightly bound or imbedded contaminants, such as the listed contaminants on the listed substrates is likely to be slight. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.	Whenever necessary, prior removal and disassembly of contaminated equipment and a glove box that is easily decontaminated in which the decontamination will be accomplished plus design and construction of a water recycle system are needed to use this technology. Development cost: about \$1.2M Superheated water system: ~\$175K Glove box: ~\$50K Work room: ~\$250K Operating cost: \$0.05-\$2/ft ²
M	Water Flushing DCON-54-OL <i>Ranking:*</i> M-4-1 (1.3M;<\$1/ft ²)	Accepted Flushing with hot water is often used following scrubbing, or before other chemical treatments. Efficacy: The technique is not effective on fixed insoluble contamination. Waste: The waste generated is the contaminated water from the flushing operation.	Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the hot water cleaning operation.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: ~\$1.2M Capital cost: ~\$5K Operating cost: ~\$1/ft ²
M	Steam Cleaning DCON-55-OL <i>Ranking:*</i> M-4-1 (1.3M;\$1/ft ²)	Accepted The technique has proven useful, especially on complex shapes and large surfaces. Efficacy: Technology is not expected to be effective for listed contaminants and substrates. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.	Improvement - To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Remote operation will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.	Whenever necessary, prior removal and disassembly of contaminated equipment and a glove box that is easily decontaminated in which the decontamination will be accomplished plus design and construction of a water recycle system are needed to use this technology. Development cost: about \$1.2M Steam system: \$50-75K Glove box: ~\$50K Work room: ~\$250K Operating cost: \$0.05-\$2/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TlF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt Metal Heavy Water	Refer to Vol. 1, PIA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Surf
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Cleaning Methods	<p>M</p> <p>Automated Brushing DCON-57-OL</p> <p>Ranking:* M-3-2 (1M;\$300/ft)</p>	<p>Demonstration This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.</p>	<p>Development: Tests to demonstrate that this technology is effective for the problems at ORNL.</p>	<p>Vacuum Collection system Development cost: \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe</p>
	<p>L</p> <p>Dry Heat (Bulk Roasting) DCON-4-OL</p> <p>Ranking:* L-1-1 (2M;N)</p>	<p>Evolving technology The technology is available, but has not been demonstrated or accepted for decontamination at the X-10 Site. Efficacy: It is not known what the technology can do. Waste: Any removed contaminants and other volatiles in filters, scrubber, or condenser.</p>	<p>Science: The characteristics of the specific materials and their contaminants must be defined before a decontamination plan can be formulated. The characteristics of the specific contaminants must be matched to the decontaminating advantages of roasting. Development: After a sound technical basis is shown, the primary process could be optimized for worker safety and efficiency. Secondary waste logistics need to be defined.</p>	<p>Off-gas treatment is needed for this technology. Overall cost: ~\$10/lb is typical for this process.</p>
	<p>M</p> <p>Solvent Washing to Remove Radiological Contamination DCON-61-OL</p> <p>Ranking:* M-3-2 (1M;N)</p>	<p>Conceptual Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.</p>	<p>Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available in Private Sector.</p>	<p>Vapor collection system Development cost: ~\$1M to identify and demonstrate the replacement solvent. Capital cost: \$300K (1980 dollars) Operating cost: an average of 7.5 minutes per item was required when decontaminating small items.</p>
	<p>M</p> <p>Vacuum Cleaning DCON-64-OL</p> <p>Ranking:* M-4-0 (<0.1M;\$1/ft²)</p>	<p>Accepted Vacuum cleaners have long been used to clean up loose contamination at the gaseous diffusion plants. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective in cleaning the listed contaminants from the listed substrates. Waste: The waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.</p>	<p>None</p>	<p>Normal Implementation needs. Capital Cost: <\$10K Operating cost: >\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TiF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods M	Ultrasonic Cleaning DCON-65-OL <i>Ranking:*</i> M-2-1 (0.1M, >\$2/ft ²)	Accepted Ultrasonic cleaning has been used for many years in the private sector and in government installations for removing surface contamination from relatively small metal parts which can fit into an ultrasonic bath. Efficacy: Technology will work well for loosely bound surface deposits, but not for tightly bound materials. Waste: Wastes would be spent ultrasonic bath solutions containing any removed contaminants.	Improvement: Definition of acceptable cleaning liquids which (1) are not hazardous, (2) can be separated from the contaminants, and (3) can be reused to minimize secondary wastes. Improvement: More aggressive cleaning action.	Requires removal, disassembly, and size reduction of contaminated equipment. Development cost (Improvements): \$1M Capital cost: \$10K-\$100K Operating cost: \$2 - \$10/ft ² or more
Melt Refining Methods H	Smelt Purification DCON-31-OL <i>Ranking:*</i> H-3-3 (100M, \$1/lb)	Demonstration Smelt purification of radioactive metals has been performed by a large number of investigators on a lab scale and by some investigators on a large scale. The metals include mild steel, stainless steel, nickel, copper, monel, aluminum, and others. Efficacy: Metal purification has been demonstrated. U is removed to 0.01-4ppm. Tc is not removed. Waste: Waste are slags, scrubber solutions, chemical trap materials, and HEPA filters.	Development: Attempt to demonstrate fluxing agent for removing radionuclides of interest. If possible, demonstrate removal of radionuclides of interest on a larger scale.	Scientific Ecology Group (SEG) personnel estimate the costs of metal smelting at roughly \$0.93/lb of metal in 1992 dollars, depending on the type metal and configuration of the metal. Kellogg et al. estimated that the capital and operating costs of smelting the 90,000 tons of DOE scrap metal presently on hand at K-25 could be recovered through sale of the metal if a <i>de minimis</i> were established. The quantity of metals at ORNL is probably not sufficient to be cost effective unless added to this. The technology development needs will require further lab and pilot-scale evaluation. The development costs are roughly estimated by the investigator at \$3M - \$5M.
M	Electrorefining DCON-32-OL <i>Ranking:*</i> M-2-5 (200M, \$6/lb)	Predemonstration Electrorefining is a well-established commercial technology. However, this technology cannot be considered mature concerning its use for decontaminating radioactive metal because this application is much less established. Efficacy: Tc plates out on the cathode. Technology is likely to be effective for the listed contaminants and substrates. Waste: Waste would be solid mixed waste from assumed treatment of electrolyte solutions for recycle.	Development: Demonstrate (1) separation of radionuclides and substrates of interest and (2) recycle electrolyte solutions.	An electrorefining plant used for recovery of nickel would also require a smelting and anode forming facility to form the impure nickel into anodes of proper configuration. The capital costs altogether are estimated at \$200M. The cost of an operating facility with a 10 million-pound/year capacity is estimated at \$2M capital and \$6/lb operating costs, which exceed the present value of nickel (\$3.60/lb) because commercial nickel companies operate on a much larger scale. Development costs are estimated at \$3M. To allow sale of the purified nickel, either a <i>de minimis</i> level must be established in the USA or permission must be obtained to sell the metal in Europe, where a <i>de minimis</i> level exists.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TiF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt <u>Metal</u> Heavy Water	Refer to Vol. 1, P.I.A., Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Melt
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					Chem

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Refining Methods	<p>M</p> <p>Leach/Electrowinning DCON-34-OL</p> <p>Ranking:* M-2-5 (200M;\$3.80/lb)</p>	<p>Predemonstration Leach/Electrowinning is a well-established commercial method for producing nickel from nickel ore, but is not used commercially to refine impure nickel metal.</p> <p>Efficacy: Scientific Ecology Group, Inc. (SEG), has purified nickel to <1 Bq/g of Tc on a small scale. The Tc must be removed from the electrolytic solutions by ion exchange or some other method. The method has not been evaluated for treatment of metals other than nickel. At ORNL, nickel was not used extensively.</p> <p>Waste: Recycle of electrolytic solutions will result in a solid mixed waste bearing the contaminants and traces of the purified metal amounting to roughly 2% by weight of the metal purified.</p>	<p>Development: Pilot-scale testing of this method is needed with special attention to the leaching process, decontamination efficiency, and recycle of the electrolytic solutions. The development work by SEG may satisfy some of this requirement.</p>	<p>A leach/electrowinning plant would require a size-reduction facility, a leaching facility, and a tankhouse for the electrolytic cells. The costs of an operating facility with a 10-million-pound-per-year capacity are estimated by INCO at \$200M capital and \$3.80/lb operating costs. The operating costs exceed the present value of most all metals because commercial nickel companies operate on a much larger scale. The development costs are estimated by INCO at \$440K if the work were done at their facilities. To allow sale of the resulting purified metal, either a <i>de minimis</i> must be established for the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> standard exists.</p>
Chemical Surface Cleaning	<p>M</p> <p>Chemical Foams DCON-8-OL</p> <p>Ranking:* M-4-1 (3M;\$0.50-\$2/ft²)</p>	<p>Demonstration Widely used throughout the nuclear industry. Foam is used as a carrier of chemical decontamination agents; not as the agent itself. It can be sprayed on and wiped, rinsed, or vacuumed off.</p> <p>Efficacy: Effectiveness for listed contaminants and substrates has not been demonstrated.</p> <p>Waste: Small amount of contaminated sulfonated detergents, synthetic wetting agents, coupling agents, rinse water, and drying cloth.</p>	<p>Development: Scale-up/development of the process to a size appropriate for ORNL use. The technology itself is inexpensive, but development and scale-up will probably require support.</p> <p>Improvement: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.</p>	<p>These estimated costs are: Development cost: \$1M-\$4M; Capital cost: \$50K Operating cost: \$0.50-\$2/ft²</p>
	<p>H</p> <p>Organic Acid Treatments DCON-10-OL</p> <p>Ranking:* H-4-2 (2M;N)</p>	<p>Demonstrated The technology is currently in use by BNFL at Capenhurst gaseous diffusion plant. BNFL uses citric and sulfuric acids in sequence for removal of U and Tc, respectively, from metal surfaces (mostly wrought aluminum).</p> <p>Efficacy: DF of 300 for U alpha and 40 for Tc beta are reported (11.1 Bq/g alpha, 0.04 Bq/g beta). Has not been demonstrated to remove other radionuclides.</p> <p>Waste: Wastes include citric and sulfuric acids containing uranium and other metal ions and ion exchange media containing the metals. Uranium is difficult to precipitate.</p>	<p>Development: Pilot plant development for waste treatments (ion exchange columns) to verify that we can meet our standards and regulations. More fundamental studies are needed in secondary waste disposal.</p>	<p>Purchase of technology, regulatory compliance for pilot-scale decontamination, and waste treatment demonstrations. BNFL's expertise may reduce the amount of original research, etc. necessary to begin implementation. No present ORNL facility could be adapted for citric acid cleaning, but decontamination with BNFL's citric acid process should pose no undue difficulties. It may well be less costly to implement than the more familiar nitric acid process would be due to the relative nontoxicity and ease of treating secondary waste stream.</p> <p>Development cost: \$400K-\$1M (rough estimate) Capital cost: \$4M-\$10M if new equipment is required Operating cost: \$300/Mg (BNFL estimate)</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	<u>Stainless Steel Pipe Interior</u> UO ₂ SO ₄ , Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Fission Products, Corrosion Products <u>Stainless Steel Pipe Interior</u> Cs-137, Sr-90 <u>Steel Pipe Interior</u> <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>Steel Pipe Interior</u> U, Th, Coolant Salt <u>Steel Pipe Interior</u> U, Th, Molten Salt <u>INOR Piping Interior</u> U, Be, L, F, TiF ₃ <u>Aluminum Piping Interior</u> Fission Products, Corrosion Products <u>Copper Tubing Interior</u> U, Th, H-3, Molten Salt Metal Heavy Water	Refer to Vol. 1, Pt.A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning	<p>H</p> <p>Fluoboric Acid Treatment DCON-11-OL</p> <p>Ranking:* H-4-2 (2M;N)</p>	<p>Demonstration Technology was designed specifically for D&D. Efficacy: Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF).</p>	<p>Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.</p>	<p>Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital cost in 1990 to set up a plant for decontaminating 5 tons/day of steel was DM 1.3 million (\$774K); excluding development, planning, and buildings. Operating cost will be relatively low; this is a very simple process.</p>
	<p>M</p> <p>Inorganic Acid Treatments DCON-12-OL</p> <p>Ranking:* M-3-0 (4M;N)</p>	<p>Accepted Nitric acid decontamination has been the preferred method at ORNL for cleaning items in various facility operations since the 1940s. In addition, the technique has been widely used at K-25 and Portsmouth. Efficacy: DFs are in the 100 range. Waste: Wastes consist of large quantities of corrosive wastes containing the removed contaminants and require treatment and disposal as mixed waste.</p>	<p>Improvements: Adaptation of modifications to system (i.e., scrubbers, filters, treatment for nitrates and heavy metals) in order to meet regulatory requirements. Possible development of HNO₃/HF decontamination methods, with or without ultrasonic agitation. Continuing research and development, waste treatment, and volume reduction. Possible research and development in control of base metal dissolution. Available at X-10, K-25.</p>	<p>Nitrate treatment facility either on site or accessible to decontamination facility. Operating costs may be relatively high. Nitric acid decontamination was used extensively at most DOE plants, but data is not available regarding costs. Currently, Portsmouth plant is developing a data base to track costs, but it will not contain historical data. Development cost: (improvements): \$400K-1M (rough estimate). Capital cost: <\$4M-\$10M (rough estimate).</p>
	<p>M</p> <p>Detergent Treatment DCON-13-OL</p> <p>Ranking:* M-4-0 (0M;>\$1/ft²)</p>	<p>Accepted Surface smearable decontamination with caustic chemicals (soap and water) is accepted technology and is used extensively at ORNL. The caustic hand-scrubbing process was applied to cleaning small items. Efficacy: Since many of the listed contaminants are expected to be fixed, caustic scrubbing is expected to only partially decontaminate the contaminated surfaces. Waste: Wastes would consist of used caustic solution containing the removed contaminants.</p>	<p>None for removal of smearable contamination with carbonates, soaps, etc. Available at X-10, K-25.</p>	<p>This is an established process that could be implemented at ORNL with no major changes. Capital cost: <\$10K Operating costs: >\$1/ft.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<p>HRT Process Piping</p> <p>ORR Demineralizer Piping (Outside Pool)</p> <p>Bldg. 3517 Process Piping and Tankage</p> <p>MSRE Off-gas System</p> <p>Drain Lines from Molten Salt Cells, Bldg. 9201-3</p> <p>Drain Lines from Coolant Salt Cell, Bldg. 9201-3</p> <p>Drain Lines from Bldg. 9419-1</p> <p>MSRE Reactor Piping</p> <p>ORR Primary Coolant Piping</p> <p>Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3</p> <p>Pulse-feeder Pumps</p>	<p>Stainless Steel Pipe Interior UO₂SO₄, Fission Products, Corrosion Products</p> <p>Stainless Steel Pipe Interior Fission Products, Corrosion Products</p> <p>Stainless Steel Pipe Interior Cs-137, Sr-90</p> <p>Steel Pipe Interior</p> <p>Steel Pipe Interior U, Th, Molten Salt</p> <p>Steel Pipe Interior U, Th, Coolant Salt</p> <p>Steel Pipe Interior U, Th, Molten Salt</p> <p>INOR Piping Interior U, Be, L, F, TIF3</p> <p>Aluminum Piping Interior Fission Products, Corrosion Products</p> <p>Copper Tubing Interior U, Th, H-3, Molten Salt</p> <p>Metal Heavy Water</p>	<p>Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	Decontamination	Chemical
<p>EM Problems</p> <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Cleaning	<p>REDOX Treatments DCON-14-OL</p> <p>Ranking:*</p>	<p>Demonstration: REDOX treatments have been demonstrated for nuclear power plant decontamination, but not for the contaminants of interest.</p> <p>Efficacy: DFs of 10-100 can be expected based on experience in nuclear power plants.</p> <p>Waste: With recycle, waste is spent ion exchange media containing removed contaminants. With neutralization and evaporation, waste is a solid mixed waste containing the removed contaminants and chemicals from the REDOX reagents.</p>	<p>Development: All REDOX techniques will require demonstration to determine their usefulness to decontamination of ORNL operations and applicability to various contaminant films.</p>	<p>A system for treating the REDOX reagents to permit recycling these reagents will be needed to use this technology.</p> <p>Development cost: >\$1M Capital cost: >\$1M Operating cost: <\$1/ft</p>
	<p>Electropolishing DCON-15-OL</p> <p>Ranking:*</p> <p>M-4-2 (3M;>\$1/ft2)</p>	<p>Demonstration: Electropolishing is a surface removal technique and the amount of surface removed is proportional to factors such as current, time, and voltage. Electropolishing is essentially a "line of sight" process so cracks, crevices, areas out of sight of, or shadowed by, the electrode will not be decontaminated. Contaminated electrolyte must be removed for complete decontamination to be achieved. Electropolishing is difficult to apply to in-situ equipment.</p>	<p>Primary and secondary waste treatment and solution recycle need to be developed. Cleanup principles (e.g., ion exchange and filtering) are well established, so that only design and demonstration are needed.</p>	<p>Development cost: ~\$400K to \$1M Operating cost: >\$1/ft² with additional capital cost.</p>
	<p>Gas Phase Decontamination DCON-16-OL</p> <p>Ranking:*</p> <p>M-4-4 (5M;<\$0.50/lb)</p>	<p>Predemonstration: Lab-scale studies have demonstrated that ClF₃ is capable of effectively removing U deposits at room temperature.</p> <p>Efficacy: Gas phase decontamination is expected to be largely or completely effective only on contaminants that form volatile fluorides.</p> <p>Waste: Spent NaF trapping material and spent caustic scrubber solution or fluoride trapping media.</p>	<p>Science: The effectiveness of the process on the problem areas and contaminants at X-10 must be investigated.</p> <p>Development: Full-scale development and demonstration of the decontamination process equipment is needed. Development of mechanical methods and chemical methods to remove reaction byproducts so that ClF₃ can be recycled are needed.</p>	<p>A permitted vent will be needed to implement this technology. Air with trace amounts of UF₆, chlorides, and fluorides will be vented.</p> <p>Development cost: ~\$5M Capital cost: >\$3M Operating cost: ~\$15K (\$0.52/ft²) if a 00 gaseous diffusion converter is treated in situ (estimate for removal of uranium deposits at the K-25 Site).</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Process Piping ORR Demineralizer Piping (Outside Pool) Bldg. 3517 Process Piping and Tankage MSRE Off-gas System Drain Lines from Molten Salt Cells, Bldg. 9201-3 Drain Lines from Coolant Salt Cell, Bldg. 9201-3 Drain Lines from Bldg. 9419-1 MSRE Reactor Piping ORR Primary Coolant Piping Instrument Air Lines and Air Lines in Coolant Salt Cell, Bldg. 9201-3 Pulse-feeder Pumps	Stainless Steel Pipe Interior UO ₂ SO ₄ , Fission Products, Corrosion Products Stainless Steel Pipe Interior Fission Products, Corrosion Products Stainless Steel Pipe Interior Cs-137, Sr-90 Steel Pipe Interior Steel Pipe Interior U, Th, Molten Salt Steel Pipe Interior U, Th, Coolant Salt Steel Pipe Interior U, Th, Molten Salt INOR Piping Interior U, Be, L, F, TlF ₃ Aluminum Piping Interior Fission Products, Corrosion Products Copper Tubing Interior U, Th, H-3, Molten Salt Metal Heavy Water	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Chemical Surface Cleaning</p> <p>M</p>	<p>Chelation Treatment DCON-21-OL</p> <p>Ranking:* M-4-2 (1.5M; <\$1/ft²)</p>	<p>Demonstration Efficacy: Excellent DFs. Easy to apply in-situ as agent acts at neutral pH and are non-hazardous, non-fuming, have no gas evolution and are biodegradable. The technology has been employed at various facility operations and nuclear power plant sites achieving acceptable decontamination levels resulting in unconditional release. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development: Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech Meth
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
<p>Ultrasound Surface Removal</p> <p>Ranking: H</p> <p>DCON-35-OL</p> <p>High-Pressure Water</p>	<p>Accepted</p> <p>Technology has been used by industry.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the metal.</p> <p>Waste: Unless a recycle system is developed, waste would be 3-5 gal water/lb metal cleaned that contains metal residue, plus the contaminants removed.</p>	<p>Demonstration</p> <p>Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft decontamination mechanism.</p> <p>Efficacy: Technology is likely to be successful with very high decontamination factors.</p> <p>Waste: The waste will be HPA filters containing the combination of contaminants and substrate material.</p> <p>Predemonstration</p> <p>Efficacy: Likely to be effective with nearly infinite decontamination factors.</p> <p>Waste: Waste would be removed contaminants contained in a cyclone and a HEPA filter.</p>	<p>Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled.</p> <p>Improvement: Automation.</p>	<p>A water treatment/recycle system is needed to minimize liquid wastes from this technology.</p> <p>Development cost: \$1.3M</p> <p>Capital cost: ~\$500K</p> <p>Operating cost: ~\$1/lb</p>
<p>Centrifuge Cryogenic CO₂ Pellet Blasting</p> <p>Ranking: H</p> <p>DCON-39-OL</p>	<p>Demonstration</p> <p>Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft decontamination mechanism.</p> <p>Efficacy: Technology is likely to be successful with very high decontamination factors.</p> <p>Waste: The waste will be HPA filters containing the combination of contaminants and substrate material.</p> <p>Predemonstration</p> <p>Efficacy: Likely to be effective with nearly infinite decontamination factors.</p> <p>Waste: Waste would be removed contaminants contained in a cyclone and a HEPA filter.</p>	<p>Improvement: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$1M</p> <p>Capital cost: ~\$100K</p> <p>Operating cost: ~\$1/lb</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$500K</p> <p>Capital cost: ~\$1M</p> <p>Operating cost: ~\$1/lb</p>
<p>Supercritical CO₂ Blasting</p> <p>Ranking: H</p> <p>DCON-41-OL</p>	<p>Predemonstration</p> <p>Efficacy: Likely to be effective with nearly infinite decontamination factors.</p> <p>Waste: Waste would be removed contaminants contained in a cyclone and a HEPA filter.</p>	<p>Development: Develop and demonstrate system for processing waste.</p> <p>Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$500K</p> <p>Capital cost: ~\$1M</p> <p>Operating cost: ~\$1/lb</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$500K</p> <p>Capital cost: ~\$1M</p> <p>Operating cost: ~\$1/lb</p>
<p>Plastic Pellet Blasting</p> <p>Ranking: M</p> <p>DCON-42-OL</p> <p>M-4-0 (<0.1M, \$1/lb)</p>	<p>Accepted</p> <p>Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate.</p> <p>Efficacy: Technology should remove smearable, but not fixed contamination.</p> <p>Waste: Waste would be spent plastic pellets plus removed contamination.</p>	<p>Improvement: Develop and demonstrate system for processing waste.</p> <p>Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$500K</p> <p>Capital cost: ~\$1M</p> <p>Operating cost: ~\$1/lb</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants, plus oxygen depletion precautions.</p> <p>Development cost: ~\$500K</p> <p>Capital cost: ~\$1M</p> <p>Operating cost: ~\$1/lb</p>

See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, Pt. A, Chap. 7; for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Automated Grinding DCON-44-OL</p> <p><i>Ranking:*</i> H-2-1 (\$1M;\$1M;N)</p>	<p>Conceptual Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found.</p> <p>Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused into the metal.</p> <p>Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: The applicability of this technology to items with rad contamination should be demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. ~\$600K Capital cost: \$250K Operating cost: ~\$1/ft²</p>
Thermal Surface Removal Methods	<p>M</p> <p>Laser Heating DCON-73-OL</p> <p><i>Ranking:*</i> M-4-4 (3M;\$1/ft²)</p>	<p>Demonstration Currently being used to remove organic coatings from metal surfaces.</p> <p>Efficacy: Current prototype systems are capable of removing 2-mil-thick coatings at the rate of 100 ft²/hr. Effectiveness on contaminants and substrates of interest is uncertain.</p> <p>Waste: Waste will be prefilters and HEPA filters filled with contaminants.</p>	<p>Development: Current prototype needs to be evaluated for possible use on contaminated areas. Systems with different operational parameters (e.g., wavelength, pulse durations) should be evaluated as well.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$500k- \$1M+/machine; Operating Cost: ~\$1/ft²</p>
	<p>M</p> <p>Laser Etching and Ablation DCON-74-OL</p> <p><i>Ranking:*</i> M-4-4 (3.5M;>\$1/ft²)</p>	<p>Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces.</p> <p>Efficacy: The technique is slow to remove large deposits.</p> <p>Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.</p>	<p>Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$0.5- 1M/machine Operating Cost: >\$1/ft²</p>
	<p>H</p> <p>Compressed Air Cryogenic CO₂ Pellet Blasting DCON-51-OL</p> <p><i>Ranking:*</i> H-4-1 (0.7M;>\$1/ft²)</p>	<p>Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment.</p> <p>Efficacy: The efficacy of this technology for removing the listed contaminants from concrete has not been demonstrated and is doubtful.</p> <p>Waste: Wastes would be HEPA filters filled with the removed contaminants.</p>	<p>Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants. Development cost: about \$0.50M Capital cost: About \$200,000 Operating Cost: >\$1/ft²</p>

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Therm Meth
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>nal Surface Removal ods</p> <p>M</p> <p>M</p> <p>M</p> <p>M</p> <p>L</p>	<p>Superheated Water DCON-53-OL</p> <p>Ranking:* M-4-1 (1.4M;\$1/ft²)</p>	<p>Accepted Technology is available and has been used by industry. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has penetrated into the metal. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Improvement - Remote operation will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.</p>	<p>A water treatment system is needed to minimize waste. Development Cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: About \$175K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>Water Flushing DCON-54-OL</p> <p>Ranking:* M-4-1 (1.3M;<\$1/ft²)</p>	<p>Accepted Flushing with hot water is often used following scrubbing, especially on floors. Efficacy: The technique is not effective on fixed insoluble contamination. Waste: The waste generated is the contaminated water from the flushing operation.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the hot water cleaning operation.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology. Development Cost: About \$1.2M Capital cost: ~\$5K Operating Cost: >\$1/ft²</p>
	<p>Steam Cleaning DCON-55-OL</p> <p>Ranking:* M-4-1 (1.3M;\$1/ft²)</p>	<p>Accepted The technique has proven useful, especially on complex shapes and large surfaces. Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has penetrated into the metal. Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Improvement - To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused. Remote operation will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.</p>	<p>Normal implementation needs. Development Cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating Cost: >\$1.00/ft²</p>
	<p>Automated Brushing DCON-57-OL</p> <p>Ranking:* M-3-2 (1M;\$300/ft)</p>	<p>Demonstration This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.</p>	<p>Development: Tests to demonstrate that this technology is effective for the problems at ORNL.</p>	<p>Vacuum Collection system Development costs \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe</p>
	<p>Dry Heat (Bulk Roasting) DCON-4-OL</p> <p>Ranking:* L-1-1 (2M;N)</p>	<p>Evolving technology The technology is available, but has not been demonstrated or accepted for decontamination at the X-10 Site. Efficacy: It is not known what the technology can do. Waste: Any removed contaminants and other volatiles in filters, scrubbers, or condenser.</p>	<p>Science: The characteristics of the specific materials and their contaminants must be defined before a decontamination plan can be formulated. The characteristics of the specific contaminants must be matched to the decontaminating advantages of roasting. Development: After a sound technical basis is shown, the primary process could be optimized for worker safety and efficiency. Secondary waste logistics need to be defined.</p>	<p>Off-gas treatment is needed for this technology. Overall costs: ~\$10/lb. is typical for this process.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Surface Cleaning Methods	M Solvent Washing to Remove Radiological Contamination DCON-61-OL <i>Ranking:*</i> M-3-2 (1M;N)	Conceptual Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.	Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available in Private Sector.	Vapor collection system. Capital cost: \$300K (1980 dollars) Development cost: <\$1M to identify and demonstrate the replacement solvent. Operating cost: an average of 7.5 minutes per item was required when decontaminating small items.
	M Vacuum Cleaning DCON-64-OL <i>Ranking:</i> M-4-0 (<0.1M; \$1/ft ²)	Accepted Vacuum cleaners have long been used to clean up loose contamination. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective. Waste: The waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.	None	Normal Implementation needs. Capital Cost: <\$10K Operating cost: >\$1/ft ²
	M Ultrasonic Cleaning DCON-65-OL <i>Ranking:*</i> M-2-1 (0.1M; >\$2/ft ²)	Accepted Ultrasonic cleaning has been used for many years in the private sector and in government installations for removing surface contamination from relatively small metal parts which can fit into an ultrasonic bath. Efficacy: Technology will work well for loosely bound surface deposits, but not for tightly bound materials. Waste: Wastes would be spent ultrasonic bath solutions containing any removed contaminants.	Improvement: Definition of acceptable cleaning liquids which (1) are not hazardous, (2) can be separated from the contaminants, and (3) can be reused to minimize secondary wastes. Improvement: More aggressive cleaning action.	Requires removal, disassembly, and size reduction of contaminated equipment. Development cost: (Improvements): \$1M Capital cost: \$10K-\$100K Operating Cost: \$2 - \$10/ft ² or more
Melt Refining Methods	H Smelt Purification DCON-31-OL <i>Ranking:*</i> H-3-3 (100M; \$1/lb)	Demonstration Smelt purification of radioactive metals has been performed by a large number of investigators on a lab-scale and by some investigators on a large-scale. The metals include mild steel, stainless steel, nickel, copper, monel, aluminum, and others. Efficacy: Metal purification has been demonstrated. U is removed to 0.01-4ppm. Tc is not removed. Waste: Waste are slags, scrubber solutions, chemical trap materials, and HEPA filters.	Development: Attempts to demonstrate fluxing agent for removing radionuclides of interest. If possible, demonstrate removal of radionuclides of interest on a larger scale.	Scientific Ecology Group (SEG) personnel estimate the costs of metal smelting at roughly \$0.93/lb of metal in 1992 dollars, depending on the type metal and configuration of the metal. Kellogg et al. estimated that the capital and operating costs of smelting the 90,000 tons of DOE scrap metal presently on hand at K-25 could be recovered through sale of the metal if a <i>de-minimis</i> were established. The quantity of metals at ORNL is probably not sufficient to be cost effective unless added to this. The technology development needs will require further lab and pilot-scale evaluation. The development costs are roughly estimated by the investigator at \$3M - \$5M.

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, PL A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste- specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Melt
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					Chem

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Refining Methods	Electrorefining DCON-32-OL Ranking:* M-2-5 (200M;\$6/lb)	Predemonstration Electrorefining is a well-established commercial technology. However, this technology cannot be considered mature concerning its use for decontaminating radioactive metal because this application is much less established. Efficacy: Tc plates out on the cathode. Technology is likely to be effective for the listed contaminants and substrates. Waste: Waste would be solid mixed waste from assumed treatment of electrolyte solutions for recycle.	Development: Demonstrate (1) separation of radionuclides and substrates of interest; and (2) recycle electrolyte solutions.	An electrorefining plant used for recovery of nickel would also require a smelting and anode forming facility to form the impure nickel into anodes of proper configuration. The capital costs altogether are estimated at \$200M. The cost of an operating facility with a 10 million-pound/year capacity is estimated at \$2M capital and \$6/lb operating costs, which exceed the present value of nickel (\$3.60/lb) because commercial nickel companies operate on a much larger scale. Development costs are estimated at \$3M. To allow sale of the purified nickel, either a <i>de minimis</i> level must be established in the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> level exists.
	Leach/Electrowinning DCON-34-OL Ranking:* M-2-5 (200M;\$3.80/lb)	Predemonstration Leach/Electrowinning is a well-established commercial method for producing nickel from nickel ore, but is not used commercially to refine impure nickel metal. Efficacy: Scientific Ecology Group, Inc. (SEG), has purified nickel to <1 Bq/g of Tc on a small scale. The Tc must be removed from the electrolytic solutions by ion exchange or some other method. The method has not been evaluated for treatment of metals other than nickel. At ORNL, nickel was not used extensively. Waste: Recycle of electrolytic solutions will result in a solid mixed waste bearing the contaminants and traces of the purified metal amounting to roughly 2% by weight of the metal purified.	Development: Pilot-scale testing of this method is needed with special attention to the leaching process, decontamination efficiency, and recycle of the electrolytic solutions. The development work by SEG may satisfy some of this requirement.	A leach/electrowinning plant would require a size-reduction facility, a leaching facility, and a tankhouse for the electrolytic cells. The costs of an operating facility with a 10-million-pound-per-year capacity are estimated by INCO at \$200M capital and \$3.80/lb operating costs. The operating costs exceed the present value of most all metals because commercial nickel companies operate on a much larger scale. The development costs are estimated by INCO at \$440K if the work were done at their facilities. To allow sale of the resulting purified nickel, either a <i>de minimis</i> must be established for the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> standard exists.
	Chemical Foams DCON-8-OL Ranking:* M-4-1 (3M;\$0.50-\$2/ft ²)	Demonstration Widely used throughout the nuclear industry. Foam is used as a carrier of chemical decontamination agents, not as the agent itself. It can be sprayed on and wiped, rinsed, or vacuumed off. Efficacy: Effectiveness for listed contaminants has not been demonstrated. Waste: Small amount of contaminated sulfonated detergents, synthetic wetting agents, coupling agents, rinse water, and drying cloth.	Development: Scale-up/development of the process to a size appropriate for ORNL use. The technology itself is inexpensive, but development and scale-up will probably require support. Improvement: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.	Normal implementation needs. Development Cost: \$1M-\$4M Capital cost: \$50K Operating cost: \$0.50-\$2/ft ²
Local Surface Cleaning				

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, P.L.A., Chap. 7, for potentially applicable proposed and promulgated environmental laws; Signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste- specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning	M Organic Acid Treatments DCON-9-OL Ranking:* M-4-2 (3M;N)	Ionized The technology is currently in use by BNFL at Capenhurst gaseous diffusion plant. BNFL uses citric and sulfuric acids in sequence for removal of U and Tc, respectively, from metal surfaces (mostly wrought aluminum). Efficacy: DF of 300 for U alpha and 40 for Tc beta are reported (11.1 Bq/g alpha, 0.04 Bq/g beta). Has not been demonstrated to remove other radionuclides. Waste: Wastes include citric and sulfuric acids containing uranium and other metal ions and ion exchange media containing the metals. Uranium is difficult to precipitate.	Development: Pilot plant development for waste treatments (ion exchange columns) to verify that we can meet our standards and regulations. More fundamental studies are needed in secondary waste disposal.	Purchase of technology, regulatory compliance for pilot-scale decontamination, and waste treatment demonstrations. BNFL's expertise may reduce the amount of original research, etc. necessary to begin implementation. No present ORNL facility could be adapted for citric acid cleaning, but decontamination with BNFL's citric acid process should pose no undue difficulties. It may well be less costly to implement than the more familiar nitric acid process would be due to the relative nontoxicity and ease of treating secondary waste stream. Development Cost: \$400K-\$1M (rough estimate) Capital cost: \$4M-\$10M if new equipment is required Operating Cost: \$300/Mg (BNFL estimate)
	H Fluoboric Acid Treatment DCON-11-OL Ranking:* H-4-2 (2M;N)	Demonstration Technology was designed specifically for D&D. Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF).	Development: Although the method has seen application at Chernobyl with good results, development work is needed to test applicability at ORNL.	Fluoboric acid exhibits low vapor pressure and requires only standard precautions for acid or base work. The plant can be manufactured in modular form and installed in existing buildings. Hardware (equipment): Fabrication of all key plant parts from polypropylene or from Halar-coated metal. Capital cost in 1990 to set up a plant for decontaminating 5 tons/day of steel was DM 1.3 million (\$774K), excluding development, planning, and buildings. Operating cost will be relatively low; this is a very simple process.
	M Inorganic Acid Treatments DCON-12-OL Ranking:* M-3-0 (4M;N)	Accepted Nitric acid decontamination has been the preferred method at ORNL for cleaning items in various facility operations since the 1940s. In addition, the technique has been widely used at K-25 and Portsmouth. Efficacy: DFs are in the 100 range. Waste: Wastes consist of large quantities of corrosive wastes containing the removed contaminants and require treatment and disposal as mixed waste.	Improvements: Adaptation of modifications to system (i.e., scrubbers, filters, treatment for nitrates and heavy metals) in order to meet regulatory requirements. Possible development of HNO ₃ /HF decontamination methods, with or without ultrasonic agitation. Continuing research and development, waste treatment, and volume reduction. Possible research and development in control of base metal dissolution. Available at X-10, K-25.	Nitrate treatment facility either on site or accessible to decontamination facility. Operating cost: may be relatively high. Nitric acid decontamination was used extensively at most DOE plants, but data is not available regarding costs. Currently, Portsmouth plant is developing a data base to track costs, but it will not contain historical data. Development cost: (improvements) \$400K-1M (rough estimate) Capital cost: <\$4M-\$10M (rough estimate)

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Chem
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Cleaning	<p>M</p> <p>Detergent Treatment DCON-13-OL</p> <p>Ranking:* M-4-0 (0M;>\$1/ft²)</p>	<p>Accepted Surface smearable decontamination with caustic chemicals (soap and water) is accepted technology and is used extensively at ORNL. The caustic hand-scrubbing process was applied to cleaning small items. Efficacy: Since many of the listed contaminants are expected to be fixed, caustic scrubbing is expected to only partially decontaminate the contaminated surfaces. Waste: Wastes would consist of used caustic solution containing the removed contaminants.</p>	<p>None for removal of smearable contamination with carbonates, soaps, etc. Available at X-10, K-25.</p>	<p>This is an established process that could be implemented at ORNL with no major changes. Capital cost: <\$10K Operating costs: >\$1/ft²</p>
	<p>M</p> <p>REDOX Treatments DCON-14-OL</p> <p>Ranking:* M-4-1 (3M;<\$1/ft²)</p>	<p>Demonstration REDOX treatments have been demonstrated for nuclear power plant decontamination, but not for the contaminants of interest. Efficacy: DFs of 10-100 can be expected based on experience in nuclear power plants. Waste: With recycle, waste is spent ion exchange media containing removed contaminants. With neutralization and evaporation, waste is a solid mixed waste containing the removed contaminants and chemicals.</p>	<p>Development: All REDOX techniques will require demonstration to determine their usefulness to decontamination of ORNL operations and applicability to various contaminant films.</p>	<p>Development cost: >\$1M Capital cost: >\$1M Operating Cost: <\$1/ft²</p>
	<p>M</p> <p>Electropolishing DCON-15-OL</p> <p>Ranking:* M-4-2 (3M;>\$1/ft²)</p>	<p>Demonstration Electropolishing is a surface removal technique and the amount of surface removed is proportional to factors such as current, time, and voltage. Electropolishing is essentially a "line of sight" process so cracks, crevices, areas out of sight of, or shadowed by, the electrode will not be decontaminated. Contaminated electrolyte must be removed for complete decontamination to be achieved. Electropolishing is difficult to apply to in-situ equipment.</p>	<p>Development: Primary and secondary waste treatment and solution recycle need to be developed. Cleanup principles (e.g., ion exchange and filtering) are well established, so that only design and demonstration are needed.</p>	<p>Development Cost: ~\$400K to \$1M Operating Cost: >\$1/ft² with additional capital cost.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Tank S.E. of Building 7500	Stainless Steel Fission Products, Corrosion Products	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
<p>↓</p>				
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Chemical Surface Cleaning</p> <p>M</p>	<p>Chelation Treatment DCON-21-OL</p> <p>Ranking:* M-4-2 (1.5M; <\$1/ft²)</p>	<p>Demonstration Efficacy: Excellent DFs. Easy to apply in-situ as agent acts at neutral pH and is non-hazardous; non-fuming, has no gas evolution and is biodegradable. The technology has been employed at various facility operations and nuclear power plant sites achieving acceptable decontamination levels resulting in unconditional release. Waste: Simple waste minimizing treatment and disposal as a non-RCRA waste. Minimizes waste through oxidative destruction of chelate agent, partitioning of organics (including PCBs) and concentration of radionuclides precipitated out in the flocculent sludge which can be further de-watered.</p>	<p>Development Validation of updated chelating agents is needed and is currently underway at ORNL to confirm total efficacy and economic advantage.</p>	<p>Application equipment for in-situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics and/or complete partitioning will be necessary. Spray booth or dipping tank facilities with heating capabilities desirable on-site or accessible by decontamination facility. Operating Cost: <\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Reactor LITR Tank Internal Surfaces LITR Water Piping	<u>Zincalloy</u> UO ₂ SO ₄ , Fission Products, Corrosion Products, Activation Products <u>Steel</u> Corrosion Products, Fission Products, Activation Products <u>Aluminum Piping</u> Fission Products, Corrosion Products, Activation Products	Refer to Vol. 1, PLA, Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Metal
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Refining Methods	<p>H</p> <p>Smelt Purification DCON-31-OL</p> <p>Ranking:* H-3-3 (100M;\$1/lb)</p>	<p>Demonstration Smelt purification of radioactive metals has been performed by a large number of investigators on a lab-scale and by some investigators on a large scale. The metals include mild steel, stainless steel, nickel, copper, monel, aluminum, and others. Metal purification has been demonstrated except for aluminum.</p> <p>Efficacy: Only activation products that are different chemical species from the bulk of the metal can be removed.</p> <p>Waste: Waste are slags, scrubber solutions, chemical trap materials, and HEPA filters.</p>	<p>Development Pilot-scale testing of this method is needed with special attention to decontamination efficiency for activation products.</p>	<p>Scientific Ecology Group (SEG) personnel estimate the costs of metal smelting at roughly \$0.93/lb of metal in 1992 dollars, depending on the type metal and configuration of the metal. Kellogg et al. estimated that the capital and operating costs of smelting the 90,000 tons of DOE scrap metal presently on hand at K-25 could be recovered through sale of the metal if a <i>de minimis</i> were established. The quantity of metals at ORNL is probably not sufficient to be cost effective unless added to this. The technology development needs will require further lab and pilot-scale evaluation. The development costs are roughly estimated at \$3M-\$5M.</p>
	<p>M</p> <p>Electrorefining DCON-32-OL</p> <p>Ranking:* M-2-5 (200M;\$6/lb)</p>	<p>Predemonstration Electrorefining is a well-established commercial technology. However, this technology cannot be considered mature concerning its use for decontaminating radioactive metal because this application is much less established.</p> <p>Efficacy: Only activation products that are different chemical species from the bulk of the metal can be removed.</p> <p>Waste: Waste would be solid mixed waste from assumed treatment of electrolyte solutions for recycle.</p>	<p>Development Pilot-scale testing of this method is needed with special attention to decontamination efficiency for activation products, and recycle of the electrolytic solutions.</p>	<p>An electrorefining plant used for recovery of nickel would also require a smelting and anode forming facility to form the impure nickel into anodes of proper configuration. The capital costs are estimated at \$200M. The cost of an operating facility with a 10 million-pound/year capacity is estimated at \$2M capital and \$6/lb operating costs, which exceed the present value of nickel (\$3.60/lb) because commercial nickel companies operate on a much larger scale. Development costs are estimated at \$3M. To allow sale of the purified nickel, either a <i>de minimis</i> level must be established in the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> level exists.</p>
	<p>M</p> <p>Leach/Electrowinning DCON-34-OL</p> <p>Ranking:* M-2-5 (200M;\$3.80/lb)</p>	<p>Predemonstration Leach/Electrowinning is a well-established commercial method for producing nickel from nickel ore, but is not used commercially to refine impure nickel metal.</p> <p>Efficacy: Scientific Ecology Group, Inc. (SEG) has purified nickel to <1 Bq/g of Tc on a small scale. The Tc must be removed from the electrolytic solutions by ion exchange or some other method. The method has not been evaluated for treatment of metals other than nickel. At ORNL, nickel was not used extensively. Only activation products that are different chemical species from the bulk of the metal can be removed.</p> <p>Waste: Recycle of electrolytic solutions will result in a solid mixed waste bearing the contaminants and traces of the purified metal amounting to roughly 2% by weight of the metal purified.</p>	<p>Development: Pilot-scale testing of this method is needed with special attention to the leaching process, decontamination efficiency. Pilot-scale testing of this method is needed with special attention to decontamination efficiency for activation products, and recycle of the electrolytic solutions. The development work by SEG may satisfy some of this requirement.</p>	<p>A leach/electrowinning plant would require a size-reduction facility, a leaching facility, and a tankhouse for the electrolytic cells. The costs of an operating facility with a 10-million-pound-per-year capacity are estimated by INCO at \$200M capital and \$3.80/lb operating costs. The operating costs exceed the present value of most all metals because commercial companies operate on a much larger scale. The development costs are estimated by INCO at \$440K if the work were done at their facilities. To allow sale of the resulting purified metal, either a <i>de minimis</i> must be established for the USA or permission must be obtained to sell the metal in Europe where a <i>de minimis</i> standard exists.</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	HRT Reactor LITR Tank Internal Surfaces LITR Water Piping	<u>Zircalloy</u> UO ₂ SO ₄ , Fission Products, Corrosion Products, Activation Products <u>Steel</u> Corrosion Products, Fission Products, Activation Products <u>Aluminum Piping</u> Fission Products, Corrosion Products, Activation Products	Refer to Vol. 1, P.L.A., Chap. 6, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for OPR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
<p>Metal Refining Methods</p> <p>L</p>	<p>Transmutation DCON-78-OL</p> <p>Ranking: L-1-10 (500,N)</p>	<p>Preconceptual Evolving Technology Untried for decontamination purposes. Reactors and Strategic Defense Initiative particle accelerators are capable of producing the needed particle fluxes. Efficacy: Can remove only those isotopes with significantly larger cross-sections than the bulk material. Waste: Needs to be determined.</p>	<p>Science: Determine whether activation products have cross sections that allow transmutation without activating the bulk of the material. Work out separation schemes for transmuted materials and determine wastes. Development: Demonstrate feasibility of process and gather cost data.</p>	<p>High particle fluxes from an accelerator or a nuclear reactor are needed for this technology. Development Cost: \$0.1-10M Capital Cost: ~ \$500M Operating Cost: Prohibitively high</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

September 1993

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Pavement Over 55-gal Drum Bldg. 7500 Cells Other Contaminated Asphalt Pavement Surfaces	Asphalt Pavement Fission Products, Corrosion Products Asphalt Pavement Various Radionuclides	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination	Mech Rem
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	H Ultrahigh-Pressure Water DCON-35-OL Ranking:* H-5-1 (1.7M;\$1/ft ²)	Accepted Technology has been used by industry. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the asphalt. Waste: Unless a recycle system is developed, waste would be 3-5 gal water/ft ² cleaned that contains ~0.01 ft ³ asphalt residue, plus the contaminants removed.	Improvement: To minimize waste generation, a system is needed to treat the water so that it can be recycled. Improvement: Automation.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$1.3M Capital cost: ~\$500K Operating cost: ~\$1/ft ²
	H Scabblers/Scarifiers DCON-37-OL Ranking:* H-4-2 (0.5M;\$5/ft ²)	Accepted Efficacy: Mechanical scabblers are widely used. They are generally effective, but leave some hot spots. Waste: ~0.01 ft ³ removed substrate (1/16" cut) containing removed contaminants per ft ² of substrate decontaminated.	Improvement: Automation.	Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating cost: ~\$1/ft ² (More than shot blasting)
	H Grit Blasting DCON-38-OL Ranking:* H-4-0 (<0.1\$/ft ²)	Accepted Has been used successfully for many applications in the nuclear industry. Efficacy: Technology is generally effective. Waste: Waste is ~0.01 ft ³ removed asphalt (1/16" cut) containing removed contaminants per ft ² of asphalt decontaminated plus spent grit.	Improvement: Automation.	Normal implementation needs. Development cost: None Capital cost: ~\$500K Operating cost: \$-5/ft ²
	H Centrifuge Cryogenic CO ₂ Pellet Blasting DCON-39-OL Ranking:* H-5-2 (1.0M;<\$1/ft ²)	Demonstration Centrifuge pellet acceleration has been demonstrated in the DOE fusion energy program, as a decontamination tool in the Y-12 facility waste minimization effort, and more recently as an aircraft repaint mechanism. Efficacy: Technology is likely to be successful with very high decontamination factors. Waste: The waste will be HEPA filters containing the combination of contaminants and substrate material.	Development: Demonstration of mobile system with high velocity pellets delivered at a sufficient rate and adequate collection of removed contaminants. Improvement: 1) Demonstration of an on-line, real time contaminant sensor which would minimize the decontamination effort and limit the waste stream; 2) automation	Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO ₂ containing the removed contaminants, plus oxygen-depletion precautions. Development cost: <\$1M Capital cost: \$100K Operating cost: <\$1/ft ²
	H Ice Blasting DCON-40-OL Ranking:* H-5-1 (<1.0M;\$1/ft ²)	Demonstration Efficacy: Efficacy of commercial system for this application needs demonstration. Waste: Waste would be about 14 to 18 gallons per hour waste water containing removed contaminants.	Development: Demonstration of efficacy of commercial system. Improvement: Automation/robotics.	A water treatment system is needed to minimize liquid wastes from this technology. Development cost: \$200K Capital cost: \$100K-\$1M Operating cost: <\$1/ft ²

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Mechanical Surface Removal Methods	<p>H</p> <p>Supercritical CO₂ Blasting DCON-41-OL</p> <p>Ranking:* H-5-1 (0.75+M; >\$1/ft²)</p>	<p>Predemonstration Efficacy: Likely to be effective with nearly infinite decontamination factors. Waste: Waste would be removed concrete and contaminants contained in a cyclone and a HEPA filter.</p>	<p>Development: Investigate the effect of operating parameters on removal rates and removal and collection efficiencies for contaminants. Demonstrate efficacy for contaminants of interest.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants; plus oxygen depletion precautions. Development cost: \$250K-1M Capital cost: ~\$500K Operating Cost: \$1+/ft²</p>
	<p>M</p> <p>Plastic Pellet Blasting DCON-42-OL</p> <p>Ranking:* M-4-0 (<0.1M; \$1/ft²)</p>	<p>Accepted Plastic pellet blasting is a widely used alternate to sand blasting for applications in which it is desired to impart minimal damage to the substrate. Efficacy: Technology should remove smearable, but not fixed contamination, from asphalt. Waste: Waste would be spent plastic pellets plus removed contamination.</p>	<p>Improvement: Develop and demonstrate system for processing waste. Improvement: Minimize blast media erosion to minimize waste; automation/robotics, especially for walls, etc.; improve containment of waste and removed contaminants.</p>	<p>A system for processing waste to an acceptable form is needed. Improvements: Development cost: \$5.5M+ Capital cost: ~\$50K Operating Cost: \$0.20-\$2.15/ft²</p>
	<p>H</p> <p>Hand Grinding, Honing, Scraping DCON-43-OL</p> <p>Ranking:* H-2-0 (<0.1M; \$1/ft²)</p>	<p>Accepted Efficacy: Grinding with hand-held power grinders has been successfully used for small-scale decontamination. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>None Available at X-10, K-25.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: None Capital cost: \$150 (\$5K with vacuum system and \$50-500K with remote operation) Operating cost: ~\$1/ft²</p>
	<p>H</p> <p>Automated Grinding DCON-44-OL</p> <p>Ranking:* H-2-1 (\$1M; \$1M; N)</p>	<p>Conceptual Grinding has been successfully used for small-scale decontamination. This grinding was done with hand-held power grinders. Remotely operated grinding equipment is available, but no references to its use for decontamination have been found. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the asphalt. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: The applicability of this technology to items with rad contamination should be demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: \$600K Capital cost: \$250K</p>
	<p>M</p> <p>Concrete Milling DCON-47-OL</p> <p>Ranking:* M-1-2 (<1M; \$0.75/ft²)</p>	<p>Accepted The equipment is commercially available, but no reference to its use for decontamination has been found. This technology is suited for horizontal surfaces only. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the asphalt. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Improvement: The technology to operate this equipment remotely needs to be developed and demonstrated.</p>	<p>A collection system for the vaporized deposits would be needed to implement this technology. Development cost: None Capital cost: \$400K Operating cost: \$1.50/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	<ul style="list-style-type: none"> Pavement Over 55-gal Drum, Bldg. 7500 Cells Other Contaminated Asphalt Pavement Surfaces 	<ul style="list-style-type: none"> Asphalt Pavement Fission Products, Corrosion Products Asphalt Pavement Various Radionuclides 	<p>Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	Decontamination	Mech Remc
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 					Therm Remc

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Removal Methods	<p>L</p> <p>Explosive DCON-48-OL</p> <p>Ranking:* L-2-5 (4M; \$50/ft²)</p>	<p>Demonstration Blasting has been used to decontaminate nuclear reactor shielding. Demonstration will be needed for other applications. Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures. Efficacy: The decontamination efficiency should be essentially 100% unless the contamination has diffused deep into the asphalt. Waste: Waste would be removed contaminants and substrate contained in filters and HEPA filters.</p>	<p>Development: Improvements in the methods of applying explosives and in the uniformity of the detonation are needed. The explosion will generate toxic organic vapors. The technology to control toxic vapors formed by the explosion must be developed and demonstrated.</p>	<p>A certified blasting technician will be needed. Capital cost: \$50K Operating cost: \$50/ft² Development cost: \$1-4M</p>
Chemical Surface Removal Methods	<p>M</p> <p>Laser Etching and Ablation DCON-74-OL</p> <p>Ranking:* M-4-4 (3.5M; >\$1/ft²)</p>	<p>Predemonstration Several research groups at university and government laboratories have used the technology to remove radiological and organic contaminants from various surfaces. Efficacy: The technique is slow to remove large deposits. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.</p>	<p>Development: Existing lasers, delivery systems, and filtration systems need to be integrated into a prototype system for demonstration.</p>	<p>A collection system for the vaporized contaminants would be needed to implement this technology. Development cost: \$2M+ Capital cost: \$0.5-1M/machine Operating Cost: >\$1/ft²</p>
	<p>H</p> <p>Flashlamp Cleaning DCON-77-OL</p> <p>Ranking:* H-3-3 (2.5M; \$1/ft²)</p>	<p>Predemonstration Flashlamp systems are being used to remove organic contamination from metals, precious metals, and fragile substrates. Hanford-Westinghouse Laboratory is conducting tests of xenon flashlamp systems for removing radiological contamination from surfaces inside metal storage vessels. Efficacy: Technology is likely to be effective for surface contamination. Waste: Wastes would be removed deposits, some substrate material, and HEPA filters from the filtration system.</p>	<p>Development: Commercially available flashlamp systems need to be evaluated for radiological decontamination.</p>	<p>A collection system for the vaporized contaminants would be needed to implement this technology. Development cost: ~\$2.5 M Capital cost: \$50-100K/machine Operating Cost: ~1.00/ft²</p>
	<p>H</p> <p>Compressed Air Cryogenic CO₂ Pellet Blasting DCON-51-OL</p> <p>Ranking:* H-4-1 (0.7M; >\$1/ft²)</p>	<p>Demonstration This technology is commercially available. It has been used at nuclear reactor sites to decontaminate hand tools and some equipment. Efficacy: The efficacy of this technology for removing the listed contaminants from asphalt has not been demonstrated and is doubtful. Waste: Wastes would be HEPA filters filled with the removed contaminants.</p>	<p>Development: Evaluate technology that has recently been demonstrated in Department of Defense programs regarding automation and improvements in pellet delivery.</p>	<p>Design and construction of a vacuum waste-handling system with HEPA filters to handle the vaporized CO₂ containing the removed contaminants. Development cost: about \$0.50M Capital cost: About \$200,000 Operating Cost: ~\$1/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Contamination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Thermal Surface Removal Methods	<p>M</p> <p>High-Pressure Water DCON-52-OL</p> <p>Ranking:* M-3-1 (1.3M; <\$1/ft²)</p>	<p>Accepted: High pressure water blasting has been used very successfully to decontaminate various large and complex surfaces at nuclear power plants.</p> <p>Efficacy: Technique is expected to be effective with a DF of about 50 for loosely adhering contamination. DFs will be higher if chemical cleaning agents are also used.</p> <p>Technique: is expected to be ineffective for fixed contamination on asphalt.</p> <p>Waste: Waste is 4 to >100 gpm of contaminated waste water.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused.</p> <p>Improvement - Remote operation: will necessitate the adaptation of the high pressure water and vacuum collection systems to robotic system control.</p>	<p>A water treatment system is needed to minimize waste.</p> <p>Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>M</p> <p>Superheated Water DCON-53-OL</p> <p>Ranking:* M-4-1 (1.4M; \$1/ft²)</p>	<p>Accepted: Technology is available and has been used by industry.</p> <p>Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has soaked into the asphalt. On finished asphalt, technology may drive contaminants deeper into substrate.</p> <p>Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused.</p> <p>Improvement - Remote operation: will necessitate the adaptation of the superheated water and vacuum collection systems to robotic system control.</p>	<p>A water treatment system is needed to minimize waste.</p> <p>Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: About \$175K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>M</p> <p>Water Flushing DCON-54-OL</p> <p>Ranking:* M-4-1 (1.3M; <\$1/ft²)</p>	<p>Accepted: Flushing with hot water is often used following scrubbing, especially on floors.</p> <p>Efficacy: The technique is not effective on fixed insoluble contamination. On finished asphalt, technology may drive contaminants deeper into substrate.</p> <p>Waste: The waste generated is the contaminated water from the flushing operation.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the water flushing operation.</p>	<p>A water treatment system is needed to minimize liquid wastes from this technology.</p> <p>Development cost: About \$1.2M Capital cost: <\$5K Operating cost: <\$1/ft²</p>
	<p>M</p> <p>Steam Cleaning DCON-55-OL</p> <p>Ranking:* M-4-1 (1.3M; \$1/ft²)</p>	<p>Accepted: The technique has proven useful, especially on complex shapes and large surfaces.</p> <p>Efficacy: Technology should be effective except for fixed insoluble contamination or contamination that has soaked into the asphalt. On finished asphalt, technology may drive contaminants deeper into substrate.</p> <p>Waste: Waste will be 0.4 to 2.0 gpm wastewater containing removed contaminants.</p>	<p>Improvement - To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be reused.</p> <p>Remote operation: will necessitate the adaptation of the steam and vacuum collection systems to robotic system control.</p>	<p>Normal implementation needs.</p> <p>Development cost: Water treatment system: About \$1.2M Remote operation: \$3-4M Capital cost: \$50K-\$75K (about \$250K with remote operation) Operating Cost: <\$1.00/ft²</p>
	<p>H</p> <p>Hand Brushing Used to Remove Surface Contamination DCON-56-OL</p> <p>Ranking:* H-2-0 (0M; \$1/ft²)</p>	<p>Accepted: Brushing is a common decontamination technique.</p> <p>Efficacy: Brushing is effective for loose contamination only.</p> <p>Waste: Waste consists of removed contamination plus other loose debris.</p>	<p>None Available at K-25.</p>	<p>Normal implementation needs.</p> <p>Capital cost: negligible Operating cost: <\$1.00/ft² Development cost: none</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	<ul style="list-style-type: none"> Pavement Over 55-gal Drum, Bldg. 7500 Cells Other Contaminated Asphalt Pavement Surfaces 	<ul style="list-style-type: none"> Asphalt Pavement Fission Products, Corrosion Products Asphalt Pavement Various Radionuclides 	<p>Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.</p>	Decontamination	Surfa
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Cleaning Methods	<p>M</p> <p>Automated Brushing DCON-57-OL</p> <p>Ranking: M-3-2 (1M;\$300/ft)</p>	<p>Demonstration: This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes. Efficacy: Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates. Waste: Waste would be removed contamination plus any other loose debris.</p>	<p>Development: Tests to demonstrate that this technology is effective for the problems at ORNL.</p>	<p>Vacuum Collection system Development cost: \$200K-1M Capital cost: \$250K (remotely operated system) Operating cost: \$300/linear foot of pipe</p>
	<p>M</p> <p>Sponge Blasting DCON-58-OL</p> <p>Ranking: M-3-1 (1.3M;\$2/ft²)</p>	<p>Accepted: Although the technology is relatively new, it is currently being used by at least two sites including a nuclear power plant. Efficacy: Extensive data on decontamination factors are not available. With the aggressive sponges, which are impregnated with abrasives, this technology may be effective for the listed contaminants and substrates. Waste: Wastes consist of about 0.01 ft³ of blasting media and removed contaminants per ft² of area decontaminated plus any liquid cleaning agents that may have been added.</p>	<p>Improvement: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the sponge blasting operation.</p>	<p>A wastewater treatment / recycle system will be needed to use this technology. Development cost: About \$1.2M Capital cost: Sponge blasting system: About \$20K (with sifter system) Operating Cost: About \$2/ft²</p>
	<p>M</p> <p>Solvent Washing to Remove Radiological Contamination DCON-61-OL</p> <p>Ranking: M-3-2 (1M;N)</p>	<p>Conceptual: Plutonium contaminated items at Richland, WA were rinsed with Freon. The vendor who supplied the equipment for Richland ten years ago no longer sells it. Efficacy: This technique is mainly applicable to smearable contamination. Waste: Waste would be spent solvent containing removed contaminants.</p>	<p>Science: Solvents that are less damaging to the environment need to be identified and demonstrated. Available in Private Sector.</p>	<p>Vapor collection system Capital cost: \$300K (1980 dollars) Development cost: <\$1M to identify and demonstrate the replacement solvent. Operating cost: an average of 7.5 minutes per item was required when decontaminating small items.</p>
	<p>M</p> <p>Strippable Coatings DCON-63-OL</p> <p>Ranking: M-3-0 (<0.1M;>\$1/ft²)</p>	<p>Accepted: Technology has been used for decontamination applications involving hazardous and radioactive contaminants. Efficacy: Decontamination factors of one to several hundred can be expected with two applications. Waste: Waste is a solid polymer (volume = 1 mm x surface area decontaminated) containing the removed contaminants.</p>	<p>Improvement: Develop coatings with lower material costs and greater ease of application.</p>	<p>Normal implementation needs. Capital cost: Negligible Operating cost: \$1-\$1.40/ft²</p>

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Pavement Over 55-gal Drum Bldg. 7500 Cells Other Contaminated Asphalt Pavement Surfaces	<u>Asphalt Pavement</u> Fission Products, Corrosion Products <u>Asphalt Pavement</u> Various Radionuclides	Refer to Vol. 1, PLA, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Decontamination
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 				

amination

Alternatives	Technologies	Status	Science/ Technology Needs	Implementation Needs
Chemical Surface Cleaning Methods	Vacuum Cleaning DCON-7-OL Ranking: L-1-2 (2M;N)	Accepted Vacuum cleaners have long been used to clean up loose contamination at the gaseous diffusion plants. Efficacy: Since little of the listed contaminants are expected to be in loose form, this technique is not expected to be effective in cleaning asphalt pavement at ORNL. Waste: The waste is a HEPA filter filled with the contaminants and other materials that are removed by the vacuum.	None	Normal Implementation needs. Capital cost: <\$10K Operating cost: >\$1/ft ²
	Ultrasonic Cleaning DCON-65-OL Ranking:*	Accepted Ultrasonic cleaning has been used for many years in the private sector and in government installations for removing surface contamination from relatively small metal parts which can fit into an ultrasonic bath. Efficacy: Technology will work well for loosely bound surface deposits, but not for tightly bound materials. Waste: Wastes would be spent ultrasonic bath solutions containing any removed contaminants.	Improvement: Definition of acceptable cleaning liquids which (1) are not hazardous, (2) can be separated from the contaminants, and (3) can be reused to minimize secondary wastes. Improvement: More aggressive cleaning action.	Requires removal, disassembly, and size reduction of contaminated asphalt. Development cost (improvements): \$1M Capital cost: \$10K-\$100K Operating cost: \$2 - \$10/ft ² or more

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for Decom

The identification of the technologies required to use remedial action, and waste management at ORNL was these technologies is to provide support for other necessary decontamination, and dismantlement. Hence, in this section as these "other" decommissioning activities and no attention. For example a robotic platform used to deploy a sensor dismantlement tools.

The robotics/ automation technologies were grouped into (1) Control, and (2) Sensors; with various sub-groups identified. These were selected for this section on the basis of the following: deployment of tools and sensors, adaptability of automation, waste by reduction or elimination of clothing exchange, handling redundant tasks.

tamination and Decommissioning

the robotics/ automation in the decommissioning, based upon the premise that the primary purpose of necessary activities such as characterization, action of the diagram the problem areas are identified. An attempt to differentiate between activities was made, but it was assumed to be equally applicable to deploy

and into three main categories: (1) Mechanical, (2) identified under each of the categories. Technologies and considerations: speed and economy in the use of automated equipment to repetitive tasks, ability to minimize requirements, and reliability and efficiency in

Robotics and Automation for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements	
<ul style="list-style-type: none"> • Clean Up Legacy Waste • Prevent Future Insult • Develop Environmental Stewardship 	Stabilized Hot Cells Abandoned Hot Cells Reactors and Support Facilities Storage Buildings	<p>Robotics/automation (R/A) is a cross-cutting technology that provides support to characterization, decontamination, and dismantlement activities. Specifically support is provided for the following tasks.</p> <p>I. Characterization R/A provides methods of deploying sensors and instruments required for in-situ characterization, monitoring, and surveying as described by the Characterization Data Sheets contained in Vol. 3. R/A provides methods for deploying tools to collect and prepare samples for subsequent analysis in analytical laboratories. These technologies are described in ROBA-57 and -59-OL. R/A provides the technologies required for the automation of analytical laboratories as described in ROBA-55 and -56-OL.</p> <p>II. Decontamination Provides methods of deploying decontamination tools and/or performing tasks in areas sufficiently hazardous to preclude human access. Most of these high hazard areas will be encountered in hot cells or shut-down reactors. R/A will also be required for those tasks that generate secondary environmental hazards, e.g., grinding, carbon dioxide blasting, etc.</p> <p>III. Dismantlement Provides methods of deploying dismantlement tools and/or performing tasks in areas within buildings or structures that are sufficiently hazardous to preclude human access. Similar to the decontamination activities, most of these tasks will be in hot cell or shut-down reactors.</p> <p>IV. Waste Retrieval R/A provides the vehicles, mobile platforms, or excavation systems necessary to retrieve radiologically or chemically hazard wastes or soils from waste fields or impoundments. Mobile platforms suitable for these tasks are described in ROBA-1-OL.</p> <p>V. Waste Sorting and Packaging R/A provides the bridge-mounted robotic systems (ROBA-8-OL), the manipulation systems, (ROBA-16-OL), and the End-of-Arm Tooling (ROBA-23 through -26-OL) required for the sorting and repackaging of RH-TRU waste.</p> <p>VI. Surveillance and Inspection R/A provides the vehicles or mobile platforms (ROBA-1-OL) and sensors (ROBA-43 through -46-OL) required for the periodic surveillance and inspection of waste containers in above-ground storage areas.</p>	Refer to Vol. 1, Pt. A, Chap. 7; for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Robotics/Automation	Mecha
EM Problems <ul style="list-style-type: none"> • Facility Decontamination and Decommissioning (D&D) • Remedial Action (RA)—Soils, Ground Water and Surface Water • Waste Management (WM) 					

Examination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Technical—Mobility	E Wheeled/Tracked Vehicle ROBA-1-OL <i>Ranking:*</i> E-5-2 (\$3M;N)	Accepted Efficacy: An essential technology. High probability of being useful for reactors, support buildings, and storage areas. Waste: Possible emissions. Decontamination of system after use. TTP Match	Development: -Improved controls to allow more autonomy of operation. -Improved design for decontamination after use.	-Training of operators in advanced control stations. -Development Costs: \$3.0M
	M Internal Duct/Pipe Crawler ROBA-5-OL <i>Ranking:*</i> M-3-2 (\$1M;N)	Predemonstration Efficacy: High for straight runs of pipe without obstacles; low if obstacles are present. Waste: Decontamination of system after use. TTP Match	Development: -Miniaturization of sensors/tooling. -Ability to negotiate around obstructions. -Cable management system for tethered equipment.	-No unusual needs -Development Costs: \$1.0M
	M External Duct/Pipe Crawlers ROBA-6-OL <i>Ranking:*</i> M-3-4 (\$5M;N)	Predemonstration Efficacy: High if obstacles are not present; low if obstacles are present. Waste: Decontamination of system after use. TTP Match	Development: -Robotic compatibility of tooling. -Ability to negotiate around obstructions.	-No unusual needs -Development Costs: \$5.0M
	M Specialized Robotic Deployment Platforms ROBA-7-OL <i>Ranking:*</i> M-4-3 (\$5M;N)	Demonstration Efficacy: Low for most applications in D&D. Unique applications may require extensive development. Waste: Frequent decontamination with resulting waste fluids may be necessary. TTP Match	Development: -Specialized controls and sensors -Improved vision systems	-Cold test beds and operator training. -Development Costs: \$5.0M
	M Bridge-Mounted Robotic Platforms ROBA-8-OL <i>Ranking:*</i> M-2-1 (\$5M;N)	Accepted Efficacy: High, although number of applications may be limited. Waste: Minimal waste will be generated.	None	-Standardization -Development Costs: \$1.0M
	M Long Arm Deployed Robotic Platforms ROBA-9-OL <i>Ranking:*</i> M-4-3 (\$5M;N)	Accepted Efficacy: Medium. Accurate positioning may be a problem. Limited applications in D&D. Waste: Hydraulic fluid during operation. Decontamination fluids after use.	Development: -Flexible body control. -End-point sensing. -Collision avoidance. -Weight-to-payload ratio reduction.	-Cold test beds -Extensive operator training -Development Costs: \$5.0M
	E Power Sources for Mobile Platforms ROBA-10-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Accepted Efficacy: An essential technology. Accepted status means high efficacy. Waste: Batteries, and exhaust emissions.	Technology Improvement: -Energy storage capacity -Duty cycle availability -Current capacity/discharge rate -Emission control	-No unusual needs Development Costs: \$1 to 4M
	E Failure Recovery Systems for Mobile Platforms ROBA-11-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Accepted Efficacy: High. This is an essential technology that is well established. Waste: Little or no waste.	None	-No unusual needs -Development Costs: \$0.5M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for D

Decontamination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Mechanical-Mobility	M Transportation Systems for Mobile Platforms ROBA-12-OL <i>Ranking:*</i> M-3-1 (\$0.5M;N)	Accepted for small robotic platforms Predemonstration for large platforms or unique devices Efficacy: Low. Waste: No waste. The purpose of the technology is to minimize decontamination waste. TTP Match	Development: -Light-weight containers for medium and heavy duty mobile platform. -Containers that can be easily decontaminated.	-No unusual needs -Development Costs: \$0.5M
	E Data/Signal Transmission ROBA-13-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Accepted Efficacy: High. An essential technology. Specific application may determine type of system required. Waste: None. TTP Match	None	-Testing in representative environments. -Development Costs: \$1.0M
Mechanical-Manipulation	H Long-Reach Manipulator-Light Duty ROBA-14-OL <i>Ranking:*</i> H-4-2 (\$2M;N)	Predemonstration Efficacy: Medium. Positioning accuracy and control may be problems. Waste: Hydraulic fluid during operation; decon fluid after use. TTP Match	Development: -Flexible body control -End-point sensing. -Collision avoidance. -Light-weight, small cross section design.	-Cold test beds, -Extensive operator training. -Development Costs: \$2.0M
	M Long-Reach Manipulator-Heavy Duty ROBA-15-OL <i>Ranking:*</i> M-4-3 (\$5M;N)	Predemonstration Efficacy: Low. Positioning accuracy and control may be problem Waste: Hydraulic fluid during operation; decon fluid after use. TTP Match	Development: -Flexible body control -End-point sensing. -Collision avoidance. -Weight-to-payload ratio reduction.	-Cold test beds. -Extensive operator training. -Development Costs: \$5.0M
	E Dexterous Manipulators ROBA-16-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Demonstration Efficacy: High. An essential technology. Waste: Possible hydraulic fluid during use and decon fluid after use. TTP Match	Development: -Redundant manipulator planning and control. -Modular design. -Nonreplica master/slave operation. -Cooperating and coordinated dual arm control.	-Operator Training on nonreplica master controllers. -Development Costs: \$1.0M
	H Compact, High Capacity Manipulators ROBA-19-OL <i>Ranking:*</i> H-5-1 (\$1M;N)	Evolving Efficacy: High. Constrained access may require this technology.	Development: -Compact, high-output, electrical motors. -Design/fabrication/testing of compact arms.	-No unusual needs -Development Costs: \$1.0M
Mechanical-Mechanisms	H Precise Programmable Motions ROBA-20-O <i>Ranking:*</i> H-5-1 (\$0.5M;N)	Demonstration Efficacy: High. Particularly useful in analytical laboratory. Waste: None. TTP Match	Improvement: -Standardization of mechanical interfaces.	-No unusual needs -Development Costs: \$0.5M
	H Tool Caddies ROBA-21-OL <i>Ranking:*</i> H-4-1 (\$0.5M;N)	Demonstration Efficacy: High. Will increase efficiency of operations and minimize waste. Waste: Decontamination after use.	None	-No unusual needs -Development Costs: \$0.5M
	M Stabilization/Support Mechanisms or Booms ROBA-22-OL <i>Ranking:*</i> M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Some applications may require secondary support due to deteriorating condition of facility. Waste: Minimal. Some decon waste.	Improvement: -Use of high-strength advanced materials.	-No unusual needs -Development Costs: \$0.5M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for Decontamination

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	Stabilized Hot Cells Abandoned Hot Cells Reactors & Support Facilities Storage Buildings	<p>Robotics/automation (R/A) is a cross-cutting technology that provides support to characterization, decontamination, and dismantlement activities. Specifically support is provided for the following tasks.</p> <p>I. Characterization R/A provides methods of deploying sensors and instruments required for in-situ characterization, monitoring, and surveying as described by the Characterization Data Sheets contained in Vol. 3. R/A provides methods for deploying tools to collect and prepare samples for subsequent analysis in analytical laboratories. These technologies are described in ROBA-57 and -59-OL. R/A provides the technologies required for the automation of analytical laboratories as described in ROBA-55 and -56-OL.</p> <p>II. Decontamination Provides methods of deploying decontamination tools and/or performing tasks in areas sufficiently hazardous to preclude human access. Most of these high hazard areas will be encountered in hot cells or shut-down reactors. R/A will also be required for those tasks that generate secondary environmental hazards, e.g., grinding, carbon dioxide blasting, etc.</p> <p>III. Dismantlement Provides methods of deploying dismantlement tools and/or performing tasks in areas within buildings or structures that are sufficiently hazardous to preclude human access. Similar to the decontamination activities, most of these tasks will be in hot cell or shut-down reactors.</p> <p>IV. Waste Retrieval R/A provides the vehicles, mobile platforms, or excavation systems necessary to retrieve radiologically or chemically hazard wastes or soils from waste fields or impoundments. Mobile platforms suitable for these tasks are described in ROBA-1-OL.</p> <p>V. Waste Sorting and Packaging R/A provides the bridge-mounted robotic systems (ROBA-8-OL), the manipulation systems, (ROBA-16-OL), and the End-of-Arm Tooling (ROBA-23 through -26-OL) required for the sorting and repackaging of RH-TRU waste.</p> <p>VI. Surveillance and Inspection R/A provides the vehicles or mobile platforms (ROBA-1-OL) and sensors (ROBA-43 through -46-OL) required for the periodic surveillance and inspection of waste containers in above-ground storage areas.</p>	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Robotics/Automation
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				

Examination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Mechanical-End-of-Arm- g	E End-Effectors/Alternatives ROBA-23-OL <i>Ranking:*</i> E-5-2 (\$1M;N)	Demonstration (Predemonstration for multi-fingered grippers) Efficacy: High. An essential technology. Primary interface with tools. Waste: Minimal. TTP Match	Improvement: -Robotic compatibility of tooling.	- Extensive operator training. -Development Costs: \$1.0M
	M End-Effector Changeout Mechanisms ROBA-24-OL <i>Ranking:*</i> M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications may be limited. Waste: Minimal decon waste. TTP Match	None	-Integration and testing with specific robotic systems. -Development Costs: \$0.5M
	H General Gripper/Tool Interface ROBA-25-OL <i>Ranking:*</i> H-4-1 (\$0.5M;N)	Accepted Efficacy: High. Many potential applications for tool/sensor gripping. Waste: Minimal decon waste.	None	-No unusual needs. -Development Costs: \$0.5M
	M Force Limiting/Compliant Mechanisms ROBA-26-OL <i>Ranking:*</i> M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Limited applications in D&D. Waste: Minimal	None	-No unusual needs. -Development Costs: \$0.5M
Tools-Algorithms	E Control Modes ROBA-27-OL <i>Ranking:*</i> E-5-N (\$N;N)	Accepted for Teleoperation Demonstration for: Preprogramming Predemonstration for other modes Efficacy: High. An essential technology. Type of control mode will depend on application. Waste: None.	Development: -Operator assistance technologies. -Sensor interpretation. -Task planning. Improvement: -Better human-machine interfaces.	-University level research. -Development Costs: \$N
	E Vehicle/Mobility-Driving ROBA-28-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Accepted Efficacy: High. An essential technology. Many potential applications. Waste: None.	Development: -Integration of driving algorithms with human-machine interface. -Fuzzy logic driving algorithms.	-Operator training. - Development Costs: \$0.5M
	M Vehicle/Mobility-Navigation ROBA-29-OL <i>Ranking:*</i> M-4-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Few applications in D&D. Waste: None. TTP Match	Development: -Path planning with nonholonomic constraints. -Real-time sensor feedback.	-Operator training in Global Positioning Systems. -Development Costs: \$0.5M
	H Joint Control ROBA-30-OL <i>Ranking:*</i> H-4-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications may be limited. Usage assumes desired trajectory is known. Waste: None. TTP Match	Development: -Special purpose control algorithms.	-University level research. -Development Costs: \$0.5M
	H Cartesian Control ROBA-31-OL <i>Ranking:*</i> H-4-1 (\$1M;N)	Demonstration Efficacy: Medium. Applications limited for D&D. Operator interaction is more intuitive than other control schemes. Waste: None	None	-No unusual needs. -Development Costs: \$1.0M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for E

Decontamination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Controls-Algorithms	H Special Purpose Control ROBA-32-OL <i>Ranking:*</i> H-4-2 (\$1.5M;N)	Predemonstration Efficacy: Medium. Will lead to higher efficiency and safety. Waste: None. TTP Match	Development: -Advanced testbeds for testing and evaluating candidate algorithms.	-Software development. -Development Costs: \$1.5M
	M Redundancy Control ROBA-33-OL <i>Ranking:*</i> M-3-2 (\$2M;N)	Predemonstration Efficacy: Medium. Arms with greater than 6 D.O.F. may be required for constrained areas. Waste: None. TTP Match	Development: -Advanced testbeds for testing and evaluating candidate algorithms.	-Software development. -Development Costs: \$2.0M
	M Combined Mobility/Manipulation ROBA-34-OL <i>Ranking:*</i> M-2-2 (\$1M;N)	Evolving Efficacy: Low. Minimal improvements in efficiency could be realized. Waste: None.	Development: -Redundancy resolution. -real-time task planning.	-Software development. -Development costs: \$1.0M
	H Safety-Collision Avoidance ROBA-35-OL <i>Ranking:*</i> H-4-1 (\$1M;N)	Accepted Efficacy: Medium. An increase in efficiency would be realized and potential damage to equipment minimized. Waste: None. TTP Match	None	-Use of customized sensor sites. -Development Costs: \$1.0M
	H Safety-Load/Rate Limiting ROBA-36-OL <i>Ranking:*</i> H-3-1 (\$0.5M;N)	Accepted Efficacy: Medium. An increase in efficiency would be realized and potential damage to equipment minimized. Waste: None.	Improvement: -Testing of load- and rate-limiting algorithms.	-Software development. -Development Costs: \$0.5M
	E Emergency Shutdown ROBA-37 <i>Ranking:*</i> E-4-1 (\$0.5M;N)	Accepted for Teleoperation Predemonstration for automated shutdown. Efficacy: High. An essential technology to prevent catastrophic damage to equipment. Waste: None.	None	-Software Development. -Development Costs: \$0.5M
Controls-Human/Machine Interface	E Console-Fixed/Mobile/Suitcase ROBA-38-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Demonstrated for fixed or mobile stations. Evolving for suitcase control stations. Efficacy: High. An essential technology for use of robotics/automation. Waste: None.	Improvement: -Reliability and capacity of data links requires improvements.	-Improved human-machine interfaces. -Development costs: \$0.5M
	M Console-Data Handling Methods ROBA-39-OL <i>Ranking:*</i> M-3-1 (\$1M;N)	Evolving Efficacy: Medium for D&D activities. The need to process, store, and retrieve data is limited. Waste: None. TTP Match	Development: -Design of heterogeneous data base management systems. -Integration of heterogeneous data sources. -Data fusion.	-Development Costs: \$1.0M
	H Operator Interface Command Input ROBA-40-OL <i>Ranking:*</i> H-3-1 (\$0.5M;N)	Evolving Efficacy: High. Minimizes human error and increases operational efficiency. Waste: None. TTP Match	Development: -Language expansion. -Validation of eye-gaze measures/parameters. -Head tracking	-Specialized operator training. -Development Costs: \$0.5M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for Decon

EM Goals	ORNL Problems	Problem Areas/Constituents	Reference Requirements	Subelements
<ul style="list-style-type: none"> Clean Up Legacy Waste Prevent Future Insult Develop Environmental Stewardship 	Stabilized Hot Cells Abandoned Hot Cells Reactors & Support Facilities Storage Buildings	<p>Robotics/automation (R/A) is a cross-cutting technology that provides support to characterization, decontamination, and dismantlement activities. Specifically support is provided for the following tasks.</p> <p>I. Characterization R/A provides methods of deploying sensors and instruments required for in-situ characterization, monitoring, and surveying as described by the Characterization Data Sheets contained in Vol. 3. R/A provides methods for deploying tools to collect and prepare samples for subsequent analysis in analytical laboratories. These technologies are described in ROBA-57 and -59-OL. R/A provides the technologies required for the automation of analytical laboratories as described in ROBA-55 and -56-OL.</p> <p>II. Decontamination Provides methods of deploying decontamination tools and/or performing tasks in areas sufficiently hazardous to preclude human access. Most of these high hazard areas will be encountered in hot cells or shut-down reactors. R/A will also be required for those tasks that generate secondary environmental hazards, e.g., grinding, carbon dioxide blasting, etc.</p> <p>III. Dismantlement Provides methods of deploying dismantlement tools and/or performing tasks in areas within buildings or structures that are sufficiently hazardous to preclude human access. Similar to the decontamination activities, most of these tasks will be in hot cell or shut-down reactors.</p> <p>IV. Waste Retrieval R/A provides the vehicles, mobile platforms, or excavation systems necessary to retrieve radiologically or chemically hazard wastes or soils from waste fields or impoundments. Mobile platforms suitable for these tasks are described in ROBA-1-OL.</p> <p>V. Waste Sorting and Packaging R/A provides the bridge-mounted robotic systems (ROBA-8-OL), the manipulation systems, (ROBA-16-OL), and the End-of-Arm Tooling (ROBA-23 through -26-OL) required for the sorting and repackaging of RH-TRU waste.</p> <p>VI. Surveillance and Inspection R/A provides the vehicles or mobile platforms (ROBA-1-OL) and sensors (ROBA-43 through -46-OL) required for the periodic surveillance and inspection of waste containers in above-ground storage areas.</p>	Refer to Vol. 1, Pt. A, Chap. 7, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for ORR, radiation protection standards, DOE Orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.	Robotics/Automation
EM Problems <ul style="list-style-type: none"> Facility Decontamination and Decommissioning (D&D) Remedial Action (RA)—Soils, Ground Water and Surface Water Waste Management (WM) 				Sensors

Examination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Tools-Human/Machine Interface	<div>H</div> Operator Interface-Operator Assistance ROBA-41-OL <i>Ranking:*</i> H-3-2 (\$1.5M;N)	Demonstration for most functions Evolving for other functions Efficacy: High. Will allow most efficient operation of "teleoperated" equipment. Waste: None. TTP Match	Development: -Establish validity and completeness of knowledge bases. -Conflict resolution. -Hybrid artificial intelligence architectures. -Dynamic allocation of functions.	- Extensive operator training. -Development Costs: \$1.5M
	<div>E</div> Operator Interface Status/Alert System ROBA-42-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Demonstration for most functions Evolving for other functions Efficacy: High. An essential technology to prevent damage to equipment/tools/sensors. Waste: None. TTP Match	Development: -Display navigation. -Sensor/data fusion.	-Extensive operator training. -Development Costs: \$0.5M
Sensors-Perception	<div>E</div> Vision/Aural Systems ROBA-43-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Demonstration for 3-D and HDTV. Predemonstration for directional aural. Efficacy: High. An essential technology for Robotics/Automation. Waste: None.	Development: -Sensor fusion. -Increased processing speed. -Advanced visualization.	-No unusual needs -Development Costs: \$1.0M
	<div>M</div> Range Finders ROBA-44-OL <i>Ranking:*</i> M-3-2 (\$1.5M;N)	Accepted Efficacy: Medium. Applications are limited. Waste: None. TTP Match	Improvement: -Speed/accuracy improvement.	-No unusual needs -Development Costs: \$1.5M
	<div>M</div> Proximity Probes ROBA-45-OL <i>Ranking:*</i> M-2-2 (\$1M;N)	Predemonstration Efficacy: Medium. Alternatives to probes may be more cost effective. Waste: None. TTP Match	Improvement: -Increased range and improved presentation to operator.	-No unusual needs -Development Costs: \$1.0M
	<div>M</div> Force/Torque Sensors ROBA-46-OL <i>Ranking:*</i> M-2-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Applications for D&D are very limited. Waste: None TTP Match	Improvement: -Testing of force sensing systems.	-No unusual needs -Development Costs: \$0.5M
Sensors/Control	<div>E</div> Position/Velocity Sensors ROBA-48-OL <i>Ranking:*</i> E-5-1 (\$0.5M;N)	Accepted Efficacy: High for analytical-laboratory applications or sensor sweeps. Waste: None.	None	-No unusual needs -Development Costs: \$0.5M
	<div>H</div> Force/Torque Sensors ROBA-50-OL <i>Ranking:*</i> H-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. Few applications in D&D activities. The need for force or torque control to prevent damage is limited. Waste: None. TTP Match	Improvement: -Impulse force resolution. -Stability.	-No unusual needs -Development Costs: \$0.5M
	<div>H</div> Proximity Sensors ROBA-51-OL <i>Ranking:*</i> H-3-1 (\$1M;N)	Accepted for small volumes. Predemonstration for large volumes. Efficacy: Medium. Alternatives to sensors may be more cost effective. Waste: None.	Improvement: -Increased range and better signal quality.	-No unusual needs -Development Costs: \$1.0M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.

Robotics and Automation for D

Decontamination and Decommissioning

Alternatives	Technologies	Status	Science Technology Needs	Implementation Needs
Sensors/Control	H Tooling Sensors ROBA-52-OL <i>Ranking:*</i> H-3-1 (\$0.5M;N)	Predemonstration Efficacy: High. This technology is required to prevent damage to tools or sensors. Waste: None. TTP Match	Development: -Development/testing of tactile sensing sensors, force sensors, and proximity sensors.	-Operator training -Development Costs: \$0.5M
Other Technologies	M Field Hardening ROBA-53-OL <i>Ranking:*</i> M-3-1 (\$0.5M;N)	Demonstration Efficacy: Medium. The primary environmental concern in D&D is high radiation fields as described in ROBA-54-OL <i>Ranking:*</i> . The ability to be decontaminated is essential for mechanical devices. Waste: None TTP Match	None	-Testing of hardened systems. -Development Costs: \$0.5M
	E Radiation Hardening ROBA-54-OL <i>Ranking:*</i> E-5-2 (\$2M;N)	Demonstration Efficacy: High. An essential technology for many D&D activities, particularly reactors and hot cells. Waste: None. TTP Match	None	-Extensive radiation testing of existing electronic chips. -Development Cost: \$2.0M
	E Integrated Automated Analytical Laboratory ROBA-55-OL <i>Ranking:*</i> E-5-2 (\$3M;N)	Predemonstration for hardware systems. Evolving for data interpretation. Efficacy: High. High sample loading in analytical laboratories require maximum use of automation Waste: None. TTP Match	Development: -Development of Standard Laboratory Modules (SLM) for Sample Preparation, Analytical Instruments, and Data Interpretation.	-Extensive testing of SLM's. -EPA approval of SLM -Development Costs: \$3.0M
	E Information Management for Sample Handling ROBA-56-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Demonstration Efficacy: High. Waste: None. TTP Match	Development: -Automatic data entry systems. -Improved reliability and auditability.	-No unusual needs -Development Costs: \$1.0M
	E Sample Collection ROBA-57-OL <i>Ranking:*</i> E-5-1 (\$1.5M;N)	Evolving Efficacy: Medium. Alternative, but slower methods of sample collection are available and may be more cost effective. Waste: None. TTP Match	Development: -Mobile platforms to deploy and manipulate sample collection tools. -Suitable robotic end-effectors.	-No unusual needs -Development Costs: \$1.5M
	M Characterization Sensor Integration ROBA-58-OL <i>Ranking:*</i> M-3-2 (\$1M;N)	Demonstration Efficacy: Low. May not be cost effective. Waste: None. TTP Match	Development: -Signal conditioning. -Data/Signal transmission.	-No unusual needs. -Development Costs: \$1.0M
	E Sample Preparation ROBA-59-OL <i>Ranking:*</i> E-5-1 (\$1M;N)	Evolving Efficacy: Medium. Will minimize work to be performed in analytical laboratory. Waste: Usual amount of waste normally generated in sample preparation operations. TTP Match	None	-Adaptation of current sample preparation tools to robotic devices. -Development Costs: \$1.0M

* See the Explanation and Understanding Key in the front of this document for a description of the ranking code/scheme.