New Regulation for Intermediate Depth Disposal and Future Issues in Japan

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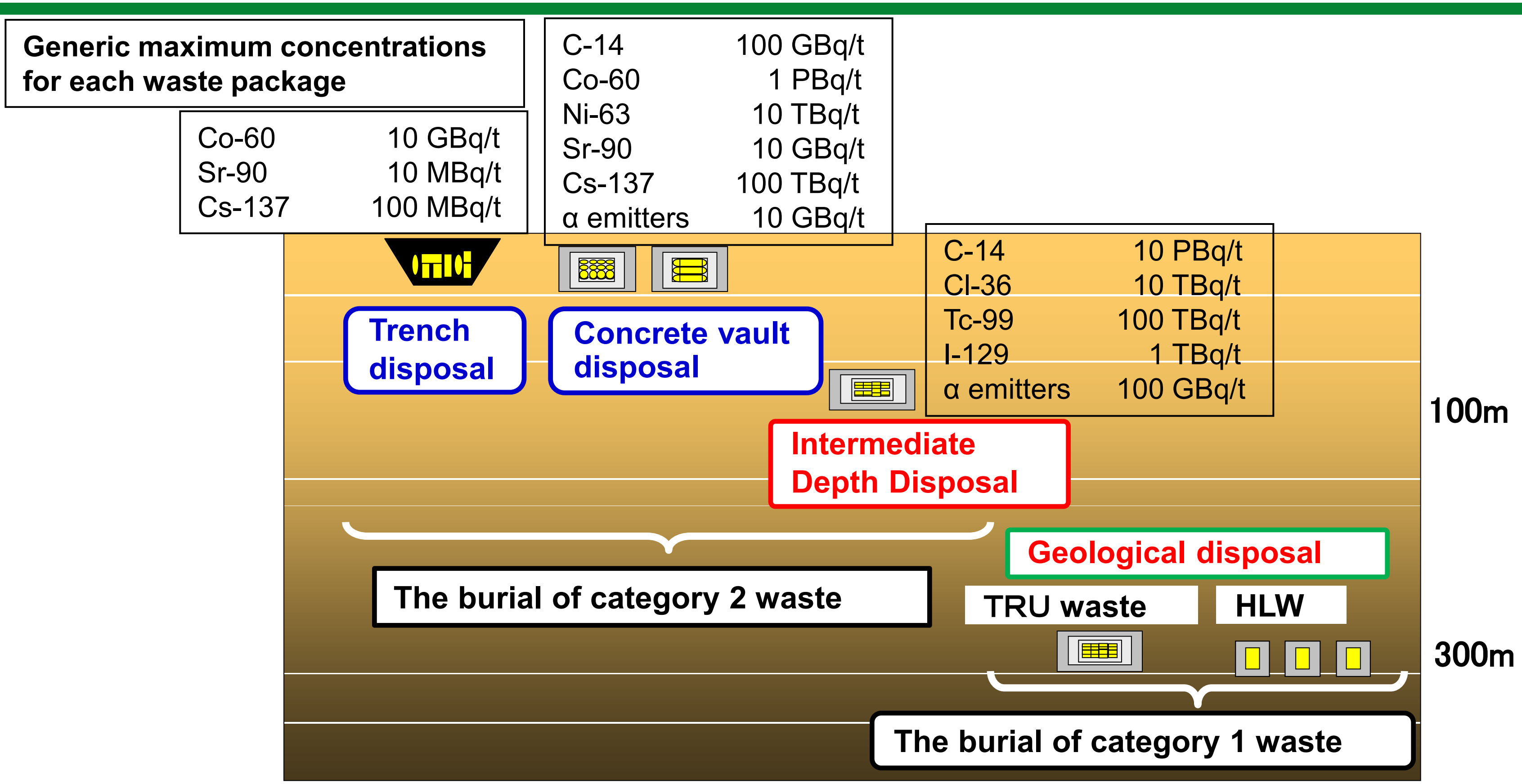
Nuclear Regulation Authority

The NCRP Symposium on Emerging Issues in Radioactive Waste Management

February 5 2018, Denver, Colorado

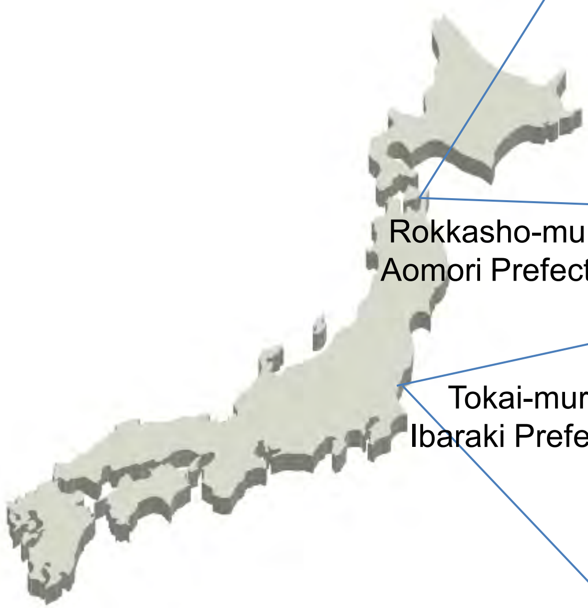
Category of Radioactive Waste Disposal



- ✓ Generic maximum radioactive concentrations are listed above for each type of repositories.
- ✓ Specific radioactive concentrations should be decided so as to comply with the dose criteria, considering the site characteristics and the repository design.
- ✓ Average concentrations of waste are well below the generic maximum concentrations.

Concrete Vault Disposal and Trench Disposal in Japan

Concrete Vault Disposal:
Low-Level Radioactive Waste Disposal Center,
JNFL (Japan Nuclear Fuel Limited)



Rokkasho-mura,
Aomori Prefecture

Tokai-mura,
Ibaraki Prefecture

Trench Disposal:
Demonstration Test of VLL Concrete Waste Disposal, JAEA (Japan Atomic Energy Agency)

Low-Level Radioactive Waste Disposal Center, JNFL
(source from Ohishi , 2012, URL: https://nuce.aesj.or.jp/_media/ws:2013:WES13-3.pdf)

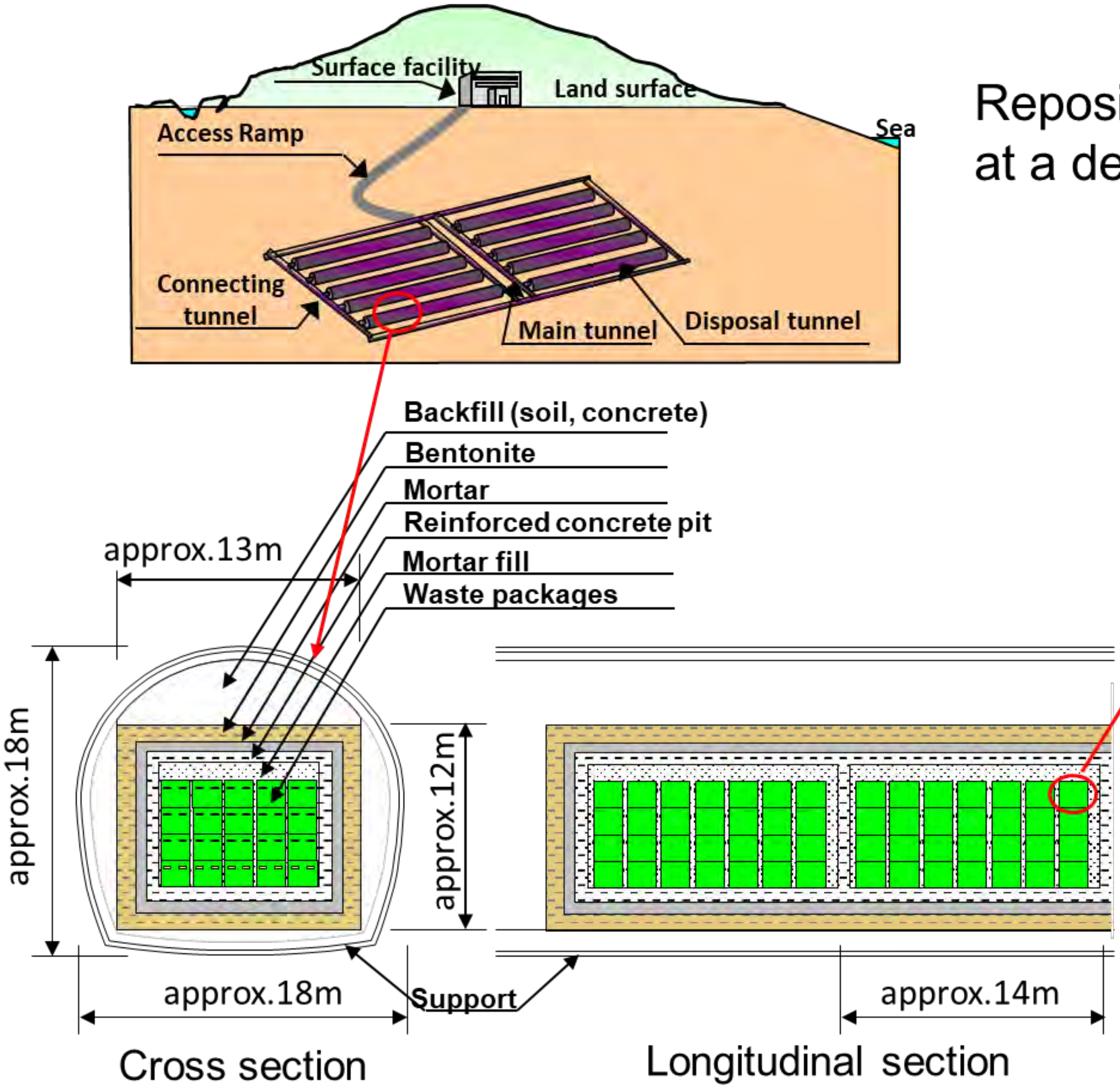
Demonstration Test of VLL Concrete Waste Disposal, JAEA
(source from JAEA HP, URL:http://www.jaea.go.jp/04/ntokai/backend/backend_01_04_01.html)

Chronology of LLW Disposal in Japan

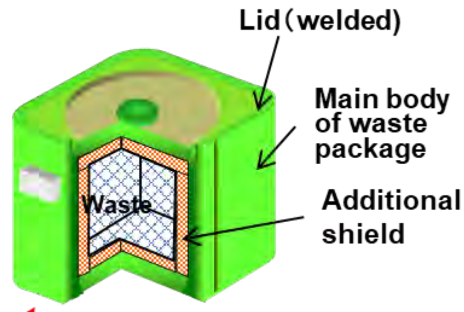
- Regulation for trench disposal and concrete vault disposal was promulgated in 1988 and 1993.
- Operation of concrete vault disposal at Rokkasho-mura was initiated in 1992.
- After the Fukushima Daiichi Accident, regulatory body was restructured and NRA was established in 2012.
- Regulation was enhanced based on the lessons learnt from Fukushima Daiichi Accident.

  W.R.T. trench disposal and concrete vault disposal, regulation was enhanced:
  - Periodical safety review is added,
  - Maintenance and monitoring are extended until termination of license.
- Development of regulation for intermediate depth disposal was initiated from 2015.

Concept of Intermediate Depth Disposal



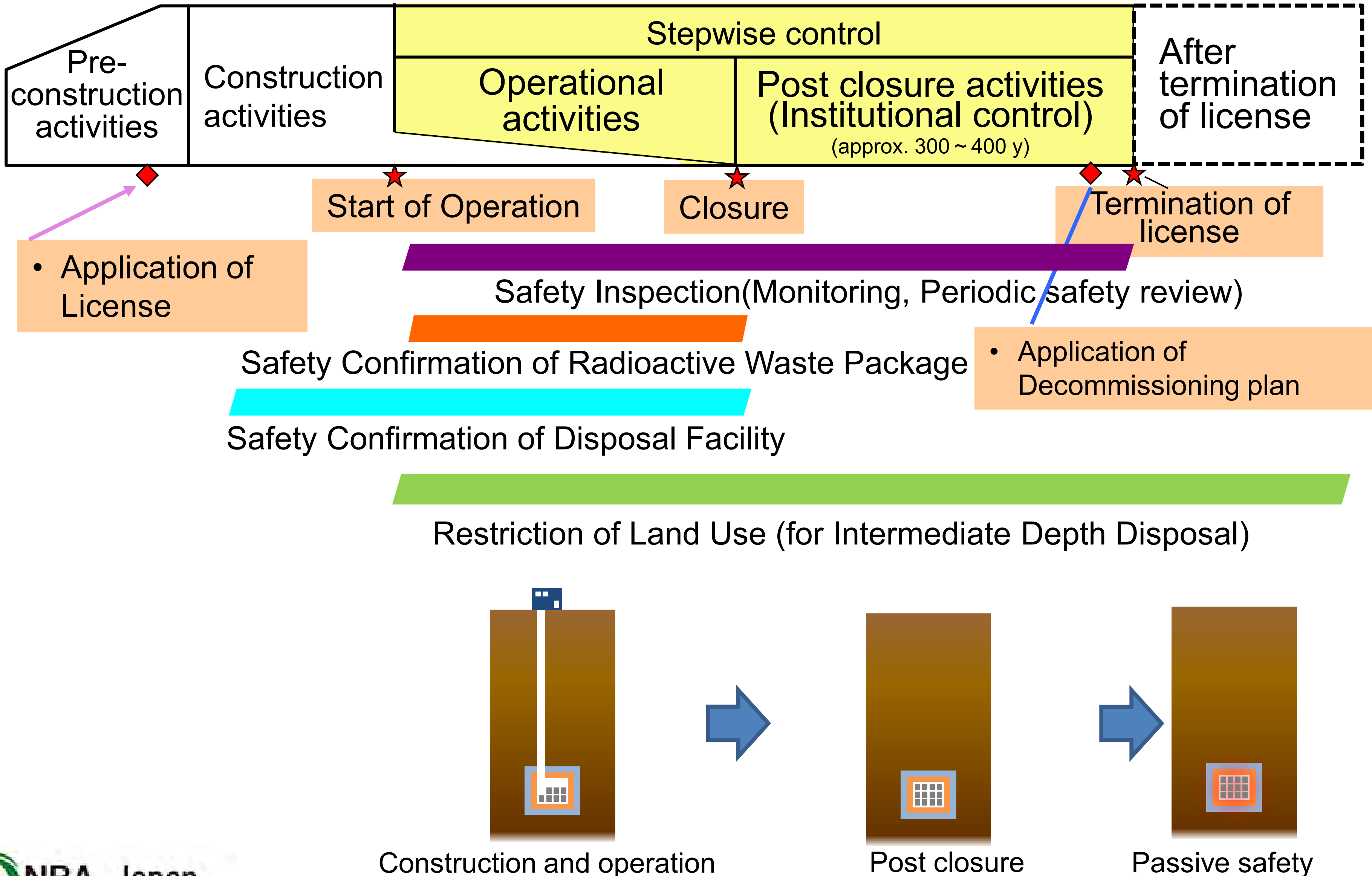
Repository will be constructed at a depth greater than 70m.



Waste package

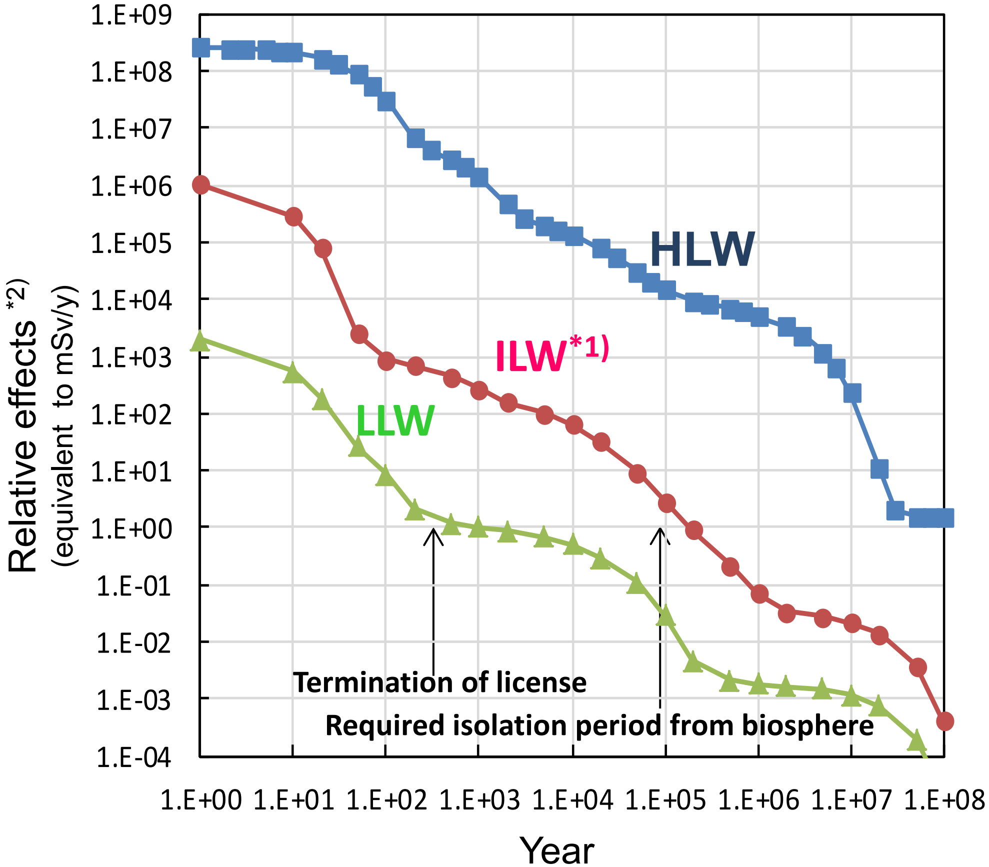
Concept of Intermediate Depth Disposal
(source: Federation of Electric Power Companies of Japan ,2015, URL:http://www.nsr.go.jp/disclosure/committee/yuushikisya/hairo_kisei/20150212.html)

Regulatory Procedures on LLW disposal



Characteristics of Radioactive Waste of Intermediate Depth Disposal

- ✓ Requirements for design and controls are related to the characteristics of wastes.
- ✓ Waste containing longer half lives of radionuclides require longer time of control and isolation.



Relative effects of wastes vs. time

*1) Average values for radioactive waste from operation and decommissioning of BWR, PWR, and GCR
*2) 1 mSv/y when sum of nuclide concentration divided by nuclide conc. of clearance level equals to 100

Requirements for Radioactive Waste Disposal

<table>
<tr><th colspan="2">Category</th><th>Requirements</th></tr>
<tr><td colspan="2">Radiation protection</td><td>During License
After license termination</td></tr>
<tr><td rowspan="6">Design</td><td rowspan="4">Natural process</td><td>Location of repository</td></tr>
<tr><td>Limitation on concentrations of long-lived nuclides</td></tr>
<tr><td>Confinement of nuclides until the termination of license</td></tr>
<tr><td>Containment of nuclides
• Engineered barriers
• Natural barrier</td></tr>
<tr><td rowspan="2">Human intrusion</td><td>Prevention of human intrusion</td></tr>
<tr><td>Mitigation of consequence of human intrusion</td></tr>
<tr><td colspan="2" rowspan="5">Control</td><td>Confirmation of barrier function</td></tr>
<tr><td>Periodic safety review</td></tr>
<tr><td>Closure of tunnel</td></tr>
<tr><td>Monitoring</td></tr>
<tr><td>Confirmation of decommissioning</td></tr>
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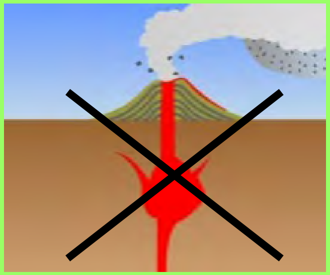
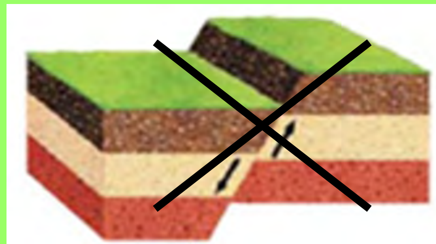
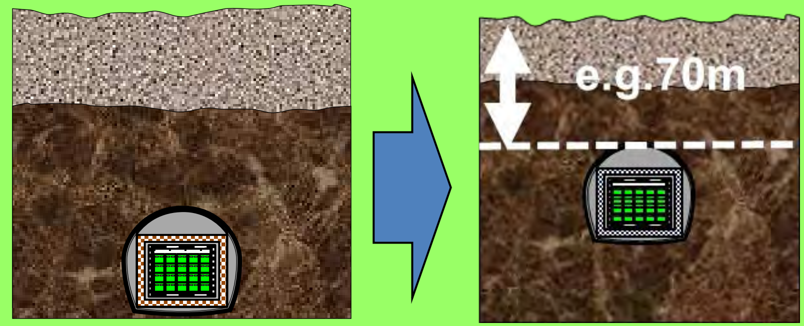
Requirements on Location of Repository (Exclusion Criteria)







Consider uplift and erosion in 100ka

- Avoid direct hit by volcanic eruption during at least 100ka
- Avoid direct hit by faulting during at least 100ka
- Maintain minimum depth of 70m taking into account of uplift and erosion at least 100ka
- Away from significant known mineral resources

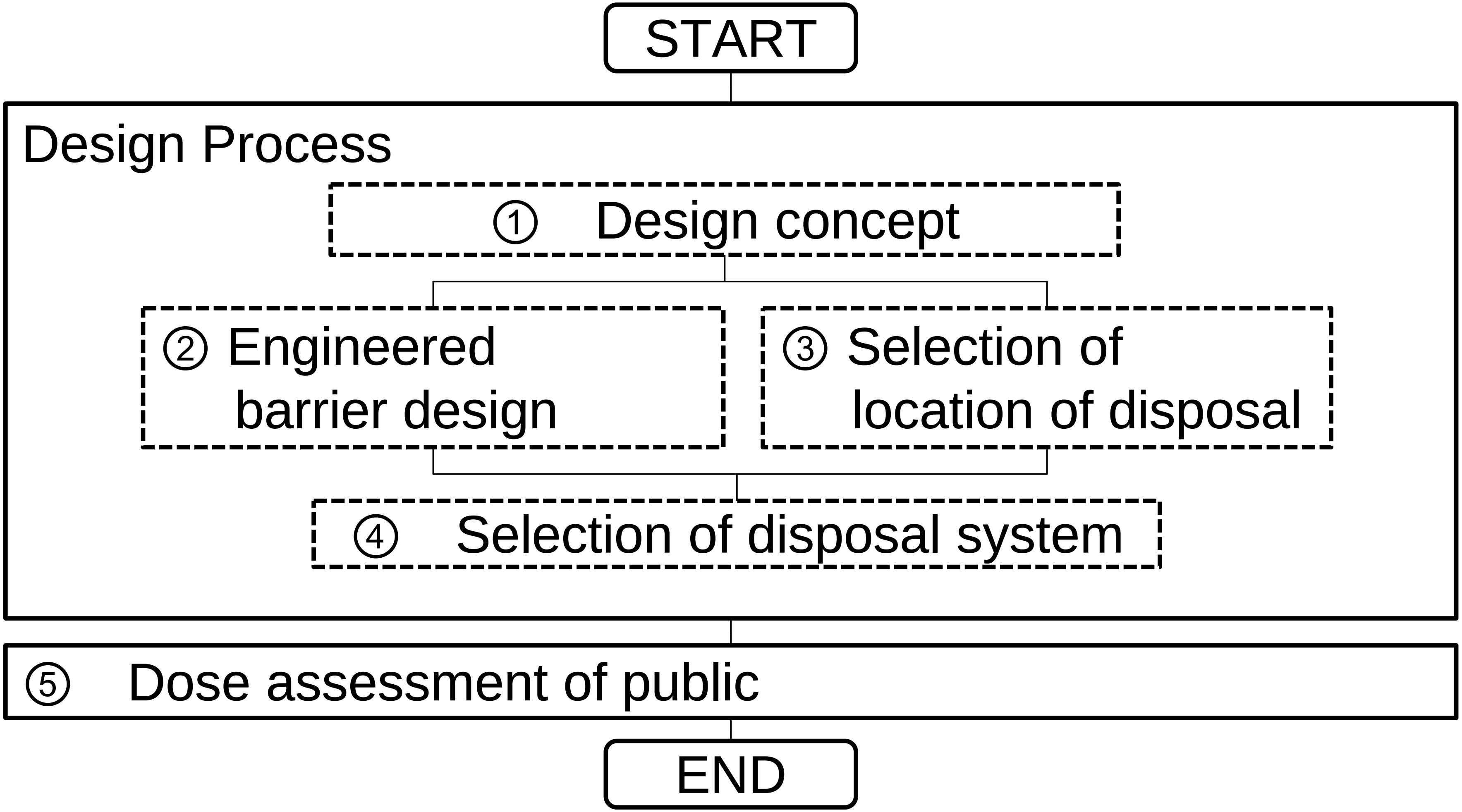
Introduction of ALARA into Regulation

- Current Regulation
  - ・Adequacy of the design is judged based on the dose criteria:
    - 10μSv/y for likely scenario,
    - 300μSv/y for less likely scenario.

- Challenges
  - ・Protection after the termination of license relies on the characteristics of the selected site and the design of the disposal facility.
  - ・Estimated dose and risk in the far future are not the absolute measure to ensure safety.
  - ・Site characteristics, element of Best Available Technique (BAT), concept of good practice, reliable engineering, etc. are important.

- New Regulation Under Discussion
  - ・Review design process itself to see if design follows ALARA concept:
    - 300μSv/y as a dose constraint,
    - Select preferable design from several candidate designs using dose as an index of ALARA.

Requirements on Disposal Design



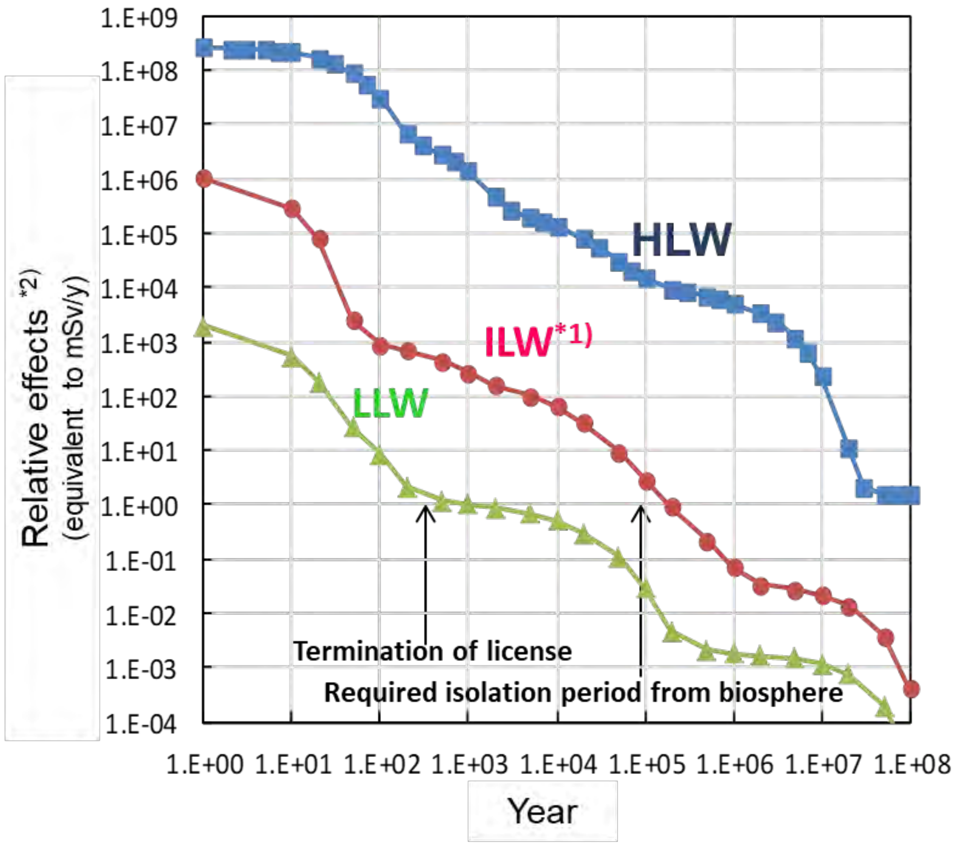
Example of Engineered Barrier Function

Barrier function		Barrier Performance	Related Feature
Confinement and Containment of Nuclide	Confinement	Duration of waste package until holes penetrate	• Corrosion rate
	Retardation	Long travel time of nuclide in barriers	• Kd value • Solubility
	Low release rate	Low release rate from engineered barrier	• Diffusivity • Thickness • Number of concrete cracks
Stable Condition	Restrict ground water inflow	Low groundwater flux to engineered barrier	• Permeability
	Stabilize mechanical condition	Small deformation	• Young's modulus • Compressive strength
	Stabilize geochemical condition	Red-ox buffering capacity and chemical condition	• Corrosion condition of metal • Degradation condition of cement and clay material

Example of Natural Barrier Function

Barrier Function		Barrier Performance	Related Feature
Containment	Retardation	• Long travel time of groundwater • Long travel time of nuclides	• Kd value • Groundwater velocity • Distance from highly conductive geological feature
Stable Condition	Stabilize geochemical condition	• Stagnant groundwater flow • Buffer against red-ox and chemical condition	• Buffering capacity of minerals • Distribution of geological formation • Distribution of geochemical condition

Characteristics of HLW



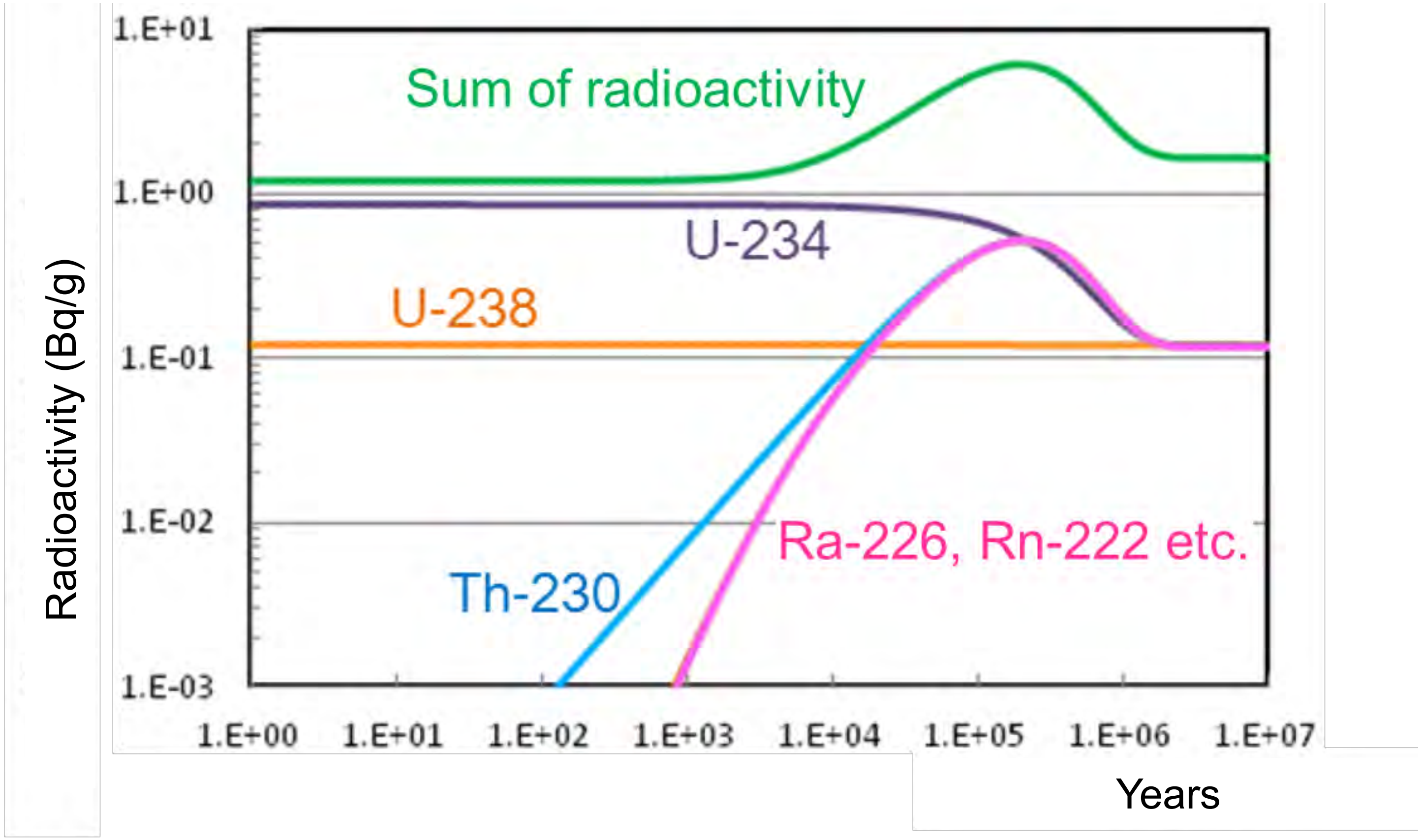
Relative effects of wastes vs. time

*1) Average values for radioactive waste from operation and decommissioning of BWR, PWR, and GCR

*2) 1 mSv/y when sum of nuclide concentration divided by clearance level equals to 100

- ✓ HLW takes much longer time to decay until relative effects reduces to the same level as that of ILW at the time of 100k years.

Buildup of Radioactivity in Uranium Waste



Generation of uranium progeny nuclides at 5wt% enrichment of U235

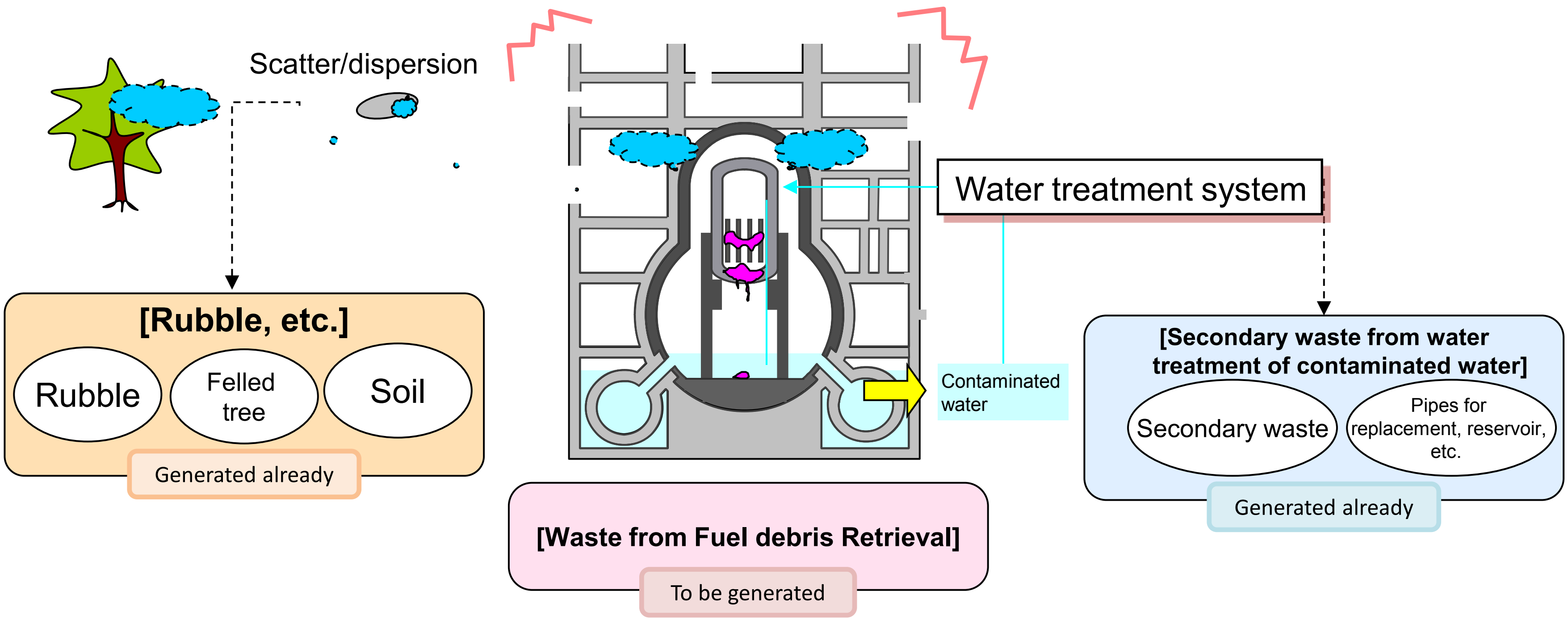
(source: Atomic Energy Society of Japan, 2014, URL:www.aesj.or.jp/special/report/2014/s_1fteilevel_report2014.pdf)

Initial condition (at the time of 0): sum of uranium isotopes (U-234, U235, U-238) = 1Bq/g

uranium progeny nuclides = 0Bq/g

Solid Radioactive Waste Generated from the Fukushima Daiichi Accident

➢Waste can be classified into three categories:
- Rubbles/Felled Trees etc.,
- Waste from fuel debris retrieval,
- Secondary waste arising from treatment of contaminated water.



Overview of solid waste contamination sources and nuclide migration pathways

(source: Nuclear Damage Compensation and Decommissioning Facilitation Corporation, 2017, URL: www.dd.ndf.go.jp/en/strategic-plan/book/20171005_SP2017eFT.pdf)

Status and Issues of Waste from Fukushima Daiichi Accident

- 4th revision of "Road map" was published in Sep. 2017.
- Status of waste

  Rubbles/Felled Trees etc. (as of Oct. 31, 2017)

  ・Rubble (concrete, metal etc.) : 218,800m^3
  （separately stored according to surface dose rate)

  ・Felled tree : 133,700m^3

  ・Used protective clothing : 63,500m^3

  Secondary waste arising from treatment of contaminated water (as of Nov. 2, 2017)

  ・Sludge : 597m^3

  ・Concentrated waste liquid : 9,364m^3

  ・Absorbent columns（HIC) : 3,819

  (source: Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment (METI), 2017, URL:http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/pdf/20171130_e.pdf)

- Fuel debris

  ・Method will be determined by FY2019.

  ・Retrieval will be initiated in 2021.

- Issues need to be resolved

  ・Characterization of waste is a prerequisite for developing disposal strategy.
  - Waste was not produced under controlled condition.
  - Characterization facility is under construction.

  ・Fuel debris needs to be further characterized.

  ・Basic policy for waste treatment and disposal need to be developed.

Future Issues

- Trench disposal, Concrete vault disposal
  - Safety is established achieving less than 10μSv/y.
  - Should we still introduce ALARA?
- Geologic disposal
  - HLW requires isolation more than 100k years.
  - Uncertainty of geologic environment increases after 100k years, sometimes prediction becomes meaningless depending on the area.
  - Can we just ignore far future? Or, need to introduce a new logic?
- Uranium Waste
  - U concentration within waste is generally low such that an average conc. is 1Bq/g.
  - Build-up take place approx. 200k years from now.
  - Should we isolate the waste such a long time? Longer isolation requires more depth.
- Waste from Fukushima Daiichi Accident
  - Characterization is necessary to develop strategy for disposal.
  - “The Committee on Radioactive Waste Issues of the Specified Nuclear Facilities” supervises TEPCO’s activity and future plan.

Conclusion

- NRA is preparing new regulatory framework for the Intermediate Depth Disposal.
  - Disposal system should be designed so as to confine nuclides within the engineered barrier, until the termination of the license.
  - Disposal system should be secured from natural disruptive events and human activities for a period of at least 100 k years.
  - Disposal system should be designed and natural barrier should be selected so that the release of nuclides from the disposal system would be As Low As Reasonably Achievable. The dose for the representative person shouldn't exceed dose constraint.
- NRA is considering the way to take these regulation framework to that of trench disposal and concrete vault disposal, even though they wouldn't have much design options and most of radio activities will decay by the time of termination of licence.
- Geologic disposal is similar to intermediate depth disposal, however it requires longer timescale to ensure the safety, and timescale needs to be resolved.
- For uranium waste, time scale to ensure the safety needs to be resolved.
- As to waste from Fukushima Daiichi Accident, characterization will be conducted prior to development of strategy for disposal.

EMERGING ISSUES IN RADIOACTIVE WASTE MANAGEMENT

sponsored by the

National Council on Radiation Protection and Measurements

Monday, February 5, 2018

Plenary

Morning

Leonard Slosky

Rocky Mountain Low-Level Radioactive Waste Board

received a degree in Environmental Technology Assessment from the University of Colorado – Boulder. Mr. Slosky served as the Governor of Colorado's Assistant for Science, Technology and Environmental Policy from 1978 to 1985. He was the Staff Director of the Natural Resource and Environmental Task Force of the Intergovernmental Science, Engineering, and Technology Advisory Panel in the White House Office of Science and Technology Policy, 1978 to 1980. Mr. Slosky lectured at North Atlantic Treaty Organization Advanced Study Institute on Environmental Impact and Risk Analysis in Les Arc, France.

Mr. Slosky served on the NAS Committee to Review New York State's Siting and Methodology Selection for Low Level Radioactive Waste Disposal. He served on DOE's review team for the Plutonium Vulnerability Assessment at Rocky Flats and a member of the DOE's Blue Ribbon Panel on the Waste Isolation Pilot Plant.

Mr. Slosky chaired the committee that negotiated and drafted the Rocky Mountain Low-Level Radioactive Waste Compact and was intimately involved in the passage of the Low-Level Radioactive Waste Policy Amendments Act of 1985. He has been the Executive Director of the Rocky Mountain Compact since 1983. He is the Past Chair of LLW Forum, Inc.

An Update of the Low-Level Radioactive Waste Issues

An update on current issues facing the LLW Compacts including the LLW disposal landscape, improved management of disused sources, current NRC rulemakings including 10 CFR Part 61, and oil and gas naturally occurring radioactive materials (NORM) and technologically enhanced NORM.

Introduction: Evolving Radioactive Waste Management Policy & Approaches
Session 1: Remediation & Regulation

1:35 pm

Casey Gadbury

U.S. Department of Energy Carlsbad Office

came to work at the Waste Isolation Pilot Plant (WIPP) with 6 y of Naval nuclear experience as an Engineering Laboratory Technician. Mr. Gadbury was hired in 1990 by the Westinghouse Electric Corporation Waste Isolation Division (management and operating contractor for WIPP at the time). While working for Westinghouse, Mr. Gadbury attended college and received his BS in Radiation Protection in 1933, in the same year he was nationally registered as a Radiation Protection Technologist. In 2000, Mr. Gadbury became a Senior Radiological Engineer, providing radiological engineering support for the operation of WIPP. He left Westinghouse at the end of 2000 to become the Waste Operations Program Manager for the Department of Energy's Carlsbad Field Office (CBFO), where he has served several important functions. In 2010, Mr. Gadbury was assigned as the Director of the Office of Site Operations, responsible for the oversight and monitoring of the contractor that manages and operates the WIPP facility to dispose of contact handle and remote handle transuranic waste. In 2014, he was selected as the Assistant Manager of the CBFO Office of Program Management, responsible for cost, scope, and schedule management and oversight of all CBFO-funded activities. As a result of this experience, he has a thorough knowledge of CBFO, WIPP, and National Transportation Programactivities in his career that started in health physics.

Contamination Mitigation in the Waste Isolation Pilot Plant Repository

The radiological release event at the Waste Isolation Pilot Plant (WIPP) in 2014 presented unique challenges for cleanup of the contamination in the waste repository located 2,150 feet underground. WIPP was selected as a permanent disposal solution for long-lived radioactive waste based on NAS analysis that the plastic characteristics of deep geologic salt beds would completely encapsulate materials emplaced in the mined space in a relatively short period as compared to the extremely long half-lives of the radioactive isotopes in the waste. Although this proved to be a very effective design for permanent disposal of sealed containers of transuranic waste, when one of those containers released its radioactive contents into the repository, it presented challenges in measuring and decontaminating radioactivity that had not been anticipated in WIPP's mission. Unlike other nuclear facilities with solid walls built for stability, the walls in WIPP move continuously at a rate of 3 to 5 inches per year, requiring regular maintenance to stabilize the rock and remove unstable portions of the rock for safety. The salt matrix itself presents challenges in surveying for alpha-emitting transuranic isotopes and decontaminating the salt rock surfaces for worker habitability to accomplish the mission of emplacing waste containers in mined out disposal rooms. Several contamination methods have been tested and considered to reduce the source term in the working areas. A specific interesting challenge at WIPP is the contaminated exhaust shaft that is 2,150 feet deep with no hoist to access the interior surfaces. This presentation will describe the unique aspects of contamination mitigation at WIPP and offer an opportunity for health physics experts to propose additional solutions for addressing these unique challenges.

2:00 pm

Kent Rosenberger
Savannah River Remediation
is the manager of Closure and Disposal Assessment for Savannah River Remediation at DOE's Savannah River Site (SRS) near Aiken, South Carolina responsible for the Liquid Waste System Performance Assessment Program. He has a BS in Nuclear Engineering from the Pennsylvania State University and has spent the last 27 y at SRS. The first 14 y were within the Radiological Protection Department. He supported new facility design and existing operating facility health physics technical support including dose rate and shielding calculations, contamination control practices, and ventilation design primarily in the liquid waste and nuclear materials processing areas. The last 13 y have been spent supporting the development of closure and disposal regulatory documents including environmental Performance Assessments and Waste Determinations for SRS tank closures and the Saltstone Disposal Facility. In this position, he regularly interacts with DOE, NRC, EPA, and the South Carolina Department of Health and Environmental Control. He supports the DOE Low Level Waste Disposal Facility Federal Review Group and is on the Steering Committee for the Interagency Performance and Risk Assessment Community of Practice. Mr. Rosenberger also supports the Waste Management Symposium as a member of the Program Advisory Committee.

High-Level Waste Tank Closure at Savannah River Site
Fifty-one High Level Waste tanks exist at the Savannah River Site (SRS) and eight tanks have been operationally closed to date. This presentation will present an overview of the tank designs and locations, the various operational steps necessary to empty the tanks, the unique challenges some of these tanks pose, the regulatory documentation steps and approvals needed, and the final operations performed to place a tank in a stable condition for perpetuity. The presentation will include facility photographs and videos to provide perspectives on the difficulties of performing closure steps in facilities that were constructed over 50 y ago, that are extremely congested with operations and support systems and that contain highly radioactive material. In spite of the many obstacles, the presentation will illustrate the success that tank closure has been within the Liquid Waste System at SRS and its impact to reducing the risk to people and the environment now and in the future.

2:25 pm

Gregory Suber
U.S. Nuclear Regulatory Commission
is the Chief of the Low-Level Waste Branch in the Office of Nuclear Material Safety and Safeguards at NRC. In that role, he leads staff responsible for the development and implementation of the low-level radioactive waste regulatory framework for commercial disposal in the United States. He also leads NRC's role in consultation and monitoring activities associated with DOE disposal actions under the National Defense Authorization Act of 2005.

After working with the Bechtel Power Corporation, he joined NRC in 2000 as a technical reviewer in the Office of Nuclear Reactor Regulation. He served in positions of increasing responsibility and was selected as the Chief of the Environmental Review Branch in 2007. In 2009, he transitioned into his current role as Chief of the Low-Level Waste Branch.

Mr. Suber holds a BS in Mechanical Engineering from Howard University and a Graduate Degree in Environmental Science from Duke University. He is married, residing in Fulton, Maryland with his wife Sandra and their four children.

Final Rule: Low-Level Radioactive Waste Disposal 10 CFR Part 61
On September 8, 2017, the staff received direction from the Commission on path forward in Staff Requirements [SECY-16-0106 – Final Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61)]. The Commission directed the staff to make substantive revisions to the draft final rule and subsequently republish it as a supplemental proposed rule for a 90 d public comment period. Specifically, the Commission directed the staff to:

1. reinstate the use of a case-by-case basis (*i.e.*, "grandfather provision") for applying new requirements to only those sites that plan to accept large quantities of depleted uranium for disposal;
2. reinstate the 1,000 y compliance period from the proposed rule with a specific dose limit of 0.25 mSv y^{-1} (25 mrem y^{-1}) and adopt a longer period of performance assessment [the period of which would be based on site-specific considerations and a "reasonable analysis," as defined in SRM-SECY-13-0075, "Proposed Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61) (RIN 3150-AI92)] and apply the 1,000 y compliance period to the inadvertent intruder performance objective in 10 CFR Part 61.42 and the site stability performance objective in 10 CFR Part 61.44;
3. clarify that the safety case consists of the quantitative performance assessment, as supplemented by consideration of defense-in-depth measures;
4. modify the draft final rule text addressing defense-in-depth to narrow its consideration solely to providing additional assurance in mitigating the effects of large uncertainties that are identified during the performance assessment; and
5. be informed by broader and more fully integrated, but reasonably foreseeable, costs and benefits to the U.S. waste disposal system resulting from the proposed rule changes, including pass-through costs to waste generators and processors.

Staff is in the process of supplementing the final rule based on Commission direction.

2:50 pm Break

Session 2: Present & Future Issues

3:15 pm

Janet Schlueter

Nuclear Energy Institute

is currently the Senior Director, Radiation and Materials Safety at the Nuclear Energy Institute (NEI) the nuclear industry's policy organization with members representing a wide array of regulated activities. Ms. Schlueter joined NEI in February 2008 and was promoted to Director in January 2010 and Senior Director, Radiation Safety and Materials in January 2014. She is responsible for managing a wide variety of generic regulatory issues unique to the front-end of the fuel cycle, uranium recovery, low-level waste, research and test reactors, byproduct materials licensees and other areas. In 2015, her responsibilities expanded further to include radiation and environmental protection issues. Ms. Schlueter and her staff routinely coordinate with federal, state and international agencies, and other industry and professional organizations on generic issues of mutual interest. Prior to joining NEI, Ms. Schlueter spent 19 y at NRC where she held increasingly responsible positions including 8 y at the Commission where she served as Chief of Staff to the late NRC Commissioner Edward McGaffigan, Jr. and NRC Chairman Nils Diaz. She was a member of the Senior Executive Service and, among other assignments, managed the Yucca Mountain Program and was the Director of the Office of State and Tribal Programs. Prior to joining NRC in 1989, Ms. Schlueter was a radiation safety and health physics consultant to various medical, industrial and research facilities where she applied her earlier experience working in radiology and radiation oncology. Ms. Schlueter graduated from the Medical College of Virginia of the Virginia Commonwealth University and George Washington University in radiation sciences and administration. Ms. Schlueter's career has spanned from the medical field, to consulting, to being a regulator, and she now supports and represents the nuclear industry. She has received numerous performance awards and recognition for her contribution to both the public and private sectors of the nuclear industry.

Nuclear Industry Perspectives on Low Level Waste Management

Today, there are four commercial low-level radioactive waste disposal sites, all located in Agreement States, and operating under the statutorily-established radioactive waste Compact Commission system:

- EnergySolutions Barnwell Operations (Barnwell, South Carolina)
- EnergySolutions Clive Operations (Clive, Utah)
- U.S. Ecology (Richland, Washington)
- Waste Control Specialists (Andrews, Texas)

The purpose of this presentation is to provide an overview of the nuclear industry's perspective on current practices for the continued safe and secure management of radioactive waste.

Class A waste—the lowest level of radioactivity—comprises approximately 95% of all low-level waste managed today. Class B and C waste constitute approximately 90 to 95 % of the radioactivity involved in low-level waste disposal, though only about 5 to 10 % of the volume. The commercial nuclear industry has managed low-level waste safely and successfully for decades. For example, the volumes of low level waste have decreased significantly in the past decades, even as the number of nuclear power plants increased during the same period. Moreover, commercial waste generators also safely store low-level waste on-site which has resulted in significant cost savings to industry. Therefore, the evolving waste landscape benefits from a national management strategy that supports the waste disposal sites in operation today.

NRC has several ongoing and completed initiatives in the area of low-level waste management. For example, the NRC's Branch Technical Position on Concentration Averaging and Encapsulation (published in 2015) described acceptable averaging methods that could be used in classifying waste. Additionally, NRC has also released new guidance for alternative disposals under Title 10 CFR 20.2002, and will be pursuing a scoping study in 2018 to explore the concept of "very low-level waste," which would potentially offer a subcategory of "Class A" waste. We applaud such NRC efforts that recognize industry's ability to safely manage its wastes and we look forward to exploring these issues further.

3:40 pm

Chris Shaw

Waste Control Specialists LLC

served in the U.S. Navy for a period of 4 y. After which, he attended Oregon State University (OSU) where he completed his MS in Radiation Health Physics with a minor in Public Health. Chris has been with Waste Control Specialists for the last 8 y. Over that time, he has worked as a senior Health Physicist, Health Physics Supervisor with oversight of all technical programs, Integrated Services Manager, and is currently the Corporate Radiation Safety Officer and Technical Services Project Manager. In 2015, Chris was certified in the comprehensive practice of Health Physics by the American Board of Health Physics, and has been a member of the National Registry of Radiation Protection Technologists since 2013.

Present & Future Low-Level Radioactive Waste Issues, An Industrial Perspective

Waste Control Specialists LLC (WCS) accepts both DOE and commercial / industrial sources of low level radioactive waste Classes A, B, and C, byproduct, and naturally occurring radioactive materials (NORM) and technologically enhanced NORM (TENORM) waste for disposal. To facilitate this, WCS has four disposal facilities Compact Waste Facility, Federal Waste Facility, Byproduct Disposal Facility, and our Treatment Storage and Disposal Facility.

With all of our capabilities and services, it is WCS's mission to constantly improve our processes and range of services within our regulations, licenses, and permits and to plan what future changes to licenses and permits may be needed to offer our current and potential future customers the services that are needed to dispose of their low-level radioactive waste, low-level mixed waste, NORM/ TENORM material, and hazardous/toxic waste.

As such, WSC looks to the past, present, and future of low-level radioactive waste issues from the WCS perspective for what's available today and planning for the future.

4:05 pm

William Kennedy

W.E. Kennedy Consulting

has extensive experience as a project manager, task leader, and individual contributor covering a broad range of health physics and nuclear engineering topics. He received his BS and MS degrees in Nuclear Engineering from Kansas State University. Mr. Kennedy has been involved in the development of environmental pathway and radiation dosimetry models used to assess potential health and environmental impacts that resulted from releases of radionuclides to the environment. He specializes in the use of these models in environmental dose reconstruction, radioactive materials transport, radioactive waste disposal, and evaluation of nuclear facility operating practices. Over the past 37 y, Mr. Kennedy has led and contributed to a variety of projects for NRC, DOE, the Electric Power Research Institute, and private industry. He has been involved with development of the technical basis for revised standards and regulations, and serves as the chair of ANSI/HPS N13.12, *Surface and volume Radioactivity Standards for Clearance*. He served as a consultant to the International Atomic Energy Agency (IAEA), Vienna, Austria, and was a member of the IAEA Advisory Groups to evaluate the Derivation of Exempt Quantities for Application to Terrestrial Waste Disposal and Derivation of Exempt Quantities for Recycle of Materials from Nuclear Facilities. He was an invited lecturer for IAEA training courses on Management of Radioactive Waste from Nuclear Power Plants at Argonne National Laboratory; on Safety Assessment Modeling for Low and Intermediate Radwastes in Rio de Janeiro, Brazil and in Cairo, Egypt; and on Environmental Monitoring in Kiev, Ukraine. In 1990, he received the Health Physics Society's (HPS) prestigious Elda E. Anderson Award. He served as a member of the HPS Board of Directors from 1998 through 2001 and was selected as a fellow of the society in 2002. He was a member of the U.S. delegation to the 10th Congress of the International Radiation Protection Association in Hiroshima, Japan.

Waste Management Approaches for Handling Technologically Enhanced Naturally Occurring Radioactive Material

With increased demand for oil and natural gas, newer technologies associated with hydraulic fracturing, coupled with horizontal drilling, have been deployed. Application of this technology, which is termed *unconventional* oil and gas recovery, creates potential radiation exposures, environmental protection concerns, and waste management issues associated with naturally occurring radioactive materials (NORM) and technologically enhanced NORM (TENORM). EPA has estimated that about 1500,000 cubic meters per year of waste are produced by the oil and gas industry, including produced water, well casing scales, tanks, pipes sludge, and equipment. Some of this waste contains elevated concentrations of TENORM. There is no federal guidance for TENORM waste management; the regulatory authority lies with the states. Individual states that host hydraulic fracturing operations are left to cope with emerging TENORM waste management issues on an ad hoc basis with little scientific support. NCRP established Scientific Committee (SC) 5-2 to develop *Recommendations for a Uniform Approach for NORM and TENORM Waste Management and Disposal for the Oil and Gas Industry*. This effort is consistent with the overall mission of NCRP to formulate and widely disseminate information, guidance, and recommendations on radiation protection which represents the consensus of leading scientific experts. SC 5-2 is preparing a commentary that provides recommendations for a science-based, uniform NORM/TENORM waste management approach. Consistent with the NCRP charter, the purpose of SC 5-2 is to provide a commentary on the generation and disposal of TENORM waste from unconventional oil and gas recovery, including radiological and regulatory considerations, with recommendations for the content of a future NCRP report.

4:30 pm Panel Discussion

Tuesday, February 6, 2018

Introduction: Managing Radioactive Wastes Generated from Homeland Security-Related Incidents

Session 3: Radioactive Waste from Wide-Area Incidents

8:30 am

S.Y. Chen

Illinois Institute of Technology

is currently director of Professional Master's Health Physics Program at the Illinois Institute of Technology (IIT), Chicago, Illinois. Prior to joining IIT, he was Strategic Area Manager in Environment and Radioactive Waste and also Senior Environmental Systems Engineer at Argonne National Laboratory, Argonne, Illinois. Dr. Chen is a national expert in radiation protection with expertise in radiological risk analysis, environmental remediation, nuclear safety, radiological incident/terrorism risk analysis, long-term recovery and radioactive waste management. He is currently an Emeritus Member of NCRP (Council Member from 1999-2017); where he also served as Scientific Vice President of Program Area Committee 5 (Environmental Radiation and Radioactive Waste Issues, 2005 to 2017). Dr. Chen previously served on EPA's Science Advisory Board/Radiation Advisory Committee (2009 to 2015). He is a Certified Health Physicist, a Fellow Member of HPS, and a member of American Nuclear Society. Dr. Chen has also served on several committees of HPS; the latest being chair of the Academic Education Committee. At NCRP he chaired two Scientific Committees: SC 87-4 that led to the publication of NCRP Report No. 141 (2002), *Managing Potentially Radioactive Scrap Metal*; and SC 5-1 for the publication of NCRP Report No. 175 (2014), *Decision Making for Late-Phase Recovery from Major Nuclear or Radiological Incidents*.

Issues & Framework for Managing Radioactive Waste Resulting from Wide-Area Contamination

Radioactive waste of various types could be generated during major nuclear or radiological incidents. Such incidents may include those originated from terrorist acts that involve a radiological dispersal device (RDD) or improvised nuclear device; or major accidents involving nuclear facilities (such as nuclear accident at Chernobyl, Ukraine, or Fukushima in Japan). Regardless of its origin a major incident could cause a wide-spread contamination, resulting in large amounts of radioactive waste. The waste management issues present an enormous challenge to the incident response and particularly to the subsequent recovery effort once remediation actions are underway. NCRP developed Report No. 175, *Decision Making for Recovery from Major Nuclear or Radiation Incident* (2014), which advocates the use of optimization approach as a means to address the multitude of issues facing the wide-area contamination issues. Toward this end a comprehensive waste management strategy must be developed to effectively address the large volume of the waste generated during an incident. The same strategy should further incorporate flexibility into the existing waste management policy for handling a possible array of radionuclides that could be encountered in acts of terrorism (such as RDDs). Other important provisions in the waste management framework may also include the related issues such as temporary waste storage and staging, and packaging and transportation, which could substantially contribute to the overall complexity toward recovery.

9:00 am

Sang Don Lee *et al.*

U.S. Environmental Protection Agency

is a research environmental scientist for the Office of Research and Development's National Homeland Security Research Center at EPA. He has 12 y of experience at EPA in decontamination and consequence management of Chemical, Biological, and Radiological (CBR) agents. His current research areas are characterization, remediation, and fate and transport of CBR agent in a wide-area incident. He has supported Japanese government for its offsite remediation efforts following the Fukushima nuclear power plant incident since 2012. In 2016 and 2017, Dr. Lee served as the invited expert for the International Atomic Energy Agency's mission to provide technical assistance for the Japanese government's late-phase remediation activities. Dr. Lee received his PhD in Environmental Sciences and Engineering in 2004 from the University of North Carolina at Chapel Hill after earning his MS in Environmental Engineering from Korea University in 1998.

Waste Management Challenges Facing Fukushima's Long-Term Recovery

The Fukushima Daiichi Nuclear Power Plant accident in Japan in March 2011 released large amounts of radioactive contamination over a wide area. Seven years into remediation, a significant amount of waste has been generated. As a result, waste management has been a major challenge for the overall remediation and recovery effort. A majority of the waste still remains widely distributed across the impacted area, volume reduction methods are limited, and significant delays have hampered the construction of interim storage facility (ISF) to treat and store waste. Moreover, the transportation of large volumes of decontamination waste to the ISF remains a challenge for Japan. The culmination of these observations serves as an opportunity for identifying gaps for the United States. This presentation will address the current challenges observed in Fukushima and discuss what we can learn from this incident.

9:30 am

Paul Lemieux *et al.*

U.S. Environmental Protection Agency

is the Associate Division Director of the Decontamination and Consequence Management Division of EPA's National Homeland Security Research Center. Paul has a BS in Chemistry from Seattle University and a PhD in Chemical Engineering from the University of Utah. He has been with the EPA's Office of Research and Development for 30 y, initially studying formation and control of pollutants from combustion systems, and more recently has been working on management of residues from cleanup after chemical/biological/radiological incidents and foreign animal disease outbreaks, and has been working on decision support tools to aid decision makers during wide-area contamination incidents. His current research projects include an in-house project examining issues related to capture of cesium on sorbent particles during biomass combustion as a radiological dispersal device waste volume reduction method, and a project with the U.S. Forest Service to examine partitioning of cesium between residual ash and airborne fly ash particles following a wildfire in a radionuclide-contaminated forest. Paul is a member of the Air and Waste Management Association (ASME) and sits on the ASME Research Committee on Energy, Environment, and Waste.

Tradeoffs Between Decontamination Methods & Waste Management During Response to a Wide-Area Radiological Incident

A wide-area radiological contamination incident, such as a nuclear power plant accident, a radiological dispersal device, or an improvised nuclear device could result in miles of contaminated area and many displaced residents. The cleanup will likely involve the removal of contamination from a variety of surfaces and media types. All decontamination processes result in waste generation, whether it is rinsate/wastewater from the use of aqueous-based removal techniques, removed solids stripped from surfaces by mechanical means, or discarded objects that are deemed too difficult or expensive to decontaminate. Decontamination and waste management issues are inextricably coupled since limitations or constraints imposed on one element of the response tend to have a profound effect on the other aspects of the response. This presentation will discuss operational tradeoffs and potential tools that can be used to assess and manage the complex system-of-systems involved in managing a wide-area radiological response.

10:00 am Break

Session 4: Managing Incident-Specific Waste

10:20 am

John Cardarelli

U.S. Environmental Protection Agency

is a U.S. Public Health Service Officer detailed to EPA with more than 25 y of experience in the field of radiation. He serves as a Health Physicist on the Chemical, Biological, Radiological, and Nuclear Consequence Management Advisory Team (CMAT) to provide scientific and technical support for local and state governments, federal agencies and international partners on radiological issues associated with (1) emergency response, (2) risk assessment, (3) policy development, (4) decontamination technologies, and (5) environmental characterization. He is the lead for developing and maintaining the EPA airborne radiological detection capability within the Airborne Spectral Photometric Environmental Collection Technology (ASPECT) Program and serves as the Radiation Safety Officer for the NRC licensed materials within CBRN CMAT. He also is an Assistant Adjunct Professor at the University of Cincinnati, College of Medicine, Department of Environmental Health. CAPT Cardarelli received a BS in Nuclear Engineering (1990), an MS in Health Physics (1992), and PhD in Industrial Hygiene (2000) from the University of Cincinnati. He holds a Professional Engineering License (nuclear specialty), and is board certified in both Industrial Hygiene and Health Physics.

Waste Management & Decontamination of Incident Involving ^{210}Po in the United Kingdom During 2006

Following the death of Alexander Litvinenko in November 2006 a number of locations in London were found to be contaminated with ^{210}Po. The U.K. Government Decontamination Service deployed contractors within their supplier framework to remediate several locations to below the Health Protection Agency clearance limit. This presentation will (1) summarize the cleanup timeline, (2) identify representatives responsible for making final decisions, (3) describe the instruments and equipment used during the remediation, (4) describe the specific decontamination techniques, (5) address disposal issues, and (6) describe how the cleanup number was derived. Several issues encountered throughout the removal process (*i.e.*, who pays, waste management, media, communications, etc.) hampered efficient recovery efforts. How these were handled and general observations on the differences between U.K. and U.S. removal actions will be discussed.

10:50 am

Daniel Schultheisz

U.S. Environmental Protection Agency

is the Associate Director of the Center for Waste Management and Regulations in EPA's Radiation Protection Division. He has led EPA's efforts to explore management options for low-activity radioactive waste and has led or participated in numerous rulemakings, including EPA's standards for the proposed Yucca Mountain repository. He has also represented EPA in international projects and meetings, and is currently EPA's representative to the Organisation for Economic Co-operation and Development Nuclear Energy Agency's Radioactive Waste Management Committee. He has BS and MS degrees in Chemical Engineering.

Managing Waste from Radiological Incidents: Considerations for Decision Making

As demonstrated by the Chernobyl and Fukushima accidents, a large-scale radiological incident has the potential to result in volumes of waste that cannot be effectively managed by the existing disposal infrastructure. However, this aspect of response and recovery has been given limited attention in typical emergency response exercises, which tend to focus on the initial days or weeks when lifesaving and critical infrastructure are the highest priorities. More recently, recognition of the complexities involved in managing incident-related waste has led to efforts to incorporate this topic into exercises and planning documents, such as the 2010 Liberty RadEx exercise and the 2017 revision to the Protective Action Guides Manual.

Effective waste management begins with the actions of first responders, and should be integrated into planning for the duration of the response and recovery. State, local, and federal decision makers will need to understand the long-term implications of decisions related to demolition, decontamination, and remediation as they balance competing priorities and resources. State and local officials are encouraged to engage in focused and inclusive planning efforts to develop effective strategies to identify potential disposal options and staging or longer-term storage areas where waste management activities can take place (*e.g.*, segregation, characterization, treatment/volume reduction, preparation for transport).

11:20 am Panel Discussion

State and Compact Perspectives on Current LLW Issues

Presented to the Health Physics Society Mid-Year Meeting

PRESENTED BY LEONARD C. SLOSKY

EXECUTIVE DIRECTOR, ROCKY MOUNTAIN LOW-LEVEL WASTE BOARD

DENVER, COLORADO

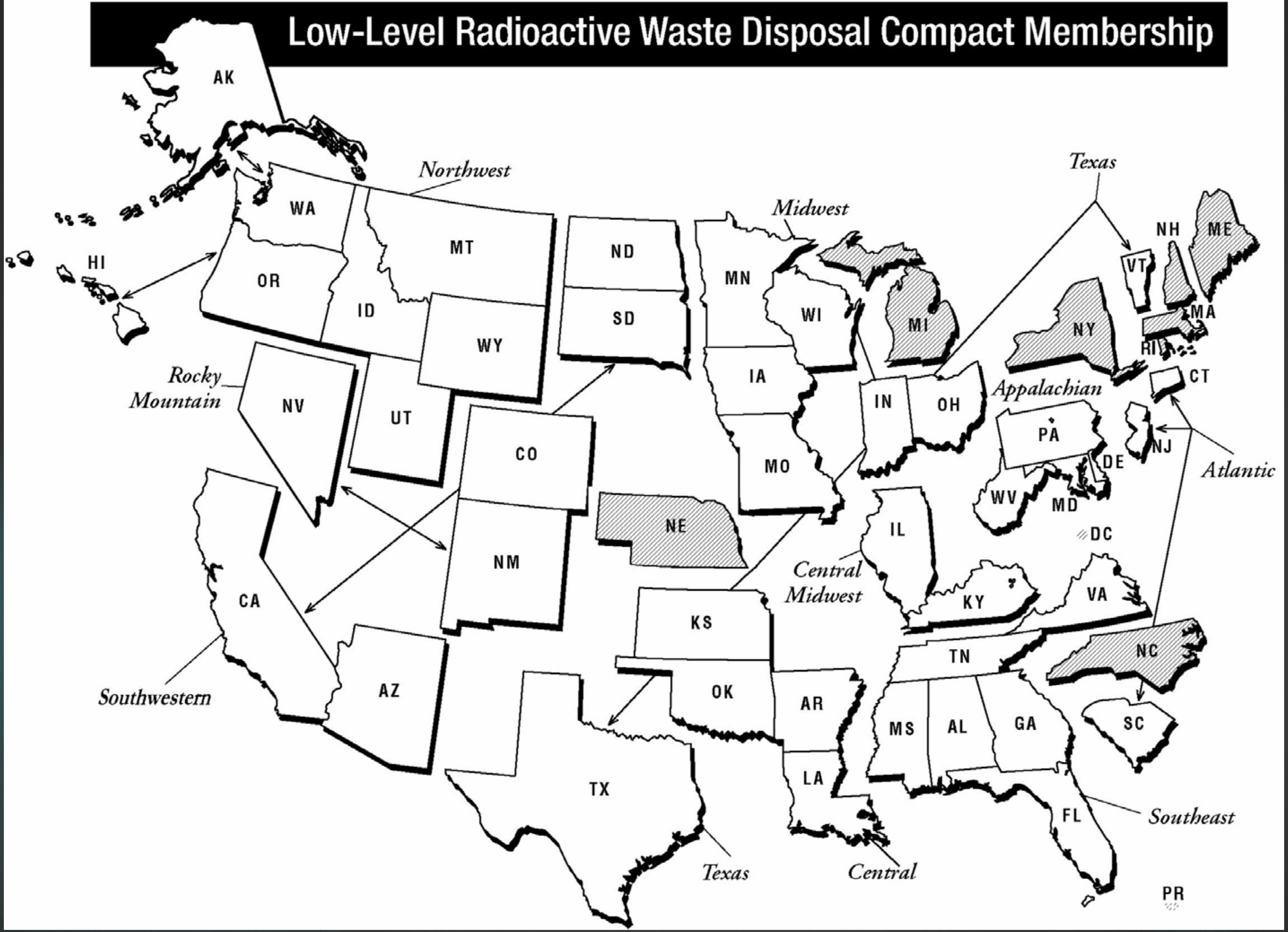
FEBRUARY 5, 2018

Current Low-Level Radioactive Waste (LLW) Issues

- Disused sources
- 10 CFR Part 61 Proposed Rule
- NORM/TENORM - oil and gas waste
- Policy/political aspects of LLW

LLW Forum, Inc.

- Non-profit organization of representatives appointed by Governors and compact commissions to facilitate implementation of Low-Level Radioactive Waste Policy Act of 1980 and the 1985 amendments, as well as to promote the objectives of the regional compacts
- Two active working groups
  - Disused Sources Working Group
  - Part 61 Working Group



Rocky Mountain LLW Board

Disused Sources Working Group (DSWG)

- Formed in 2011 at the request of National Nuclear Security Administration (NNSA)
- March 2014 released report with 24 recommendations to improve the management and disposition of disused sources
- Key findings
  - Sealed sources have many beneficial uses, and the vast majority are properly managed
  - Licensees are reluctant to reuse, recycle, or dispose of sources due to high costs, lack/cost of shipping containers, and other factors

Key DSWG Recommendations

- Regulatory improvements should be considered, including:
  - Enhanced financial assurance requirements
  - General license restrictions
  - Storage time limits
- Licensees would benefit from better information prior to acquisition, and when sources are no longer needed
- Comprehensive approach is needed to address the entire life-cycle of sources

DSWG Post-2014 Outreach Efforts

- 2015 survey with Conference of Radiation Control Program Directors (CRCPD) to affirm and help refine DSWG recommendations
  - Regulators should encourage the reuse of sources, and a source exchange registry should be evaluated
  - Enhance regulatory inspection procedures, including use status
  - Impose two-year storage limit (adopted by Texas)

DSWG Survey with CRCPD

- Financial assurance requirements should be updated to align with costs, and at least apply to Category 1 and 2 sources
- Activity in generally licensed devices should be limited, and specific licenses required for higher activity sources
- NRC needs to take the lead in regulatory improvements
- Rationalize foreign container restrictions

DSWG Outreach Efforts – 2

- 2016 established formal liaisons with HPS (Craig Little), Organization of Agreement States, and CRCPD
- Early 2017, in conjunction with CRCPD (E-34), published educational brochure for current and prospective source users, explaining
  - Life-cycle costs, including initial purchase price, license fees, financial assurance, operating costs, security, and end-of-life disposition

DSWG Educational Brochure

- Potential alternative technologies
- Potential liabilities
- Information about Source Collection & Threat Reduction (SCATR) Program and Off-Site Source Recovery Program (OSRP)
- Educational brochure available at www.disusedsources.org

DSWG Comments on NRC Activities

- March 2017 DSWG commented on NRC's review of Category 3 source protection and accountability
- May 2017 DSWG joint letter with HPS, CRCPD, and OAS supporting NRC staff recommendations for rulemaking to expand financial assurance requirements (10 CFR § 30.35) to include all Category 1 and 2 sources that are tracked in the National Source Tracking System

DSWG Disposition Guide

- Late 2017, published “Disposition Options and Costs for Certain Radioactive Sealed Sources and Devices”
  - Assist in understanding the likely options and costs of disposition on common sealed sources and devices
    - Radiography devices, fixed industrial gauges well logging brachytherapy sources, portable gauges teletherapy devices, and self-contained and panoramic irradiators

Current DSWG Efforts

- Exploring development of database on source recycle and reuse
- Workshops through states and compacts to educate licensees
- Supporting U.S. NRC efforts
  - Scoping study concerning financial planning requirements for decommissioning and end-of-life management for byproduct material

Additional DSWG Efforts

- Cooperating with CRCPD
  - Part S Working Group on suggested state regulations for financial assurance
  - E-34 Committee development of educational materials for licensees

LLW Forum 10 CFR Part 61 Working Group

- P61WG composed of the sited states of South Carolina, Utah, and Washington, as well as Pennsylvania
- July 2015 P61WG submitted 56 comments to NRC on proposed rule
- Comment period ended on September 21, 2015
- NRC staff drafted a final rule package for Commission review in September 2016

10 CFR Part 61 Working Group – 2

- Commission issued a Staff Requirements Memorandum on September 8, 2017
- NRC recently requested comments on how to improve the regulatory analysis, particularly regarding cost/benefit data
- November 15, 2017 P61WG commented on draft regulatory analysis

P61WG Concurs with Important Aspects of Proposed Rule

- Site-specific analysis using modern dose methods
- New site-specific technical analysis for protection of inadvertent intruders, including a 5 mSv/yr dose limit
- Providing flexibility by allowing waste acceptance criteria developed using site-specific analysis

P61WG Concurs with Important Aspects of Proposed Rule – 2

- Use of total effective dose equivalent in § 61.41 and dose limit of 0.25 mSv/yr
- Allowing use of ICRP dose methodologies in site-specific performance assessment

P61WG Concerns with Proposed Rule

- Sites that only take traditional waste streams should not be required to implement the new regulatory analysis
- 1,000-year technical analysis compliance period is a significant regulatory shortfall for the radiological characteristics of depleted uranium
- Maintain Compatibility Category C
  - The manner in which the essential objectives are addressed need not be the same as NRC, provided the essential objectives are met

Current NRC Issues being Monitored by LLW Forum

- Revision to 20.2006 guidance for alternate disposal of LLW
- Greater-than-Class C (GTCC) waste
- Revision to Instructions for Completing NRC's Uniform LLRW Manifest
- Very low-level radioactive waste scoping study
- Regulatory basis for new decommissioning regulations

NORM/TENORM – Oil & Gas Wastes

- A few states have regulated for a number of years
- Recent shale developments presenting challenges to additional states and compacts
- North Dakota forefront in developing H&S regulations
  - What wastes can be disposed where
- Key compact issue – regulating waste flow between compacts

NORM/TENORM – State Challenges

- Key challenges for the states
  - Non-traditional radioactive waste generators/processors
  - Radiation hazards not recognized or ignored
  - What should be regulated

Policy and Political Aspects

- Compact system never intended to be uniform regulatory system like AEA
- While system will continue to evolve, decision-making must recognize fragility of system
- Only four major disposal facilities: SC, TX, UT, WA

Upcoming Meetings

- LLW Forum hosting a panel on Hot Topics and Emerging Issues in in U.S. Commercial LLW Management at Waste Management 2018
  - John Tappert, NRC
  - Daniel Shrum Energy Solutions
  - Susan Jenkins, South Carolina DHEC
  - Lisa Edwards, EPRI
- Next meeting of the LLW Forum: April 16-17 in Burlingame, CA. Registration: www.llwforum.org

Contamination Mitigation in the Waste Isolation Pilot Plant (WIPP) Repository

Casey Gadbury, Carlsbad Field Office

Office of Program Management Director

February 5, 2018

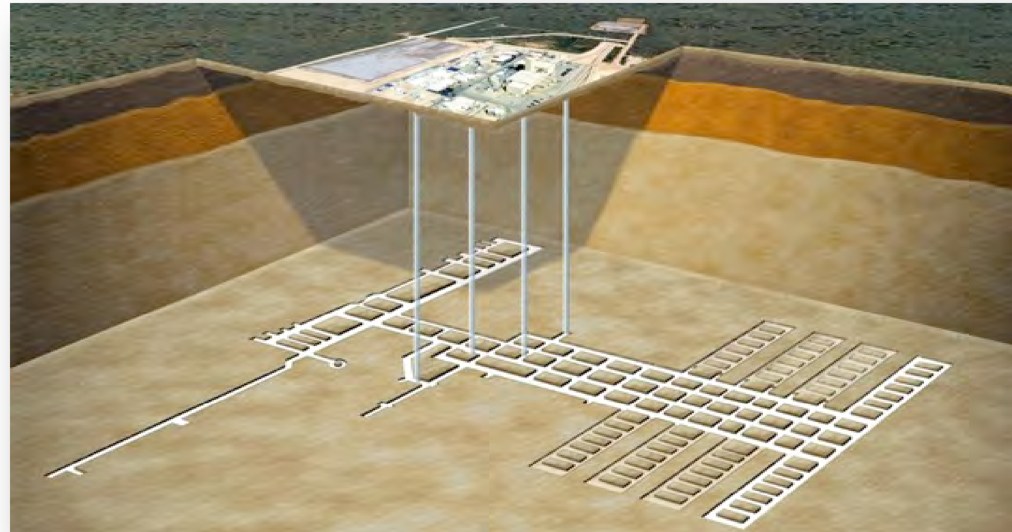
WIPP Facility Description

- 10,240 Acre Facility located in Eddy County (SE New Mexico)
- Deep geological repository
- Mined within a 2,000 foot thick salt formation that begins approximately 850 feet beneath the surface
- Formed 250 million years ago (Permian Era)
- Waste horizon is 2,150 feet beneath the ground surface
- RCRA permitted facility
- Land Withdrawal Act
- Stable geological area with no flowing water

Disposal Concept of WIPP

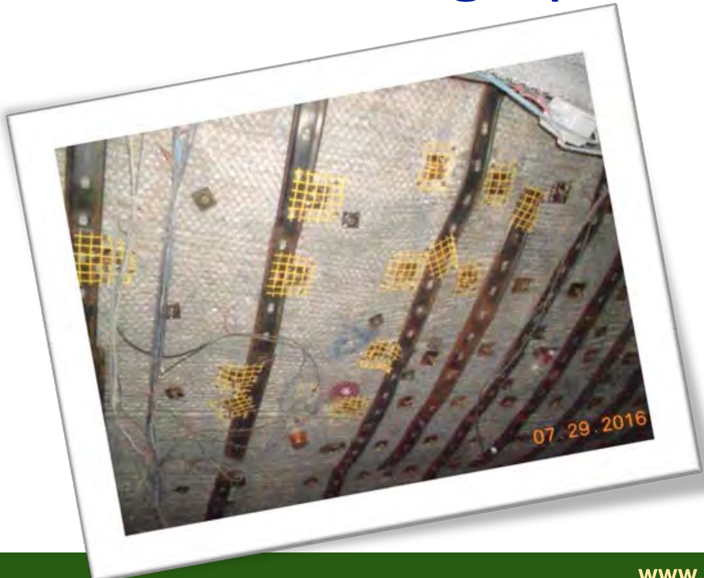
Facility mined in salt:

2,150 feet deep in ancient salt formation that closes in and entombs waste permanently



Ground Control is Unique to WIPP

- Rock falls are potentially the single highest hazard to workers and the WIPP mission
- Ground is constantly moving
- Requires daily inspections
- Re-milling of floors, bolting and bolt replacement, installation of chain mesh, and scaling operations



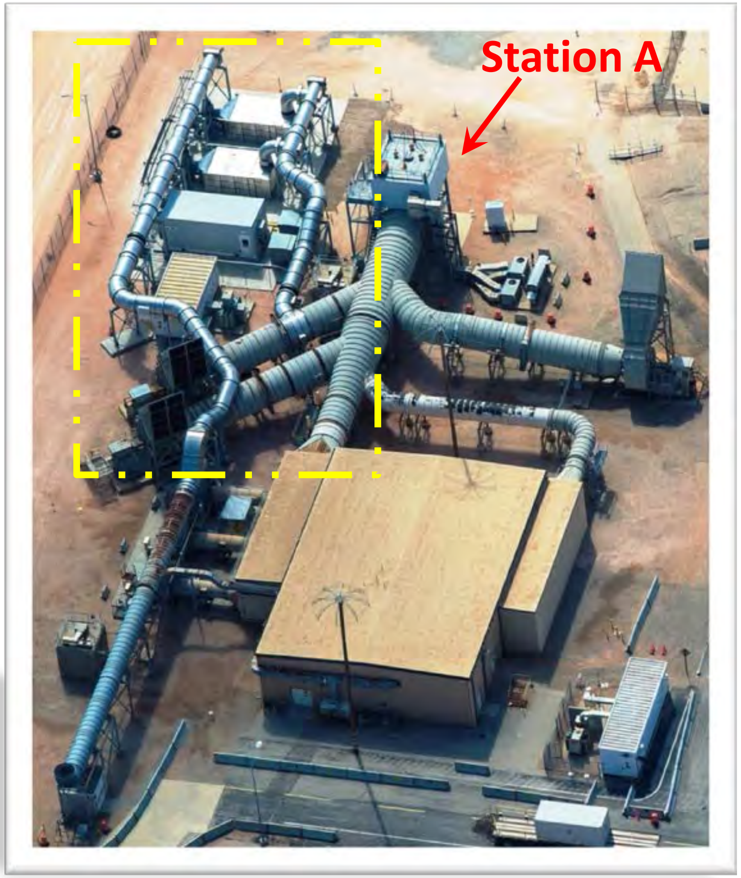
Contact Handled Waste Emplacement

Waste containers are placed on waste hoist for 2155’ descent into underground

In underground, waste is removed from the hoist and transported to a disposal room

Waste is emplaced in recently mined rooms. Magnesium oxide is placed on waste stack to control solubility of radionuclides in event of hypothetical brine intrusion

Ventilation



- Pre-Event Unfiltered Capacity – 425,000 cfm
- Filtered Capacity
  - Underground ventilation system – 60,000 cfm
  - Interim ventilation system – 54,000 cfm
- Required for air quality
  - Removes VOCs off-gassing from waste containers
  - Removes Carbon Monoxide and provides fresh air
- Provides confinement for radiological contaminants
- Limiting resource for occupancy, maintenance, ground control and operations
- Unlike fixed nuclear facilities, air volumes and flow routes are regularly changed to support different activities

WIPP is a National Solution

Quick Facts (as of Feb. 23):

- Opened: March 26, 1999
- 12,040 shipments received
- 91,100 cubic meters of waste disposed
- 171,176 containers disposed in the underground
- Over 7.5 miles of accessible areas of the underground

WIPP is America's only deep geologic repository for the permanent disposal of defense-generated transuranic (TRU) radioactive waste left from research and production of nuclear weapons.

Events & Recovery Time Line

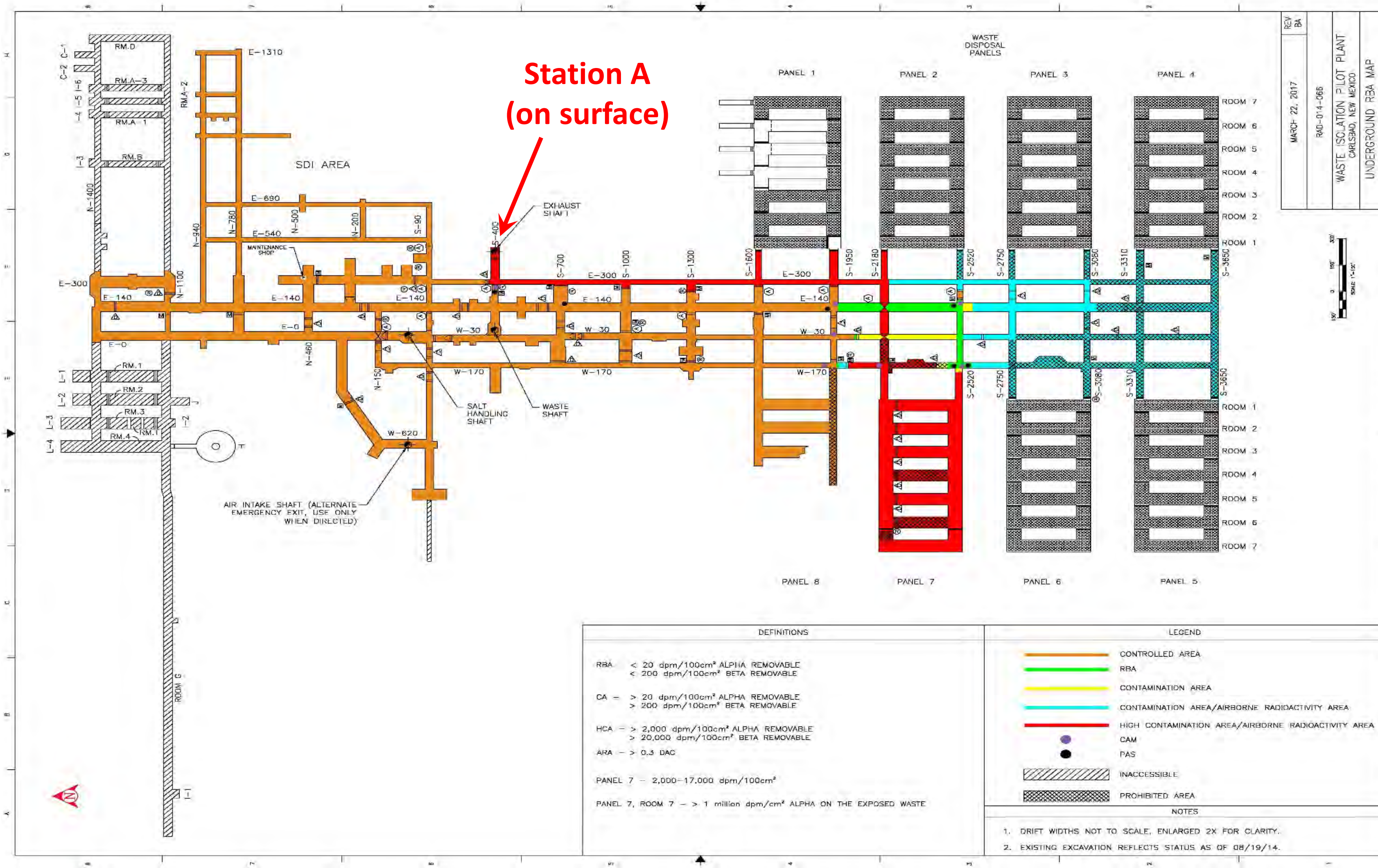
- Events occurred in February 2014
- Approximately nine months needed to return to limited underground operations
- Original Recovery Plan released November 2014
- Re-start authorization granted on December 23, 2016
- First Emplacement on January 4, 2017

Salt Haul Truck Fire – 2/5/14

Rad Release Event – 2/14/14

WIPP Restart

Radiological Conditions Underground



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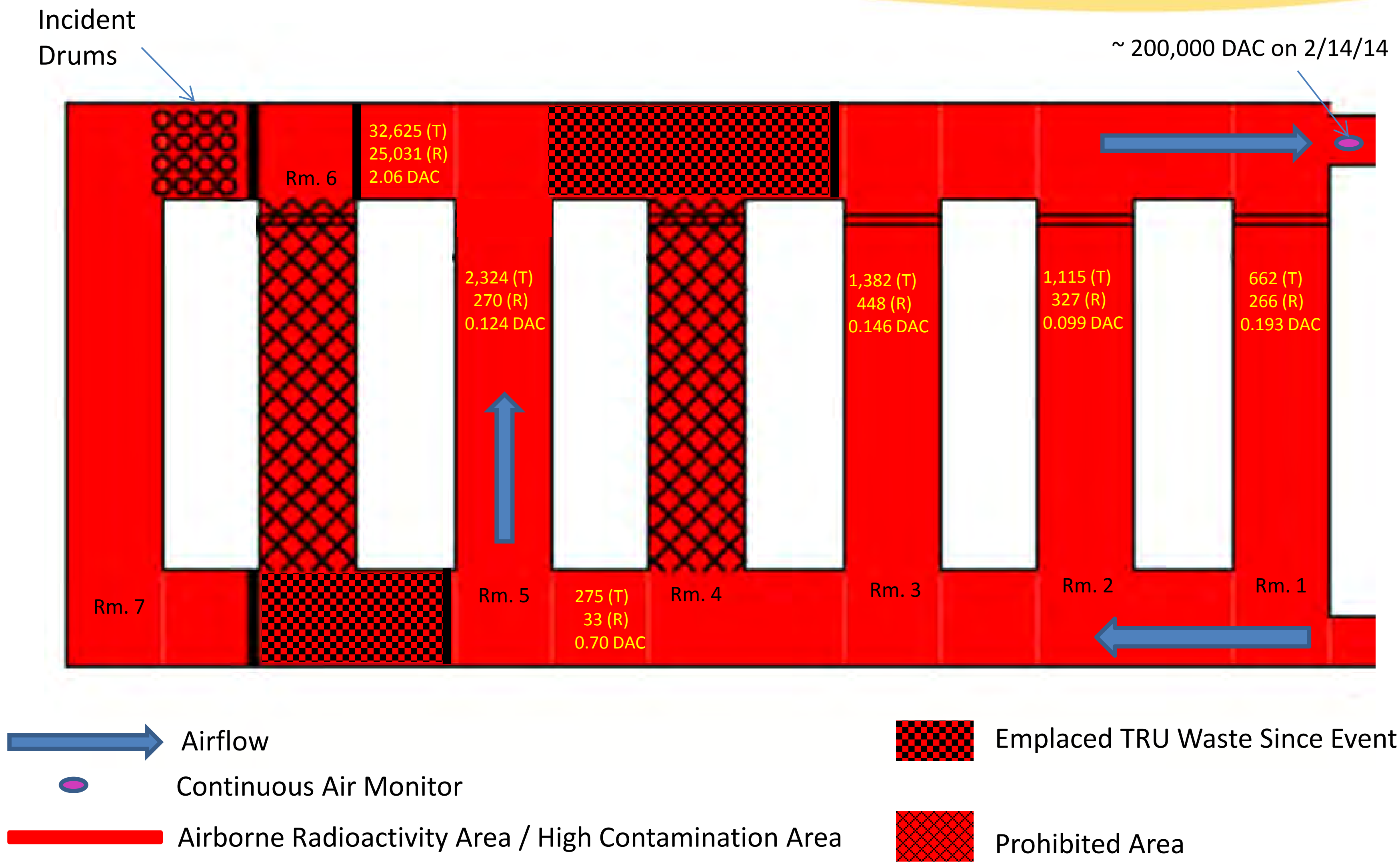
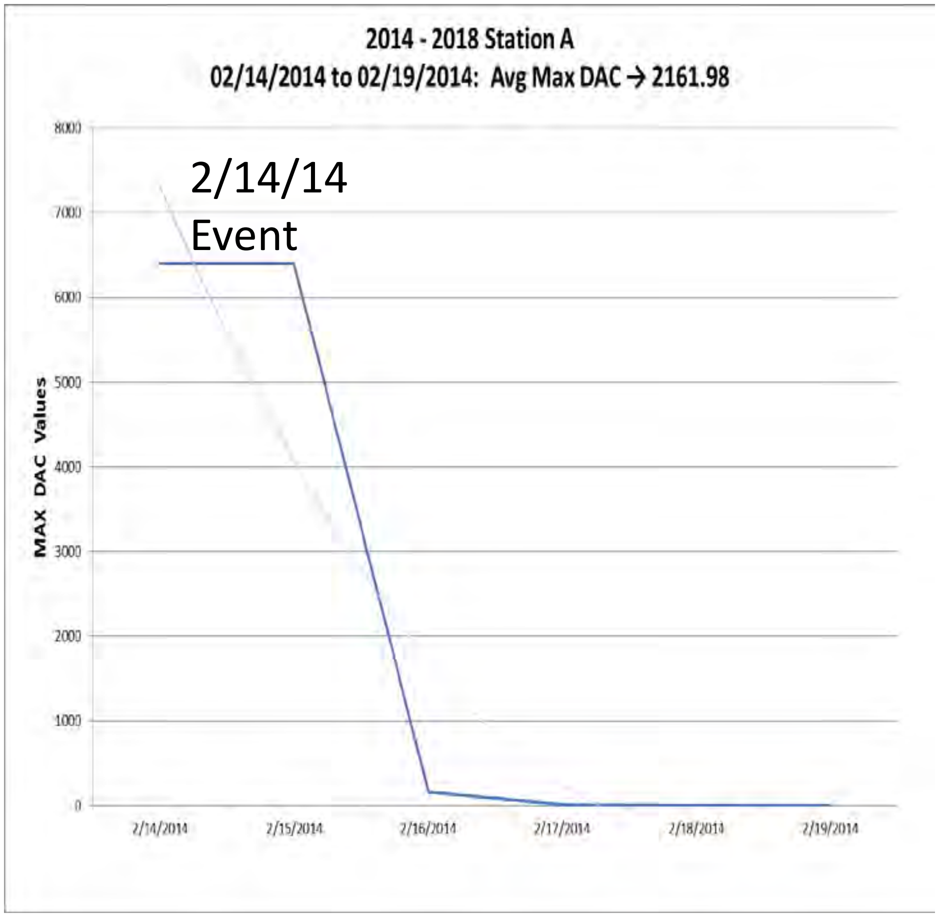
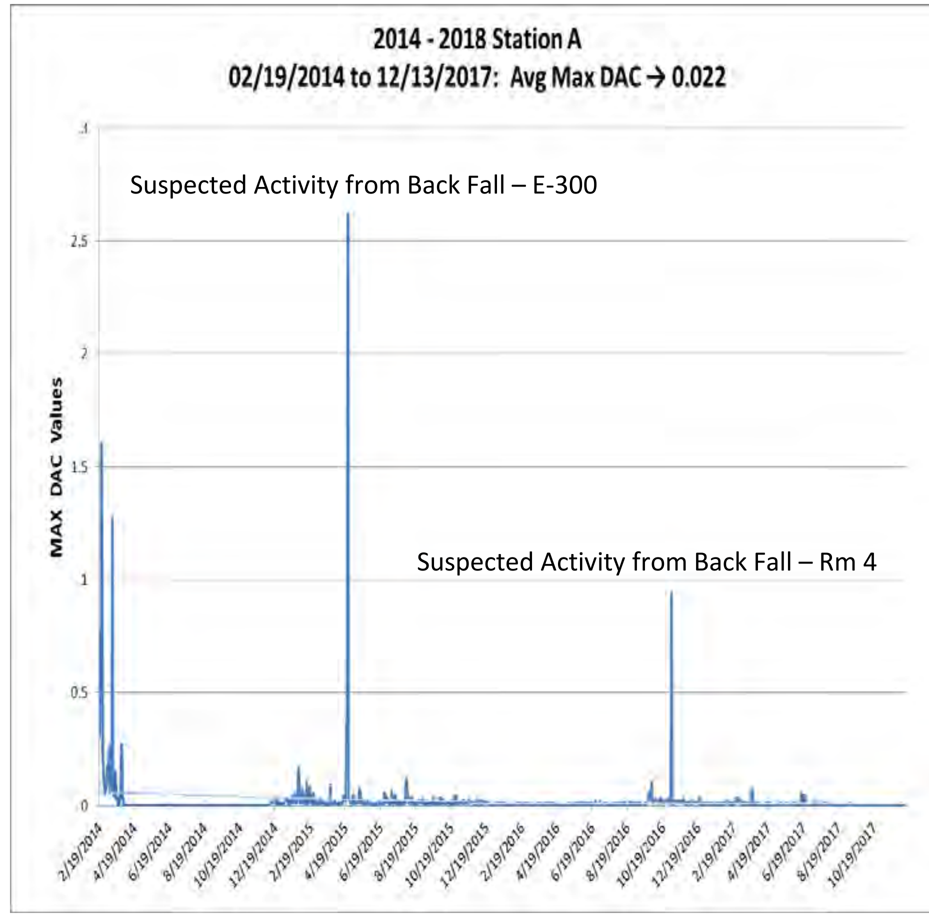
Panel 7 Max Contamination and Airborne Radioactivity



(T) = Total & (R) = Removable Contamination – dpm/100cm^2 alpha

Airborne Radioactivity Conditions





Training for Re-Entry into Underground

Dealing With Radiological Contamination

- Moving salt rock vs. facilities with fixed walls
- Salt matrix
  - Challenges survey techniques
  - Decontamination techniques challenged
- Only effective decontamination technique is physical removal of contaminated salt surfaces
- Water spray takes advantage of hygroscopic properties of salt to encapsulate contamination in the salt matrix
- Resuspension risk remains
- Mine is self-healing over time (scaling, hygroscopic effects)

Contamination Mitigation – Water Spray

OFFICE OF ENVIRONMENTAL MANAGEMENT

Emplacing in Contaminated Environment

15

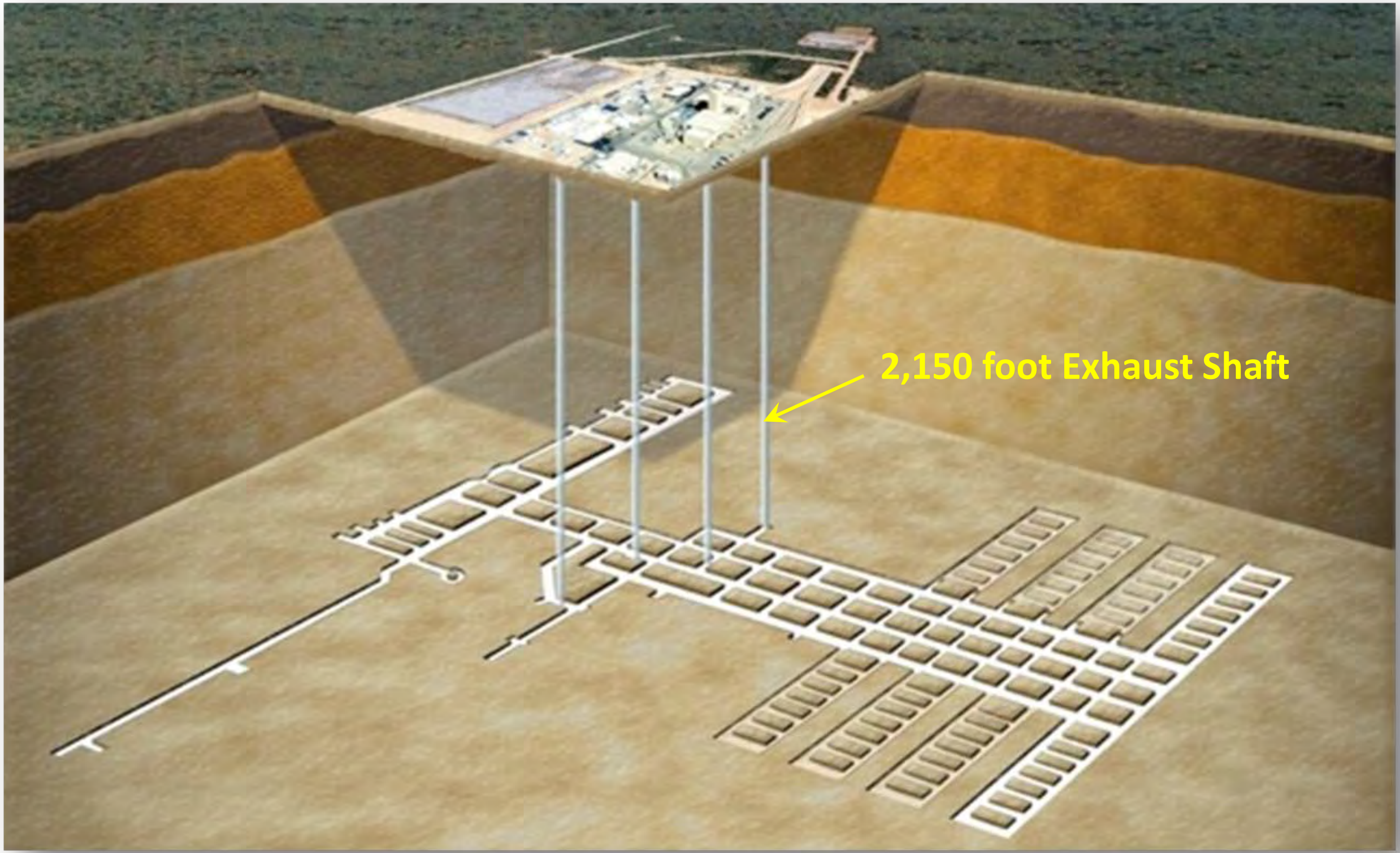
Proposed Methods to Improve Working Conditions

- Continue Water Sprays
- Address Worker Concerns: Educate workers on actual risk of rad intake relative to other hazards (i.e., ground conditions, air quality, etc.)
- Consider different type respirators: Commensurate with rad hazard, minimizes other hazards (i.e., visibility, heat stress, etc.), improves work efficiency
- Down post areas near Panel 7:
  - Improved egress potential in emergencies
  - Better location for vehicle PMs
  - Better location for clean lunch room for workers

Contamination Mitigation in Exhaust Drift (East-300)

- Downstream of Panel 7
- Still needs to be characterized
- Still needs ground control
- Still needs contamination mitigation (options)
  - Water spray
  - Fixatives
- Necessary to continue the process of contamination source reduction

Contaminated Exhaust Shaft



Considerations for Contaminated Exhaust Shaft

- Shaft surfaces contaminated from event
- No conveyance (hoist) in shaft to mitigate contamination
- Humid conditions in shaft
  - Hygroscopic properties of salt in shaft encapsulates contamination in shaft
  - Salt rock sluffs off shaft walls over time and falls to bottom
  - Result is natural contamination mitigation over time
- Station A monitoring is a leading indicator for HEPA filtration of the mine exhaust

Liquid Waste Program
Prime Contractor

U.S. DEPARTMENT OF ENERGY

Savannah River Remediation
AECOM | BECHTEL | CH2M | BWXT

High Level Waste Tank Closure at Savannah River Site

Kent H. Rosenberger

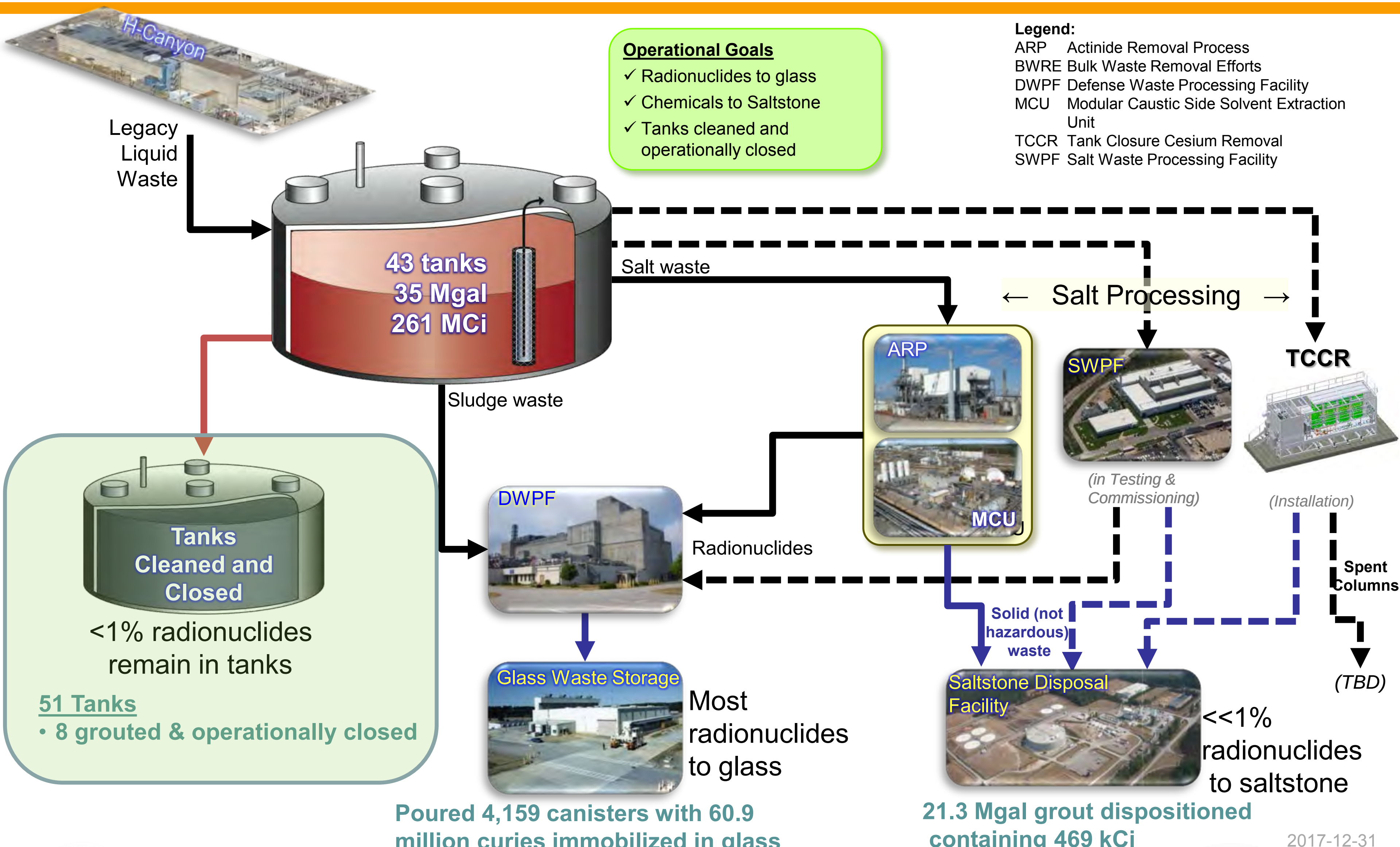
Savannah River Remediation LLC

February 5, 2018

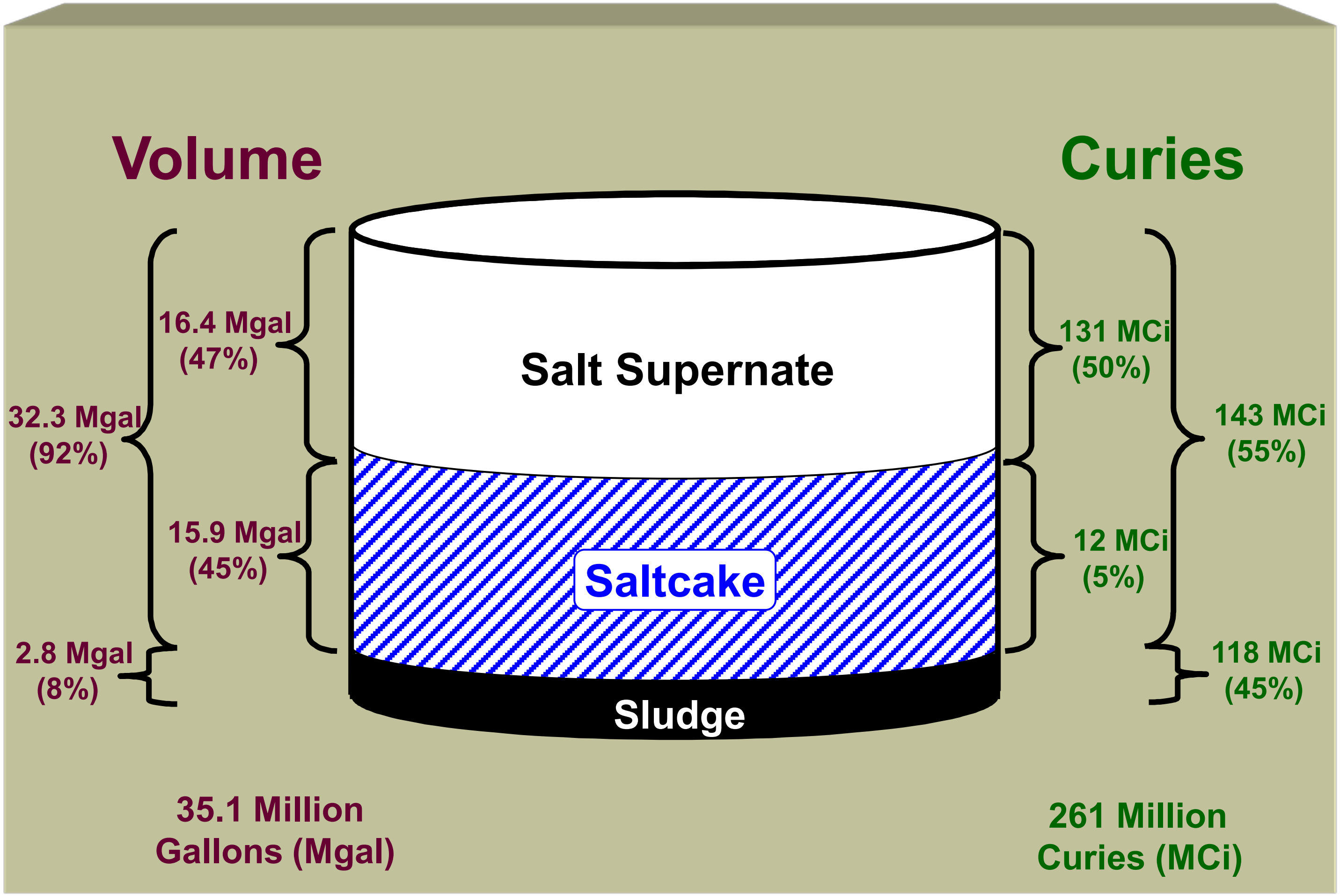
Presentation Introduction

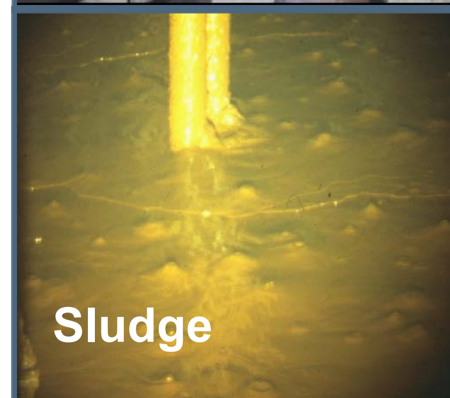
- **Tank closure at Savannah River Site involves both operational and regulatory activities that can span many years between the beginning and end of closure.**
- **Although many challenges exist, SRS has been highly successful in operationally closing 8 very large tanks that formally stored high-level waste.**
- **Today's presentation is a cursory overview of activities leading to tank closure.**

Current SRS Liquid Waste Program Status



SRS Composite Inventory



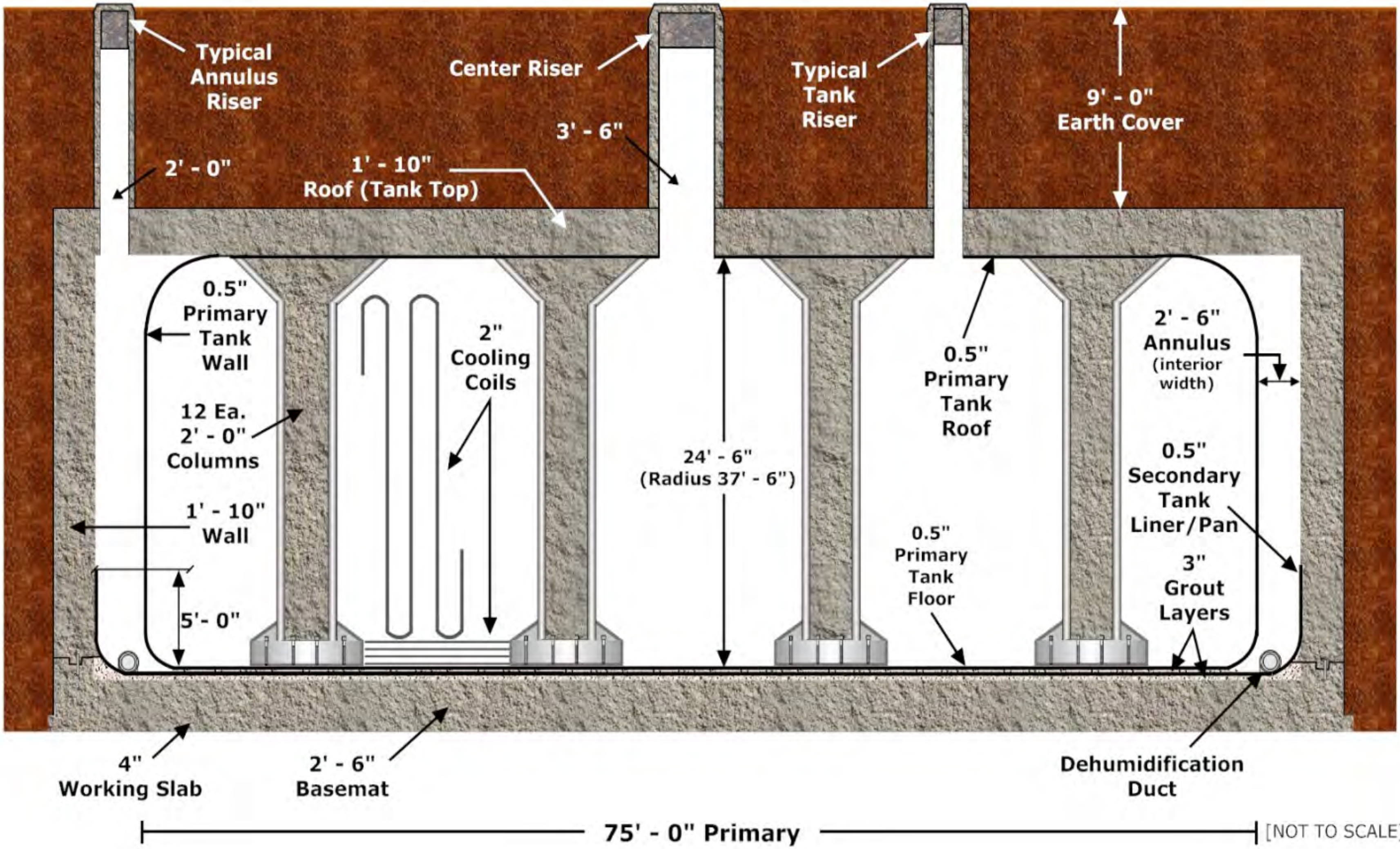


Inventory values as of 2017-12-31

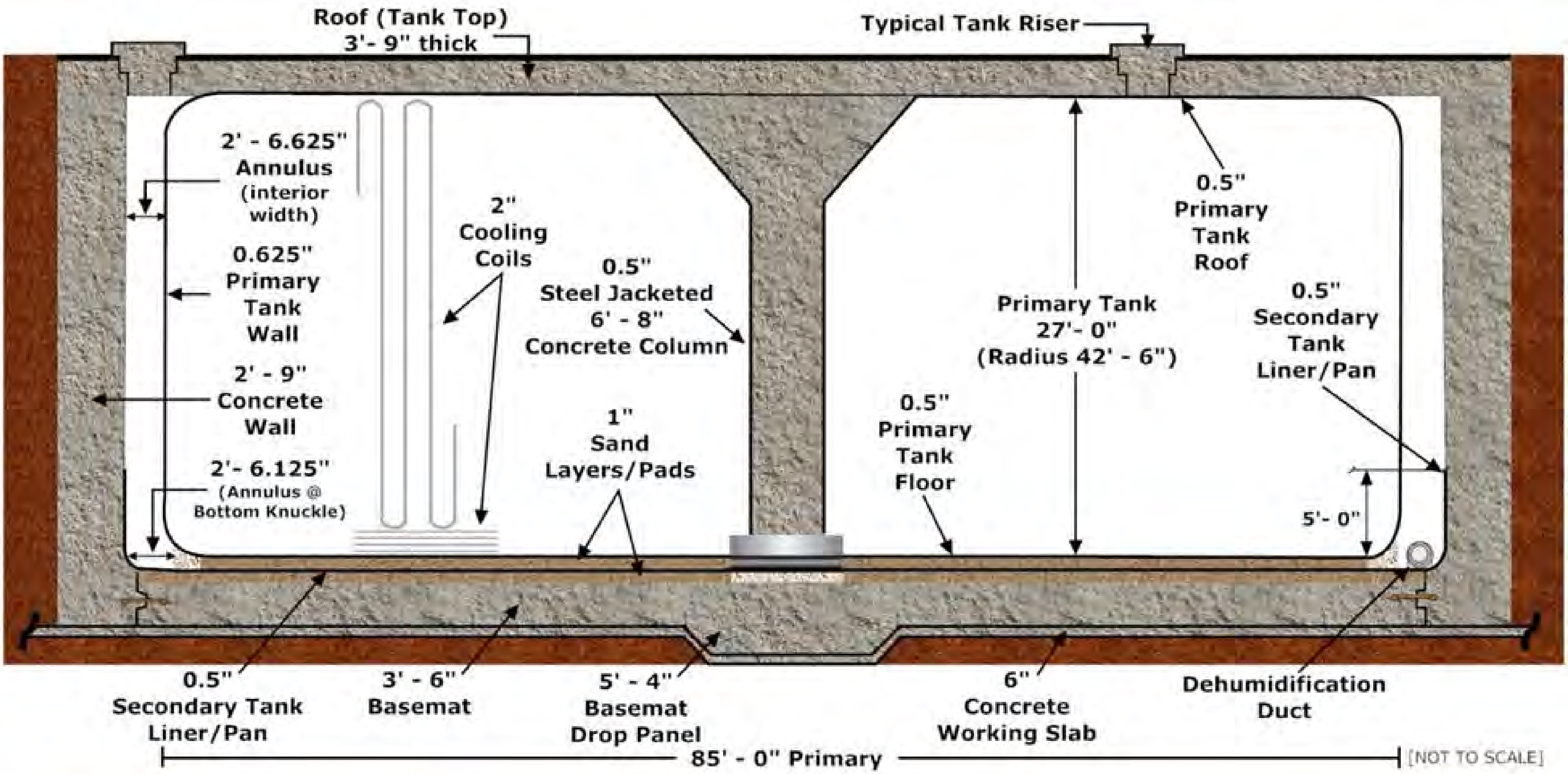
SRS Tank Closures

Tank	Tank Type	Tank Farm	Year Closed
20	IV	F	1997
17	IV	F	1997
18	IV	F	2012
19	IV	F	2012
5	I	F	2013
6	I	F	2013
16	II	H	2015
12	I	H	2016

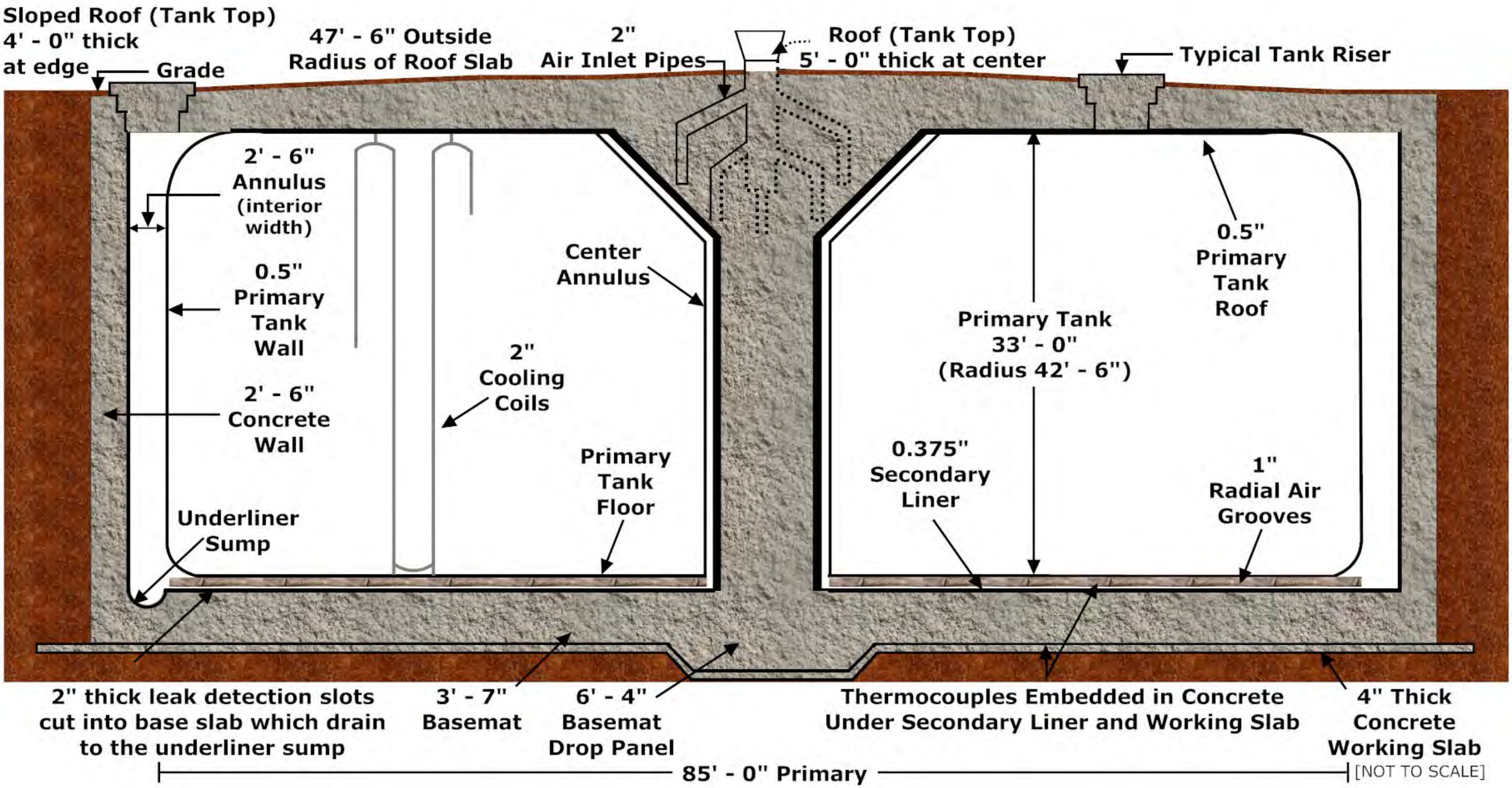
Type I Waste Tank (750,000 gallons)



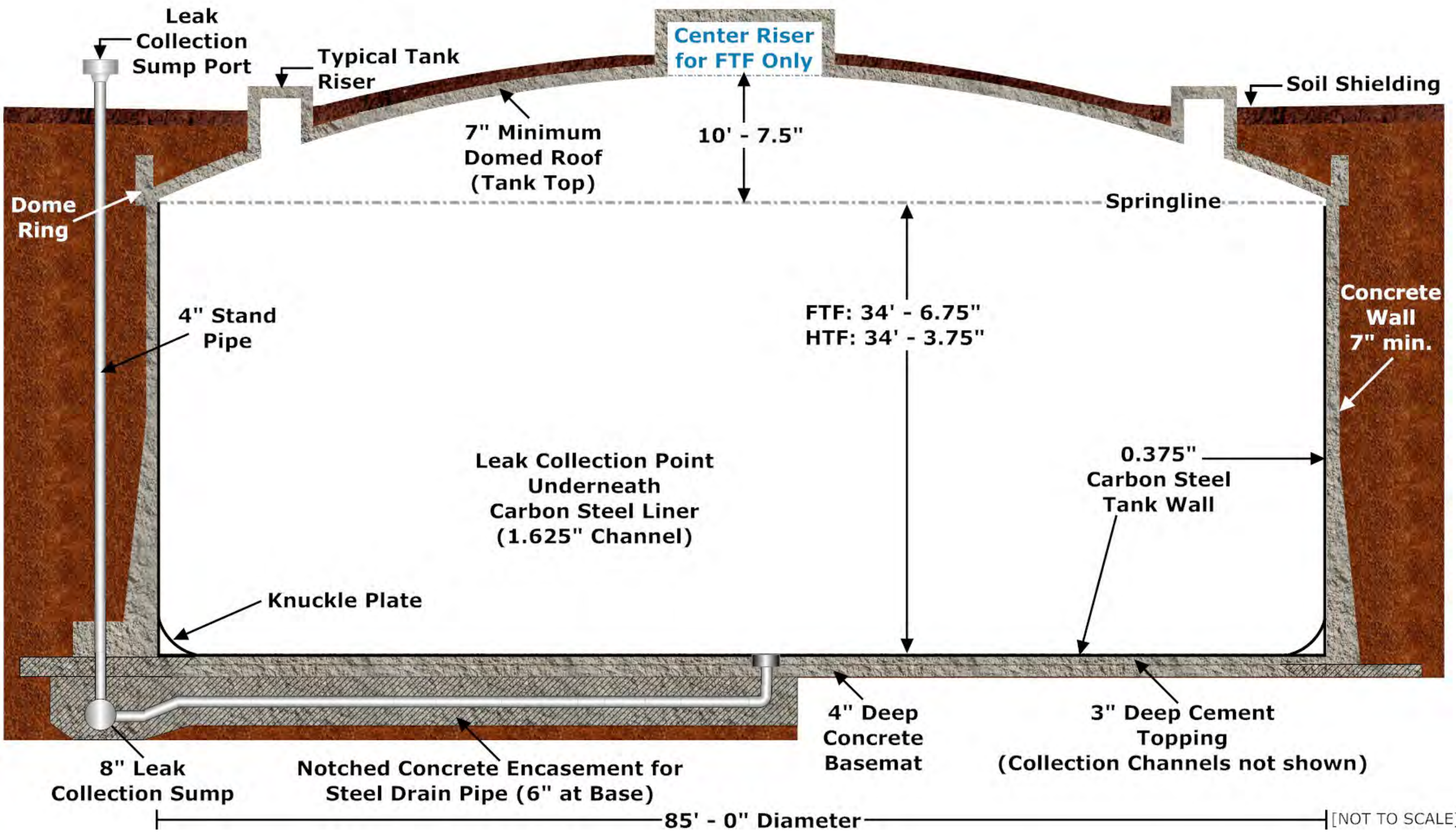
Type II Waste Tank (1,070,000 gallons)



Type III/IIIA Waste Tank (1,300,000 gallons)



Type IV Waste Tank (1,300,000 gallons)



Steps to Operational Closure

Safe Storage

Bulk Waste Removal Efforts

Final Removal Phase

- **Heel Removal** [a]
- **Cooling Coil Flushing** [b]
- **Annulus Cleaning** [c]

Tank cleaned to max. extent practical

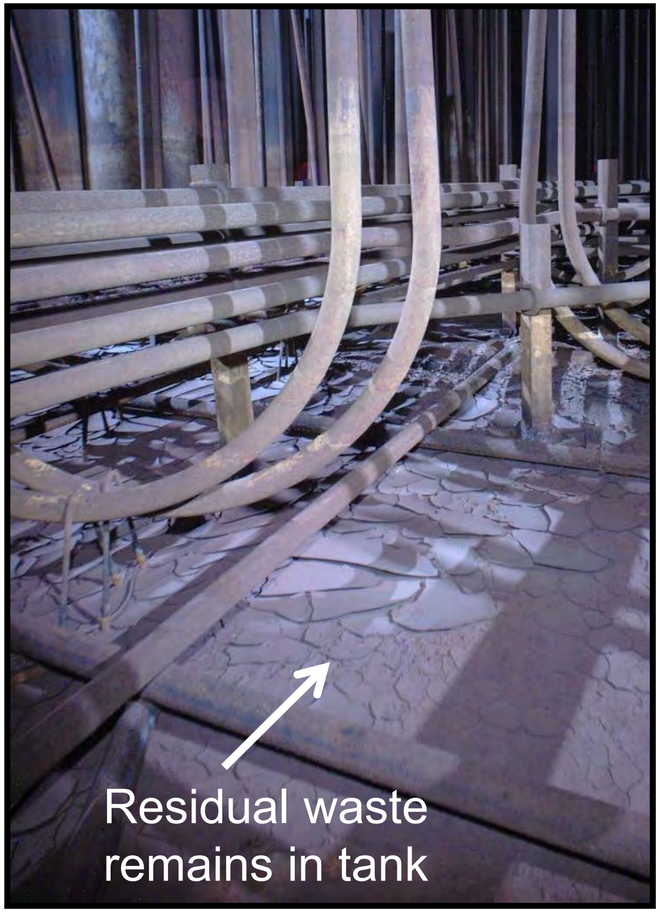
Isolation & Residual Sampling

Tank Stabilization

Grouting

Legend:
- a May not be required if no appreciable material remains in tank after BWRE
- b, c Not applicable for Type IV tanks. May be performed as part of heel removal step
- c May not be required if no appreciable material exists

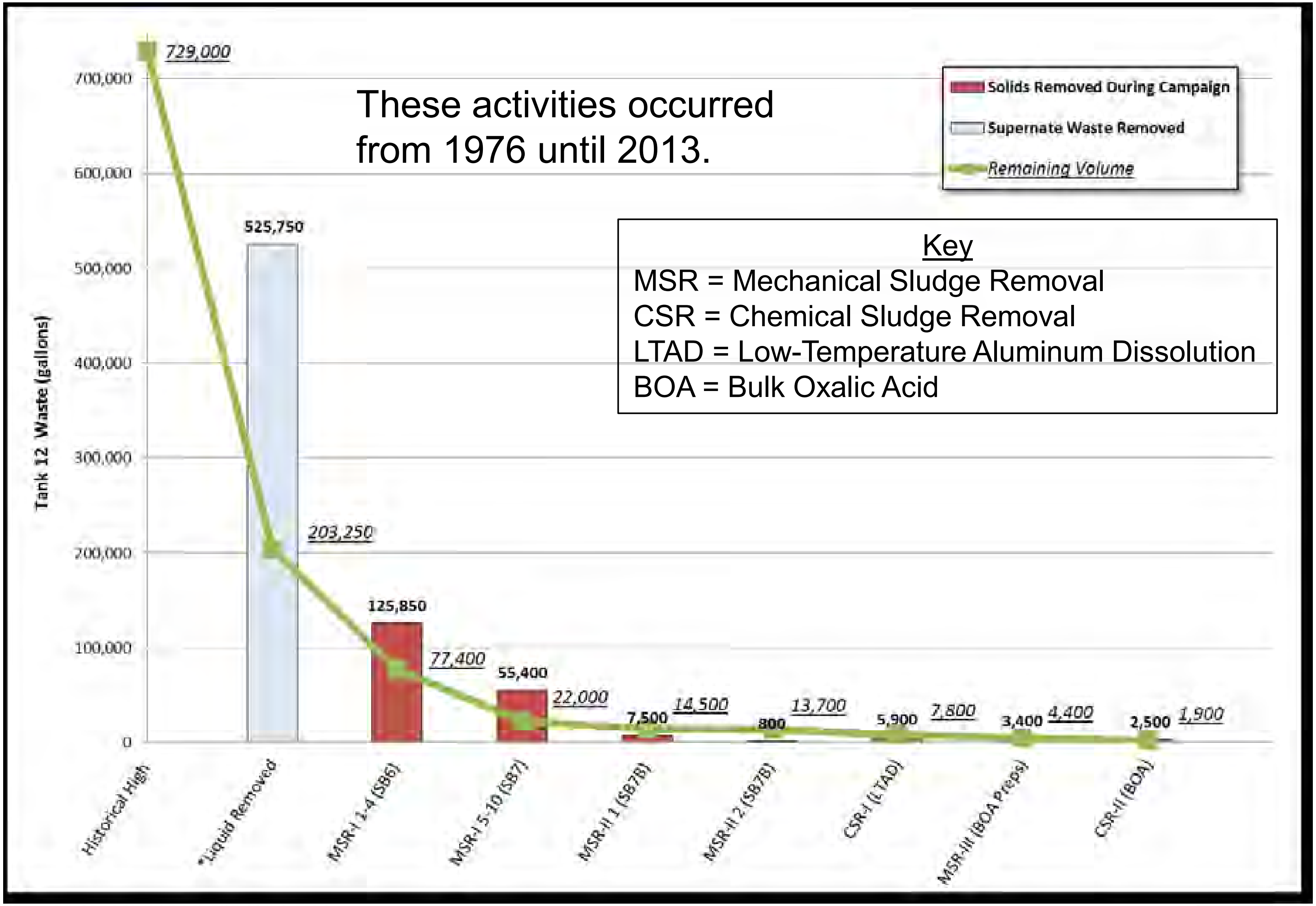
Note: Figure also applies to ancillary equipment/structures, as appropriate



Example of Waste Removal Methods

- Waste removal equipment and use of chemical cleaning is dependent on the type of tank and nature/form of the waste to be removed.
- As an example, use of purely mechanical cleaning may be efficient in tanks without cooling coils but potentially not as effective in those with coils.
- Even the example is a generalization and plans will be different for each waste tank – can pick from a menu of possible equipment/technologies available.

Example of Waste Removal Steps



These activities occurred from 1976 until 2013.

Key
MSR = Mechanical Sludge Removal
CSR = Chemical Sludge Removal
LTAD = Low-Temperature Aluminum Dissolution
BOA = Bulk Oxalic Acid

Example of Inventory Removal Results

Radionuclide	Tank 12 HRR Inventory Prior to Waste Removal (1973) (Ci)	Tank 12 HRR Residual Inventory (2015) (Ci)	Percent Removed (%)
Sr-90	1.69E+07	1.20E+05	99.3%
Tc-99	5.46E+03	7.23E-02	100.0%
I-129	1.70E+01	3.80E-02	99.8%
Cs-137	3.65E+06	9.10E+01	100.0%
U-233	3.84E+01	2.00E-01	99.5%
U-234	3.58E+00	5.50E-02	98.5%
U-235	7.71E+03	3.40E-04	100.0%
Np-237	8.01E+00	1.60E-01	98.0%
Pu-238	1.82E+05	1.01E+03	99.4%
Pu-239	3.55E+03	4.28E+01	98.8%
Pu-240	1.34E+03	1.68E+01	98.7%
Am-241	1.81E+04	1.33E+02	99.3%
Am-243	8.59E+00	1.60E-01	98.1%
Total	**2.08E+07**	**1.22E+05**	**99.4%**

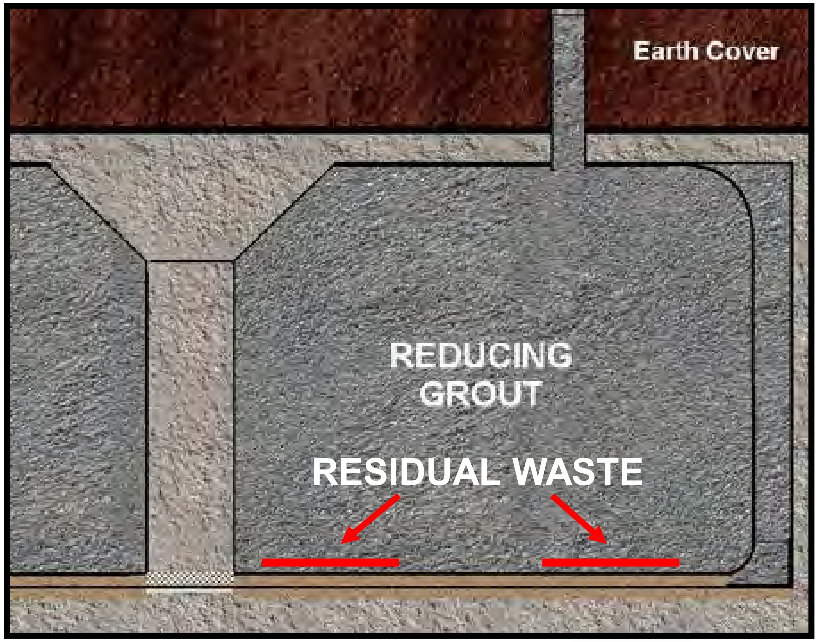
[SRR-CWDA-2015-00098]

HRR = Highly Radioactive Radionuclide
- regulatory term

Final Closure Step

- **Benefits of grouting a cleaned tank:**
  - Structural stability and prevents subsidence.
  - Reduce water impacting the residual contaminants.
  - Reducing properties that aid in immobilizing Tc-99.
  - Barrier to intrusion.

Contaminant	Risk-driving Characteristics
Tc-99	Long-lived, potentially mobile β-emitter
Np-237	Long-lived, potentially mobile α-emitter
Pu-238	Most abundant α-emitter
Pu-239	Relatively abundant, long-lived α-emitters
Sr-90/Y-90	High abundance β-emitters
Cs-137/Ba-137m	High abundance β/γ-emitters
Nitrate/nitrite	High abundance dissolved contaminants

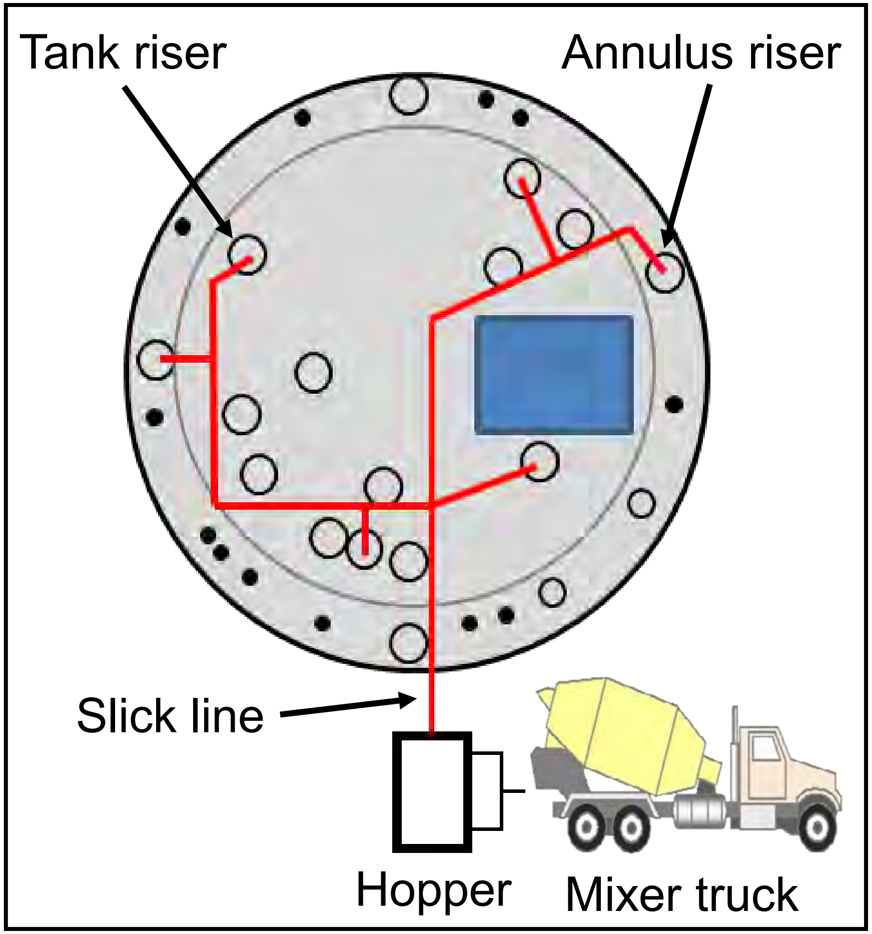


Specialized Grouts

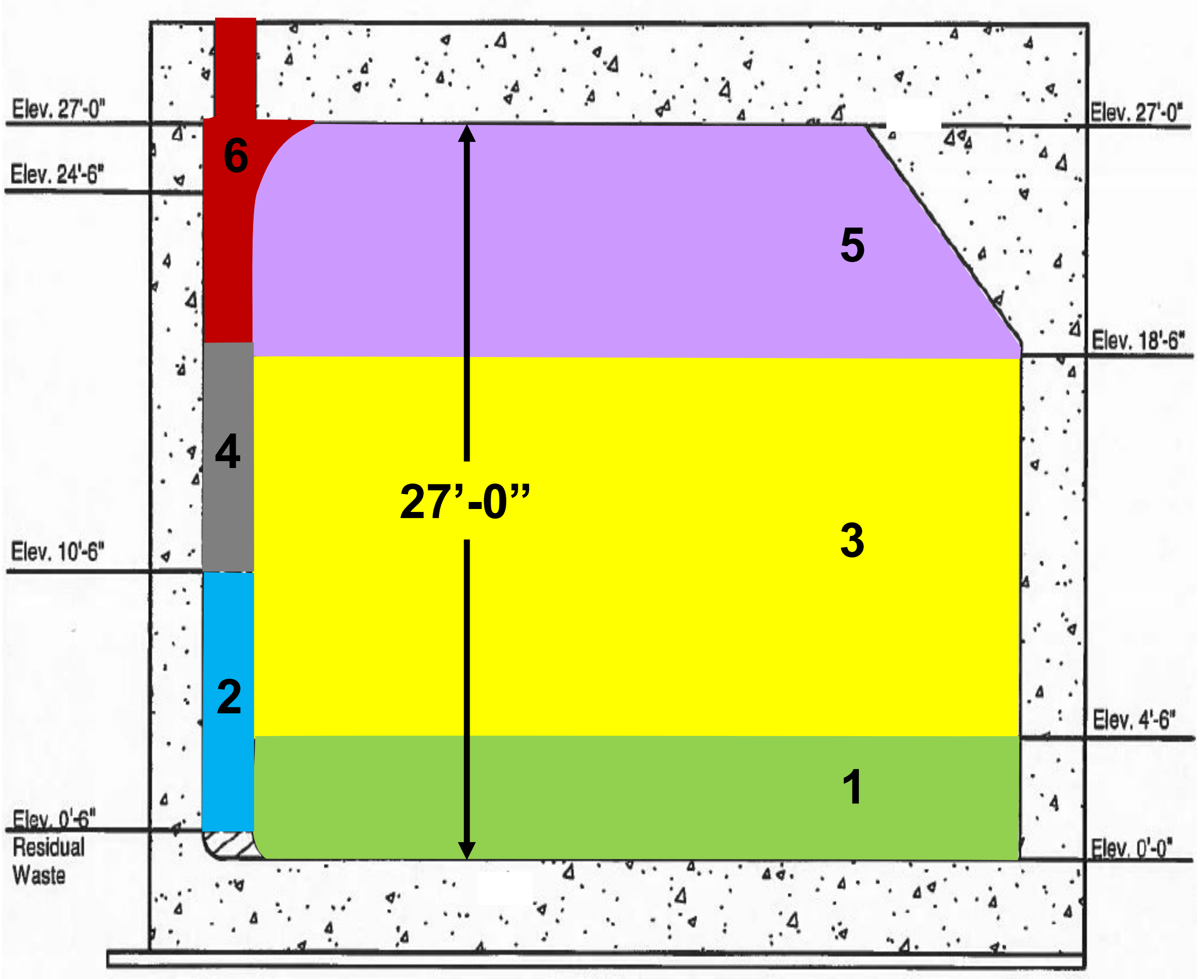
- **Developed by Savannah River National Laboratory (SRNL).**
  - Bulk fill grout for main tank and annulus.
  - Equipment fill grout for abandoned-in-place equipment.
  - Cooling coil fill grout.
- **Goal to minimize any void spaces in tank.**

Example Tank Prior to Grouting

Example Equipment Setup and Monitoring



Example Grouting Strategy

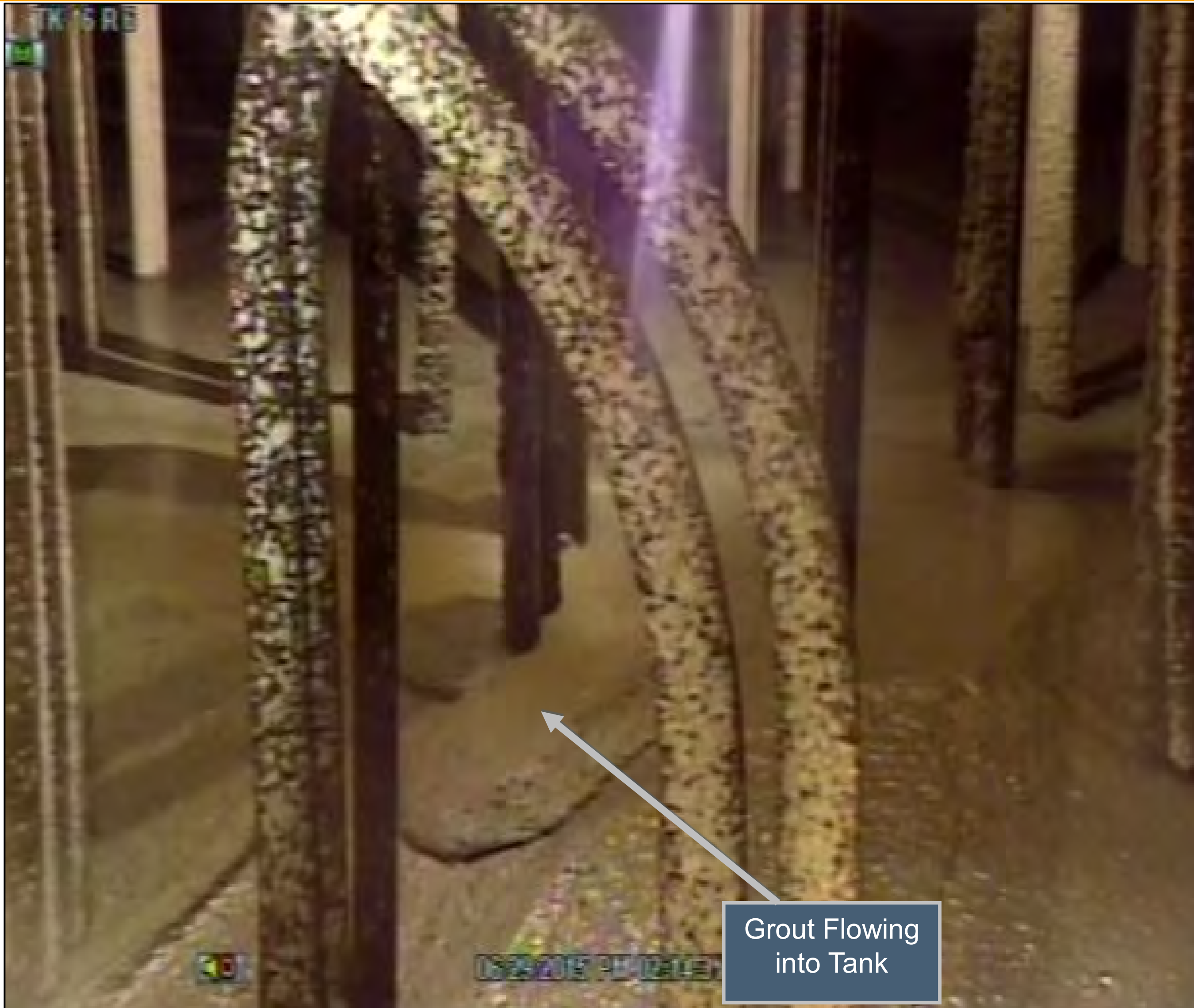


GROUT LIFTS

Approximate Values per Tank

LIFT	yd^3	Trucks	Gallons
1	936	117	189,000
2	255	32	51,500
3	2,911	364	588,000
4	214	27	43,250
5	1,768	221	357,000
6	214	27	43,250
Total:	6,298	788	1,272,000

Tank Grouting



Tank 16H Grouting Schedule

June-15

S	M	T	W	T	F	S
	1	2 Lift-1	3	4 Lift-1	5	6
7	8 Lift-1	9	10 Failed Coil	11 Lift-1 & 2[2]	12	13
14	15 Lift-2 & 3	16 Lift-3	17 Lift-3	18 Lift-3	19	20
21	22 Lift-3	23 Lift-3	24 Lift-3	25 Lift-3	26	27
28	29 Lift-3	30 Lift-3				

July-15

S	M	T	W	T	F	S
			1 Lift-3	2	**3**	4
5	6 Lift-3	7 Lift-4	8 Lift-5	9 Lift-5	10	11
12	13 Lift-5	14 Lift-5	15 Lift-5	16	17	18
19	20 Lift-5	21 Lift-5	22	23	24	25
26	27 Eval. R1 & 3	28	29 Eval. 3'-6"	30	31	

August-15

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31 Lift-5					

September-15

S	M	T	W	T	F	S
		1 Lift-6	2 Lift-6[3]	3 Lift-5[3]	4	5
6	7	8	9	10 Lift-6[5]	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Days Tank 16 primary tank received grout

Days Tank 16 annulus received grout

Days Tank 16 riser(s) received grout

Days Tank 16 failed cooling coils received grout

Days Tank 16 intact cooling coils received grout

Days Tank 16 in tank equipment received grout

The Work of Many

- Tank closure involves a large number of site workers and work groups over a period of years.
- Involves the Department of Energy at SRS and Headquarters, and all the principle contractors at SRS (SRR, Savannah River Nuclear Solutions/SRNL, Centerra).
- Involves multiple stakeholders including South Carolina Department of Health and Environmental Control, EPA, NRC, Citizens Advisory Board and the public.

Conclusions

- SRS takes great pride in their accomplishments in tank closure.
- Tank closure is a process that involves many organizations and stakeholders to achieve an operationally closed tank.
- Stakeholders pleased with closure actions.
- Everyone is looking forward to completing more closures in the future.
  - Currently limited by waste treatment capacity and funding.
- Questions?

NRC 10 CFR 61 Update on Low-Level Waste Management

2018 Health Physics Society Midyear Meeting & Exhibition
February 5, 2018
Denver, Colorado

Christepher McKenney, Chief, Performance Assessment Branch
Division of Decommissioning, Uranium Recovery and Waste Programs (DUWP)
Office of Nuclear Material Safety and Safeguards (NMSS)

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

10 CFR Part 61 Rulemaking

Why Are We Revising 10 CFR Part 61?

To require low-level waste disposal licensees or license applicants to ensure that low-level waste streams that are significantly different from the low-level waste streams considered in the current Part 61 regulatory basis can be disposed of safely

Recent Commission Direction to Staff

- The staff received direction from the Commission in Staff Requirements – SECY-16-0106 – Final Rule: Low-Level Radioactive Waste Disposal (10 CFR PART 61).
- The Commission directed the staff to make substantive revisions and republish it as a supplemental proposed rule.
- Specifically, the Commission directed the staff to:
  - 1) Reinstate the use of a case-by-case basis (i.e., "grandfather provision") for applying new requirements;
  - 2) Reinstate the 1,000 year compliance period from the proposed rule and adopt a longer period of performance assessment;
  - 3) Clarify that the safety case consists of the quantitative performance assessment, as supplemented by consideration of defense-in-depth measures; and

Recent Commission Direction to Staff (cont.)

- Specifically, the Commission directed the staff to:
  - 4) Modify the text addressing defense-in-depth to solely providing additional assurance in mitigating the effects of large uncertainties; and
  - 5) Be informed by broader and more fully integrated, costs and benefits resulting from the proposed rule changes, including pass-through costs to waste generators and processors.
    - Issued Federal Register Notice (82 FR 48283) on October 17, 2017 requesting public input
    - Had public meeting on October 19, 2017
    - Comments can be seen at: https://www.regulations.gov/docket?D=NRC-2011-0012
    - Staff is evaluating these comments

Planned Amendments to 10 CFR Part 61

- Adds requirement for site-specific analyses
- Introduces a compliance period of 1,000 years for traditional low-level waste
- Adds an analysis for long-lived low-level waste for a post-1,000-year performance period
- Allows flexibility for Agreement States to analyze longer timeframes
- Stresses the use of defense-in-depth to mitigate uncertainties in technical analyses
- Restores “grandfathering” provision

Next Steps

- Staff is developing revised rule language
- Staff will present supplemental proposed rule to Commission
- Staff will issue supplemental proposed rule for 90-day comment period
- Staff will consider comments and develop draft final rule for Commission's consideration

State of the Nuclear Industry and Low Level Waste Management

Janet Schlueter
Senior Director, Radiation & Materials Safety
Nuclear Energy Institute
NCRP Session at HPS Meeting
February 2018 • Denver, CO

Overview of Nuclear Energy Institute

- ***NEI's broad mission*** -- address policy, global market, regulatory and technical issues; advocate and foster beneficial uses of nuclear technology in its many forms
- ***Diverse membership*** -- uranium recovery, fuel cycle facilities, research and test reactors, commercial power plants, suppliers and others; over 350 members globally

NEI, with member participation…

- **Develops** policy on *legislative and regulatory issues* affecting industry
- **Serves** as *industry voice* before U.S. Congress, Federal/State agencies and others

- **Provides** forum to *resolve policy, technical, regulatory and global market issues*
- **Provides** *accurate and timely information* to its members, policymakers, news media, public, international partners, and many others

NEW NEI LEADERSHIP *Jan '17*
NEW NATIONAL NUCLEAR ENERGY STRATEGY

PRESERVE	SUSTAIN	INNOVATE	THRIVE
Appropriately value nuclear generation	Create sustainability via improved regulatory framework and reduced burden	Innovate, commercialize, and deploy new nuclear	Compete globally

State of the Nuclear Industry

State of Certain Industries

Fuel Cycle Facilities:

- 6 Operating; 1 is Idle; 1 in Construction; 1 in Decommissioning; 3 Licensed but not built (1 recently requested license termination)

Uranium Recovery Facilities:

- 11 NRC licensees (only 3, if WY becomes an Agreement State in 2018); Others in Agreement States; historically low priced uranium

Byproduct Materials Licensees (~21,000 nationwide):

- Agreement States regulate ~90% of licensees (e.g., medical, industrial)

Research and Test Reactors:

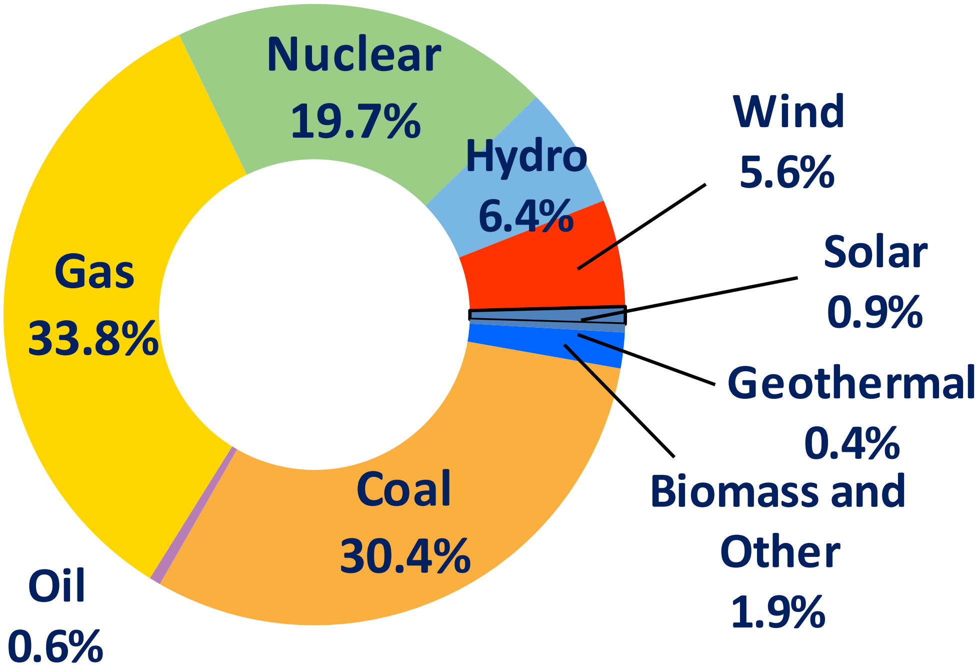
- ~33 Currently Licensed and or Operating

Others, e.g., Source/Isotope Manufacturers (e.g., Molybedenum-99)

State of RadWaste and Fuel Management

- ***Four operating LLW disposal sites***
  - *Access via LLW Compacts and by waste class*
- ***Two applications for Centralized Interim Storage (CIS) of used nuclear fuel under NRC review***
  - *Holtec (NM); Waste Control Specialists' (TX) application on hold per their request*
- ***Industry supports Yucca Mountain moving forward in parallel with CIS***
- ***GTCC disposal*** - Jurisdictional issue regarding Texas and Commission under NRC staff review

U.S. Electricity Generation Fuel Shares



99 currently licensed nuclear power plants which provide nearly 20% of U.S. electricity. Nuclear is part of critical energy infrastructure. Nuclear represents nearly 60% of electricity sources that do not produce greenhouse gases.

Premature Nuclear Plant Shutdowns 2013-2025

Plant	Reason	Closure Year
Crystal River 3	Mechanical	2013
San Onofre 2 & 3	Mechanical	2013
Kewaunee	Market	2013
Vermont Yankee	Market	2014
Fort Calhoun	Market	2016
Palisades	Market	2022
Pilgrim	Market	2019
Oyster Creek	Policy	2019
Three Mile Island 1	Market	2019
Indian Point 2 & 3	Market/Policy	2020-21
Diablo Canyon 1& 2	Policy	2024-25

State of New Builds and Initiatives

- ***New construction*** – Two units at Vogtle in GA
- ***License renewals*** underway; second license renewals under consideration
- ***Small modular reactors*** – First-ever design application submitted to NRC January 2017
- ***Advanced reactor and fuel technologies*** – industry pursuing new designs, e.g., accident tolerant fuel, higher enrichments

Low-Level Waste Regulatory Issues

Industry Priorities - BTP

- ***Further implement NRC's 2015 Branch Technical Position (BTP)*** on concentration averaging and encapsulation of wastes
  - Use EPRI guidance and updated waste characterization software
  - Result: <u>significant</u> cost savings to waste generators, e.g., less Class B and C wastes
  - Share best practices through NEI's LLRW Task Force
- ***Resulting blended LLW waste container "hot spots"*** can require Type B casks which discourages use of BTP
  - BTP allows for *concentration averaging*; NUREG-1608 should allow for *dose rate averaging* or an exemption from dose rate limit and/or approval of alternate activity equivalent

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LLW Transportation and Disposal Priorities

Transportation requirements should facilitate not impede disposal of LLW

- **NUREG-1608 --** Revise to increase 2 x A activity equivalence to 1R/hr@3m based on EPRI report; would address “hot spots” and result in fewer Type B packages
- **IN 2016-04 –** Implementation of ANSI N145-2014 for cask/package leak tests should be risk-informed depending on waste form, e.g., LLW/VLLW versus spent fuel
- **RIS 2015-02 --** Revision of waste manifest to acknowledge EPRI scaling factors for Tc-99 & I-129 and markup of certification statement for consistency with accepted industry practice

Industry Priorities (continued)

- **10 CFR 20.2002 –** final disposal guidance should allow continued practice of on-site management of licensed material which is re-evaluated at license termination
- **RG 1.21 --** revise to align waste shipment reporting for consistency with DOE MIMS
  - **DOE MIMS** – Update to restore generator report function
- **GTCC --** development of regulatory framework for management and disposal of GTCC/TRU wastes
- **LLRW Program Strategic Assessment** – periodic updates

New NRC Initiative – "Very LLW"

- ***NRC February 22, 2018 public meeting***
- ***NRC FRN coming soon*** to launch a ***scoping study*** on whether and how to define, as well as potential impacts of defining, a waste category referred to as "very low level" radioactive waste
- ***NEI supports*** NRC efforts to solicit input from a wide array of stakeholders to explore defining a category of waste based on its inherent low risk

In Conclusion

NEI is Engaged on Behalf of its Members to Help Ensure Timely and Efficient Identification and Resolution of Generic Regulatory, Technical, and Policy Issues Impacting the Nuclear Industry

THANK YOU

jrs@nei.org

WCS

ANDREWS, TEXAS

Present & Future Low-Level Radioactive Waste Issues, an industrial Perspective

Chris Shaw M.S. CHP RRPT
Corporate RSO & TSPM

- Status Update
- Facilities & Current Status
- Future initiatives
- The Crystal Ball & Other Far Flung Things

Acquisition Status

- In June 2017, we reached out to potentially interested parties about the possibility of acquiring WCS.
- We narrowed the candidates down to a single finalist and entered into an exclusivity period.
- Acquisition completed Jan 2018
- WCS is open for business and looks forward to all opportunities including both decommissioning and consolidated interim storage of spent nuclear fuel.

WCS
ANDREWS, TEXAS

Full Range of Disposal and Service Capabilities

WCS is the only facility with low activity, Class A and Class B/C disposal options.

Commercial Waste

- In- and Out-of-Compact Class A, B, and C LLRW

Federal Waste

- Federal Class A, B, and C LLRW and MLLRW

Low Activity

- Certain low activity waste in Hazardous Waste Landfill

Transportation

- 3 state-of-the-art Type B Casks
- 2 Type A Casks

Processing

- Dewatering, Stabilization, Repackaging

ANDREWS, TEXAS

WCS Current Facilities

Compact Waste Facility

ANDREWS, TEXAS

Irradiated Hardware

- WCS disposes of IH with up to 20,000 R/hr on contact with a collective dose of less than 50 mrem
- State of the art transfer system with remote handling and robust disposal
- WCS is the only disposal solution for IH for 36 states

Current Capacity and Status

Licensed LLW Disposal Capacity

- **TX Compact Waste Disposal Facility:**
  - 9,000,000 cubic feet and 3,890,000 curies
  - TCEQ has taken ownership of Texas Compact Landfill and WCS leases it back for operations
- **Federal Waste Disposal Facility:**
  - 26,000,000 cubic feet and 5,600,000 curies total
  - DOE signed Agreement to take ownership of the Federal Landfill after post-closure
- **License Term –** through September 2024 with provision for 10-year renewals thereafter

Permitted Capacity

- **Hazardous Waste Disposal Facility:**
  - 67,500,000 cubic feet of permitted capacity
  - Approved exemption process allows radioactive waste to be exempted from radioactive regulations and disposed in the Hazardous Waste Landfill
  - WCS expects more than 85% of decommissioning waste will qualify for exemption
  - Used currently for operational and decommissioning waste
  - Cost effective solution that is more secure than BFSR

Decommissioning of Nuclear Power Plants (NPP)

- WCS can provide all of the packaging, transportation and disposal services for decommissioning of NPPs.
- WCS is part of the team that won the Vermont Yankee project. Decommissioning is expected to start by 2019.
- WCS is the only disposal provider that can provide very low-activity disposal as well as Class A, B and C.
- We work together with the customer and partners to ensure the most effective solution for schedule and budget is developed.
  - We can adapt our capabilities to meet your needs

Low Activity Waste

WCS
ANDREWS, TEXAS

Hazardous Waste Landfill for Low-Activity Waste

What is Low Activity Waste (LAW) Disposal?

Process Authorized by the WCS Radioactive Materials License

- Allows disposal in the WCS RCRA cell
- Performance Assessment approved by TCEQ
- Low-Activity Class A Waste, not a New Waste Type
- TCEQ Approval Process Specified in 30 TAC 336.5 is similar to 10 CFR 61.6, and is at least as restrictive as 10 CFR 20.2002 exemption process.

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WCS LAW Disposal

Low Activity Waste Disposal

- Also referred to as LC 192 disposal (the license condition authorizing exemption)
- Controlled by the procedure RS-5.0.0 process for waste profiling, characterization, verification, and approval.
- Approximately 11,000,000 cubic feet to date

WCS LAW Disposal

What are the Advantages of LAW Disposal?

- Lower cost compared to Class A disposal in a licensed disposal facility
- Waste concentrations up to Approximately 10% of the Class A limit are acceptable for disposal
- Estimated to represent up to 85% of decommissioning waste volumes

WCS LAW Disposal

Additional Services

- WCS can perform NDA characterization upon receipt
- WCS has established subcontracts, providing a suite of options for generators, including:
  - Waste sorting and segregation to remove prohibited items and separate higher activity waste for CWF disposal
  - Packaging and transportation
  - Characterization and profiling

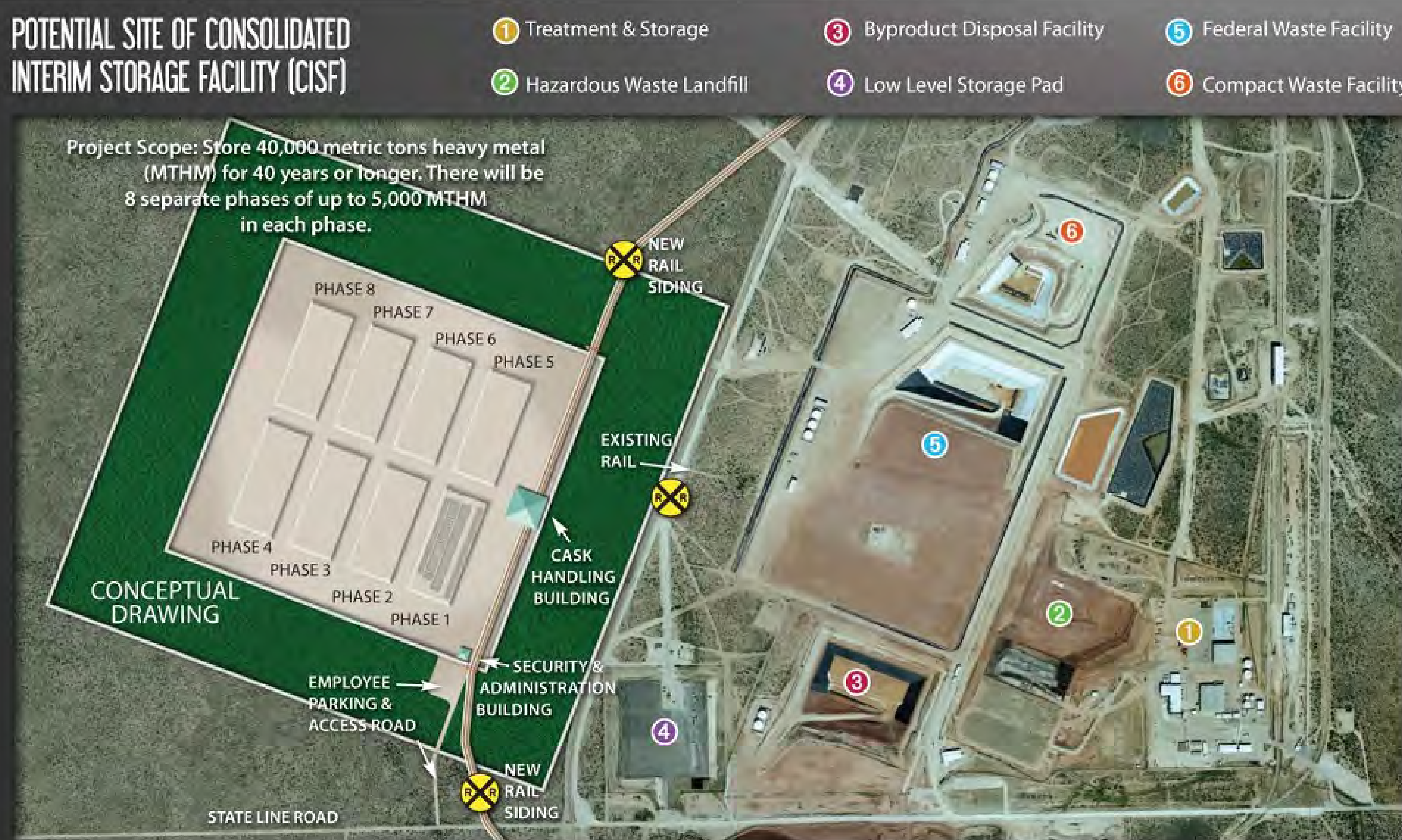
Future Planned WCS Operations

Consolidated Interim Storage of Spent Nuclear Fuel

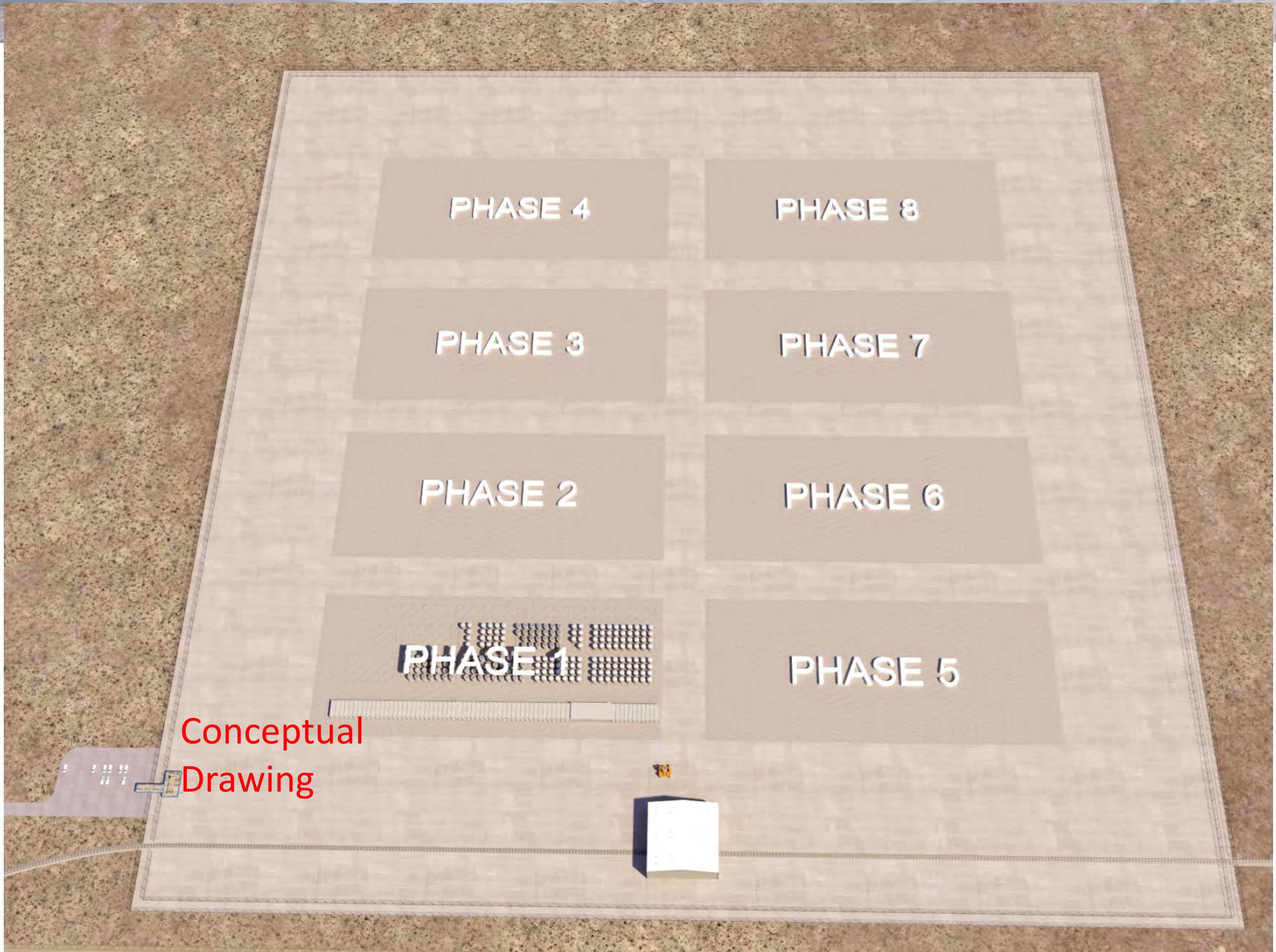
Proposed Interim Storage Project Scope

- Environmental impacts analyzed with storage of 40,000 Metric Tons of Heavy Metal (MTHM).
- 8 separate phases; storage of up to 5,000 MTHM in each phase.
- License for 40 years with multiple renewals of up to 20 years each.
- Initial SAR includes selected AREVA NUHOMS® and NAC International storage systems which prioritize shutdown sites.
  - Additional systems and sites to be added in future License Amendments.
  - Storage of used fuel from over 12 shutdown/decommissioned nuclear power plants will fit in Phase 1.
- Allows flexibility to transition beyond storage of fuel from currently decommissioned reactors.
- Ongoing discussions with DOE and the U.S. Congress on how to integrate the availability of an interim storage facility into the national strategy for used nuclear fuel management.

Location of CISF



Proposed Pad Layout for CISF



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View of Deployed Systems for Phase 1 Pad

Conceptual Drawing

Initial License Application

- Priority on currently licensed systems for shutdown sites:

  - **NAC International**
    - **Maine Yankee**
    - **Connecticut Yankee**
    - **Yankee Rowe**
    - **La Crosse**
    - **Zion**
  - **AREVA NUHOMS®**
    - **Rancho Seco**
    - SONGS Unit 1
    - Millstone Unit 1
    - Oyster Creek* (S/D scheduled 2019)

Indicates a "stranded" (ISFSI only) site identified in the 2012 Final Report of the "Blue Ribbon Commission on America's Nuclear Future" (BRC)

* Fuel Burned less than 45 GWd/MTU

Initial License Application covers ~80% of SNF and GTCC at BRC "Stranded" Sites

Estimated Timeline

- April 2016 – License application (LA) submitted
- November 2016 – Commencement of ER
- January 2017 – LA accepted by NRC for docketing
- May 2017 – ER RAIs issued; responses July
- July 2017 – SAR RAIs issued; response Sept
- Mid 2019 – Licensing Decision
- 2021 – Operations could commence

Suspension of Project

- WCS requested NRC suspend the review of the CISF license application on April 18, 2017.
- Application was cost prohibitive to pursue given the financial condition of WCS and pending acquisition
- The license is suspended and can be restarted without starting the process from scratch.
  - Environmental scoping public meetings completed

Disposal of GTCC

WCS
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GTCC Disposal

- WCS believes that the Federal Waste Facility would provide a disposal pathway for GTCC and GTCC-like LLW.
- NRC is in the process of working on regulatory guidance document.
- Guidance would clarify the authority of TCEQ (an Agreement State) to regulate disposal of GTCC and GTCC-like LLW.
- This would finally provide a disposal solution for GTCC that has been missing from the industry.

GTCC Disposal

- Waste that was not generally suitable for near surface disposal in the 1980s can be demonstrated suitable in 2018 at WCS.

At WCS:

- Deeper depth of disposal
- Multiple intrusion barriers
- Minimal rainfall
- High rate of evapotranspiration
- Lack of potable water, etc.

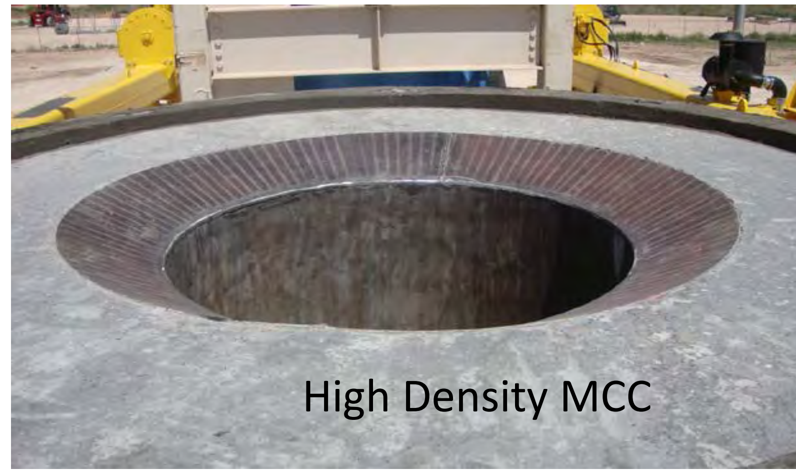
- Historical scenarios at other facilities do not reflect modern disposal practices, especially in an arid environment like at WCS.

Barnwell

WCS

Modular Concrete Canisters: Enhanced Waste Packages

- Modular Concrete Canisters (MCCs) serve as an enhanced disposal package.
- Intruder resistant, reduced radiation levels and impeded mobility of radionuclides.
- Depth of disposal deeper than 30 meters possible.



High Density MCC

THE CRYSTAL BALL & OTHER FAR FLUNG THINGS

- Expansion of current LC-192 process and offerings.
- Decommissioning, and more decommissionings.
- A few far flung ideas.

Waste Management Approaches for Handling Technologically Enhanced Naturally Occurring Radioactive Material

W.E. Kennedy, Jr.
W. E. Kennedy Consulting

Main Objectives:

- Quick overview of NORM/TENORM
- Conventional oil & gas sources
- Hydraulic fracturing – definitions and sources
- Who regulates TENORM?
- Alternative waste regulations
- The role of the NCRP

Definitions

- NORM = Naturally Occurring Radioactive Material
- Natural radionuclides in the environment (uranium, thorium, radium, radon…)
  - Some oil and gas drilling waste (shale)
  - Fertilizer (from phosphate ores – uranium)
  - Rare earth mine tailings (uranium, thorium)
  - Ceramic products (uranium in clay)
  - Welding rods (thorium sands in coatings)

Definitions

- TENORM: Technologically Enhanced NORM
- Natural material whose radioactive concentrations have been enhanced (concentrated or altered radionuclide ratios) by human activities including:
  - Oil & gas pipe scale
  - Oil & gas sludge
  - Selected mining wastes

Example: Coal Ash

- During combustion, uranium concentrates in coal ash by about 10 times
- Coal ash used in concrete products can increase background dose rates in homes
- In 2009, 850 million tons of coal burned in U.S.
  - 1,100 tons of Uranium; 2,700 tons of Thorium
  - At 1 ppm in coal, enough energy in the Uranium if used in a fast nuclear reactor to exceed that in the coal
  - Ash mined for uranium in the 1970s

Conventional Oil & Gas Summary

- NORM/TENORM present in all phases
- Concentrations depend on geology
  - Higher concentrations in production phase (pipe scale/sludge)
  - Drill cuttings – shale/rock
  - Produced water - brine
  - Radon decay products with gas

Pipe Scale

- Radium is more soluble in brine solutions than uranium or thorium
  - Carbonates and sulfates of calcium, barium, radium, and strontium may precipitate as pipe scale
  - Changes in temperature and pressure
  - Solid waste issue – landfills generally don’t accept radioactive materials

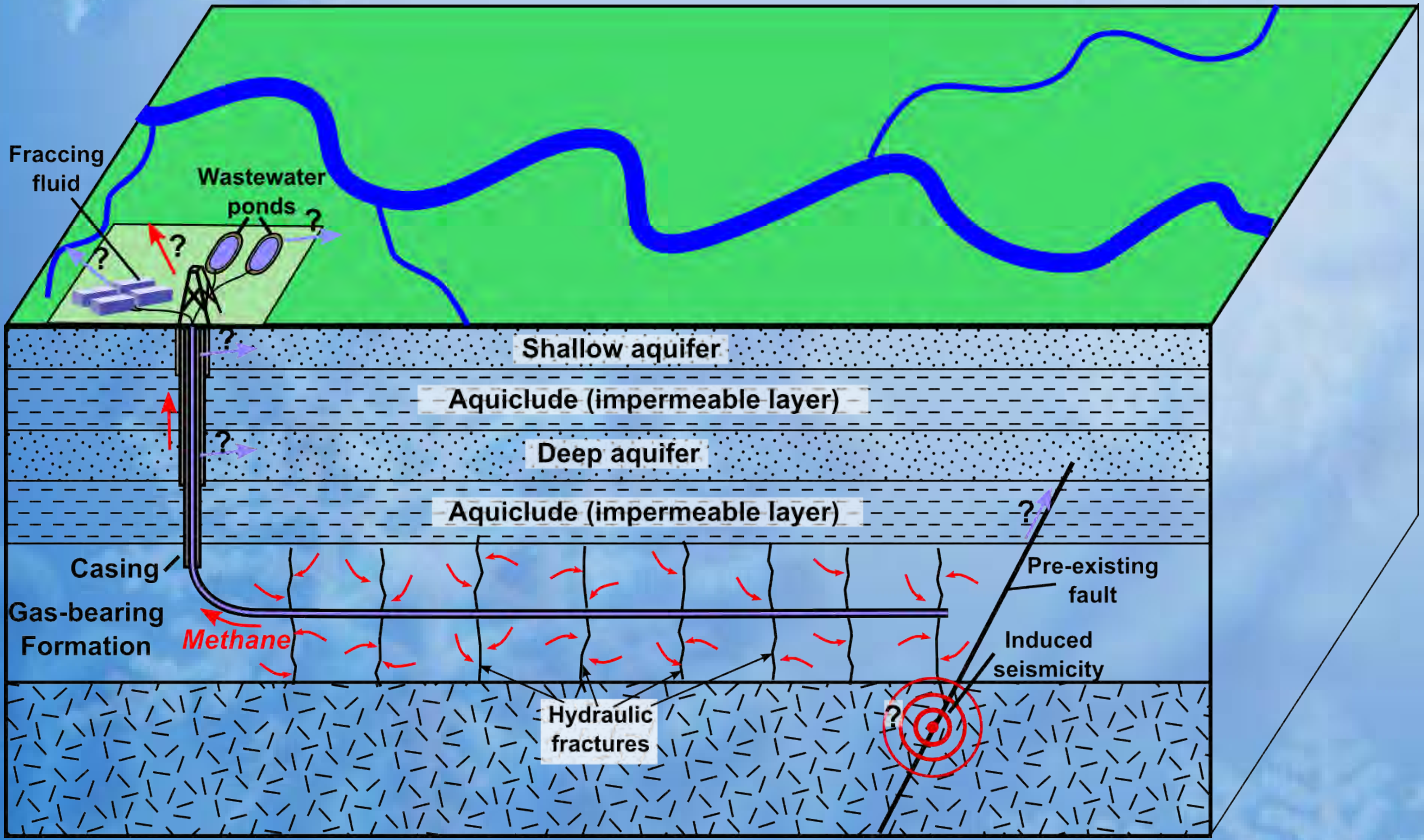
TENORM Pipe Scale

Gas Pipeline “Pigging” Waste

Unconventional Oil & Gas Sources

- Hydraulic fracturing – unconventional rock stimulation
  - Injection of fluids (water), sand, and/or chemicals into host rock under high pressure
- Pressure fractures host rock inducing cracks
  - Sand/chemicals open cracks allowing oil. Gas, and brine water to flow more freely
- Horizontal drilling is the key!
  - Technology opens up a larger well footprint
  - Relies on expensive equipment

Fracking Schematic



Fracking Equipment

Environmental Issues

- Water issues
  - Large quantities (>15,000 m^3) used for fracturing fluids
  - Waste water; flow back injection fluids, production water (saline) with oil or gas
- API estimates 10 barrels of water per barrel of oil; ~ 18 billion barrels of waste fluid per year
- Solid wastes
  - Drill cuttings
  - Used equipment
  - Legacy wastes (spills/cleanup)

Who Regulates TENORM in the U.S.?

- EPA – sets federal radiation standards for the public
- OSHA – has authority over the workplace
- States
  - Clean Air Act
  - Clean Water Act
  - May license radioactive materials usage
  - Waste management – what waste can safely go where?

National/International Standards

- ANSI-HPS Standards for surface and volume radioactive materials (limited quantities): dose based at 10 µSv/year
  - N13.53: *Control and Release of Technologically Enhanced NORM (TENORM)* – 2009
    - Natural Uranium/Thorium decay chains – 1 Bq/g
    - 1Bq/g natural Ra-226 - purified radium: 0.1 Bq/g
  - N13.12: *Surface and Volume Standards for Clearance – 2011* – Same values as N13.53: 1 Bq/g Ra-226
- International Atomic Energy Agency (IAEA); Same values as N13.12/N13.53

Comparison of State Disposal Limits

State	Ra-226 (Bq/g)	Comments
Oklahoma	0	No “measurable rad
Ohio	0.185	Per State licensing exemption
Nevada	0.185	Per State licensing exemption
Texas	1.11	Per State licensing exemption
Montana	0.55-1.85	Based on MDEQ Updates
North Dakota	1.85	“Special Waste” landfills
Michigan	1.85	Disposal with MDEQ approval
Pennsylvania	10	Dose rate and volume limits
Colorado	Variable	0-0.11-50 per facility type
Idaho	55	At RCRA Subtitle C landfills

Evolving State Positions: North Dakota

- Disposal rules
  - Allowing disposal of up to 1.85 Bq/g (50 pC/g) of TENORM from oil and gas
  - Radiation safety officer (RSO) training for specific facilities under license
  - Relieve the “sock” disposal issue
  - Consistent with Conference of Radiation Control Program Directors (CRCPD) Part N
  - Argonne National Lab report: *Radiological Dose and Risk Assessment of Landfill Disposal of…TENORM…in North Dakota* – Risk assessment of potential impacts

Evolving State Positions: Colorado

- Changes to Radiation Control Act because of the lack of EPA regulations
  - Concentrations > 0.1 Bq/g Ra-226+228, 1 Bq/g Nat U and Th generally rejected from non-approved landfills
- Approved landfill limits:
  - Clean Harbors Deer Trail ~74 Bq/g total, ~8 Bq/g Ra-226
  - Pawnee Waste: 1.85 Bq/g Ra-226+228; Nat U & Nat Th 0.37 Bq/g; Pb-201 & Po-210 $\leq$ 0.37 Bq/g
  - Waste Concentrations Southside Landfill: U only $\leq$12.6 Bq/g
- Waste from beyond Nevada or New Mexico requires Rocky Mountain LLRW Compact approval

Alternative Waste Regulations

- Adopt uranium/radium standards from other regulations (Uranium Mill Tailings Act)?
- Allow disposal in RCRA landfills
  - Develop instrument-based standards using measured dose rate or integrated dose
  - Develop concentration-based standards – define the role of sampling
  - Use "performance assessment" modeling of landfills – ground water protection
- Radon?

Origin of Radium Limits: (0.185 Bq/g – 5 pCi/g)

- Uranium Mill Tailings Act of 1978 (40 million yd^3)
- EPA established health and environmental standards for stabilization, restoration, and disposal
  - 0.185 Bq/g (5 pCi/g) in top 15 cm of soil
  - 0.56 Bq/g (15 pCi/g) below 15 cm of soil
  - Gamma < 0.2 µSv/hour (20 µR/hour) above background
  - Radon < 0.1 mSv/year (10 mrem/year) Clean Air Act
  - Surface flux limit < 0.74 Bq/m^2-second (20 pCi/m^2-sec)
- How do these standards compare with other radium sources?

Tailings versus TENORM:
Do EPA Mill Tailings Regulations Apply?

RCRA Waste versus LLW?

- RCRA versus LLW – **vastly different regulations, but similar goals** (human health)
  - RCRA *credits engineered systems* (geotextile liners), while LLW does not (natural materials only)
  - LLW *sets concentration limits* and requires onsite "performance assessments" considering geology, waste form, and radionuclide properties
  - RCRA sets a *30-year* performance period, while LLW has typically a *500-year* performance period
  - Both protect ground water, but in different ways

Develop Instrument-Based Standards

- Instrument-based standards may provide easy screening of concentrations in the field, but beware:
  - Dose or dose rate readings can be highly variable (don’t measure alpha)
  - Rely on the ability of the operator – tendency to report highest, not representative, readings
  - Should be established for a fixed geometry supported by laboratory sample analysis
  - May be most useful for screening homogeneous waste streams

Develop Concentration Standards

- Disposal regulations using concentration-based standards should rely on sampling, QA/QC, statistics, and records
  - Sampling protocols, including composite samples and laboratory procedures must be defined in the regulation
  - Again, difficult to translate to instrument readings
- May be difficult to impose on highly-variable waste streams

Performance-Based Standards

- Determine disposal limits using **modeling**
  - Approach requires definition of **performance objectives** – acceptable post-closure conditions such as **doses or concentrations** (ground water)
  - Standardized **scenarios for future** conditions
  - Site-specific **parameters** to drive models
  - Standardized **models** or components
  - Standardized consideration of **closure** systems

Performance-Based Modeling

- Several State Examples (California, Colorado, North Dakota, Pennsylvania)
  - Protect individuals to 0.25 mSv/year: site-resident (non-intrusive) scenario
  - Protect ground (drinking) water to 0.04 mSv/year: ground water migration scenario
- Example model - RESRAD
- Disposal volume and site performance should dictate disposal conditions at a given landfill

Radon?

- We know how to remediate radon disposal from uranium mill tailings experience
- Radon emanation rate from pipe scale is ~10 times lower than uranium mill tailings
- Performance assessment tools are useful in evaluating landfill post-closure conditions
  - RESRAD code has been used to conduct radon risk assessments for landfills
  - Radon is mitigated by a thicker cap in a landfill

NCRP SC 5-2

- Purpose: To prepare a Commentary that provides: Recommendations for a Uniform Approach for Hydraulic Fracturing NORM/ TENORM Waste Disposal and lays the ground work for a more comprehensive Report…
- Current status: Collecting reference materials to support development of an initial commentary – likely to recommend a focus on solid waste disposal

SC 5-2 Membership

David Allard	PDEP	
Martin Barrie	ORAU	
Phil Egidi	U.S. EPA	
Gary Forsee	Illinois Environmental Compliance	
Raymond Johnson	Radiation Safety Counseling Inst.	
Andrew Lombardo	PermaFix	
Ruth McBurney	CRCPD	
John Frazier	Consultant	Consultant
W.E. Kennedy, Jr.	Consultant	Chair

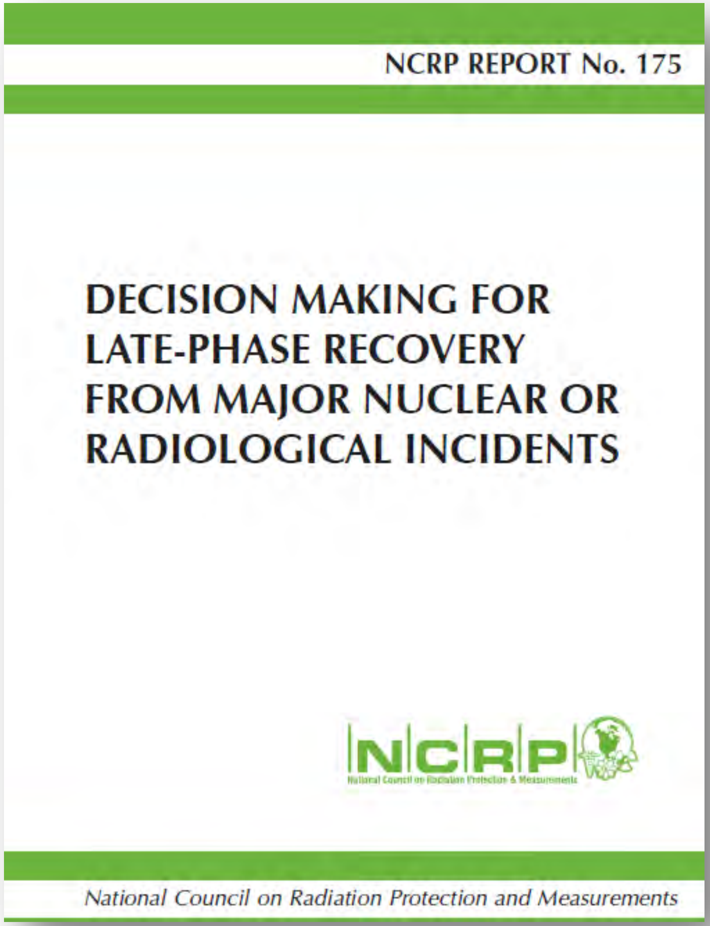
The 51st Midyear Meeting
Health Physics Society

THE NCRP SYMPOSIUM ON EMERGING ISSUES IN RADIOACTIVE WASTE MANAGEMENT

Denver, CO
February 6, 2018

S.Y. Chen, Ph.D., CHP
Illinois Institute of Technology
Chicago, IL

NCRP Report 175 (2014) Addresses Late Phase Recovery Issues



In 2008, DHS issued Protective Action Guides (PAGs) for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) incidents, providing recommendations for protection of public health in the early, intermediate, and late phases of response to an RDD or IND incident. In 2013, the Environmental Protection Agency (EPA) also issued a draft Protective Action Manual (PAG) for comment and interim use.

The NCRP Report (2014) provides **framework and approach to implementing and optimizing decision making during late stage recovery for large-scale nuclear incidents**

Radiological and nuclear incidents from terrorism RDDs and INDs

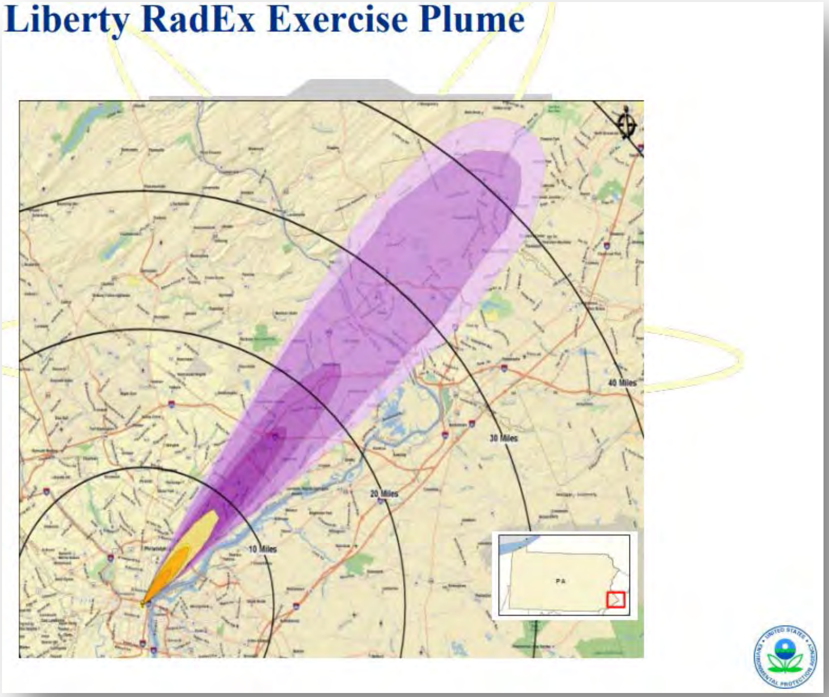
Potential Sources:

- **Radiological Dispersal Device** (RDD) refers to any method used to deliberately disperse radioactive material in the environment in order to cause harm.
- **Improvised Nuclear Device** (IND) refers to any device incorporating radioactive materials designed to result in a nuclear explosion.




Preparing for the RDD events
<u>the forever "what ifs"</u>

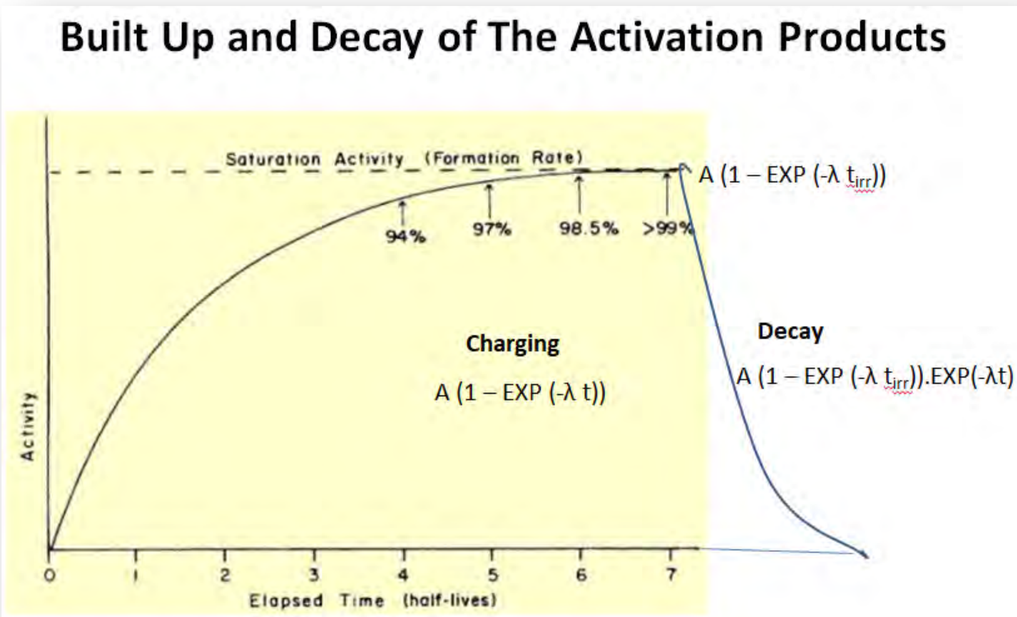
Potential sources considered for an RDD should not be stereotyped (e.g., Cs-137 as often postulated). It may take many different forms and under various scenarios.

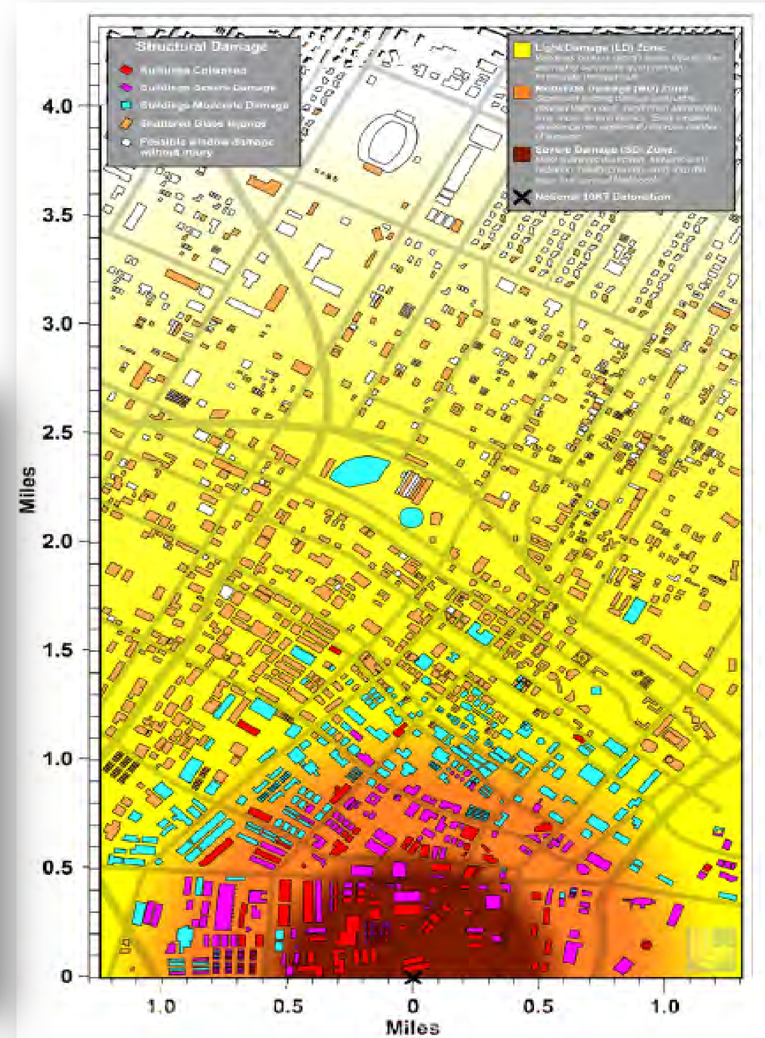


What if some uncommon radioisotopes (e.g., Am-241) are used?

Dealing with the magnitude and scale of the IND impacted zones

The IND will generate considerable radioactive contamination by radioactive fallouts and activation products (mostly structures) by neutron bombardment.





(DHS 2010)

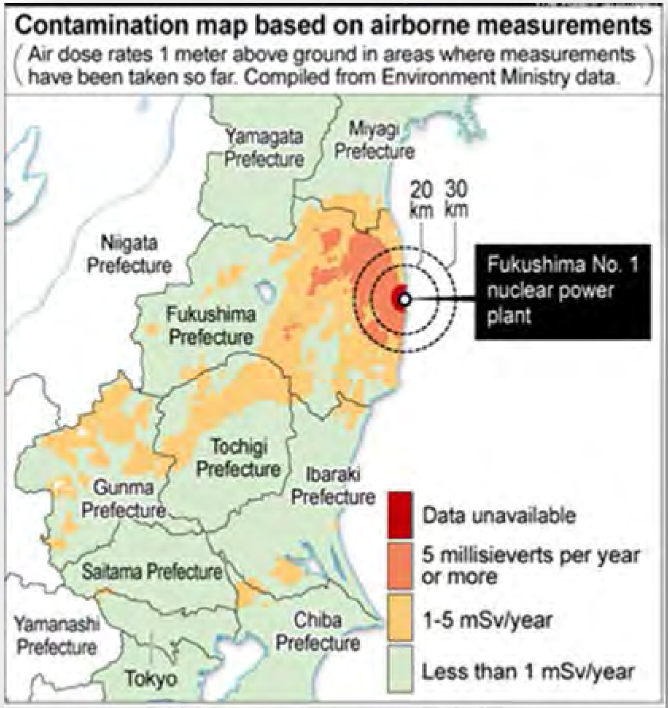
Neutron activation is generically ignored in the response preparation but should we (i.e., high-yield devices)?

Table . Activation Gamma Sources

Reaction	Activation Cross Section (barns)	Half-life	Energy (MeV)	Yield Gammas/ Decay
$^{23}Na(n, \gamma)^{24}Na$	0.534	14.96 hr	1.369	1.00
			2.754	1.00
$^{54}Fe(n, p)^{54}Mn$	1.0	314 days	0.835	1.00
$^{55}Mn(n, \gamma)^{56}Mn$	13.3	2.576 hr	0.847	0.99
			1.811	0.29
			2.11	0.15
$^{59}Co(n, \gamma)^{60}Co$	37.2	5.263 years	1.173	1.00
			1.332	1.00
$^{58}Fe(n, \gamma)^{59}Fe$	1.2	45.6 days	1.095	0.56
			1.292	0.44
$^{58}Ni(n, p)^{58}Co$	1.0	71.3 days	0.51	0.30
			0.81	0.99
			0.865	0.014
			1.67	0.006
$^{94}Zr(n, \gamma)^{95}Zr$	0.075	65.5 days	0.724	0.49
			0.756	0.49
			0.765	1.00

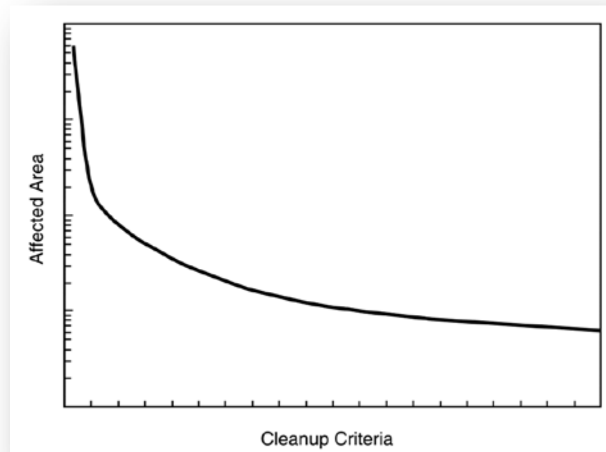
Source: O. J. Wallace, WAPD-TM-1453.

Wide-area contamination a major waste issue in a nuclear accident (Fukushima 2011)



Estimated radioactive waste volume from cleanup of nearby prefectures surrounding Fukushima NPP is 29×10^6 m^3, or about 1 billion ft^3. This *has exceeded* the US commercial LLW disposal capacities combined. Some *adaptive management strategy* is needed.

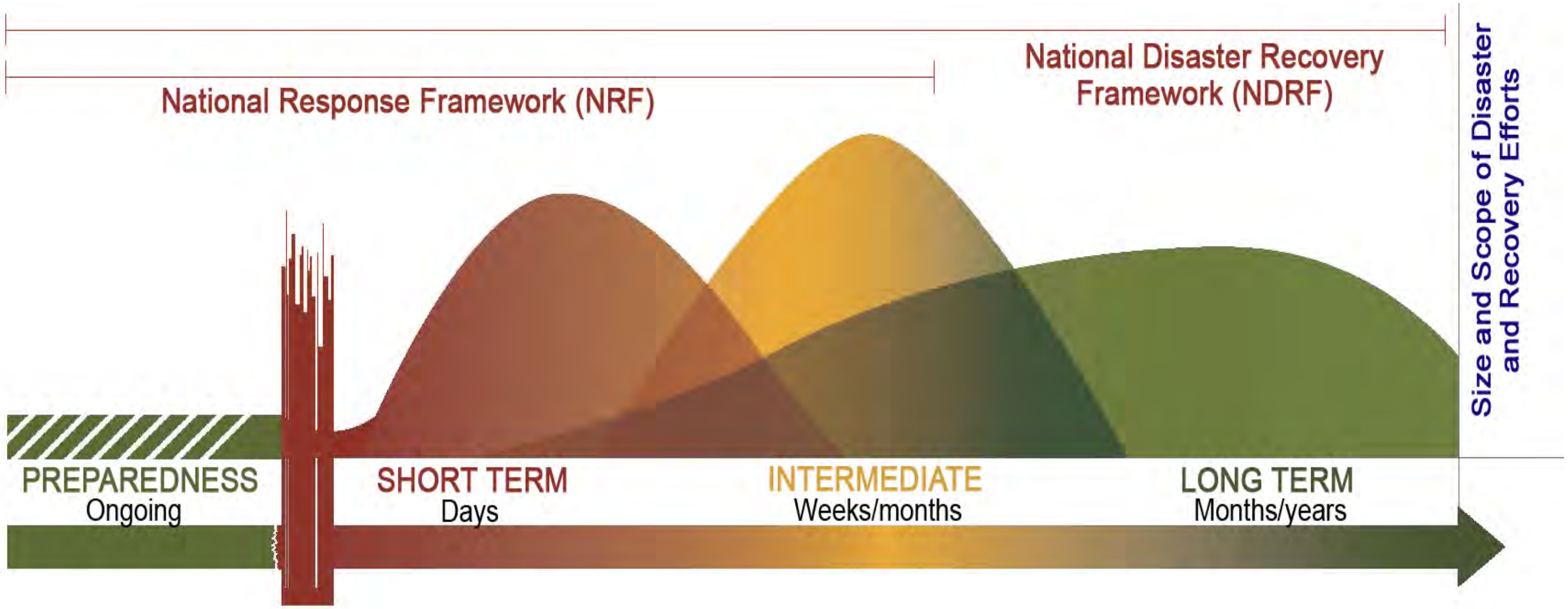
Temporary storage of contaminated material – examples from clean-up demonstration tests



Waste volume is *directly proportional* to the rigor in cleanup.

(Source: ICRP 2012)

Managing radioactive waste a key issue in responding to an event



National Disaster Recover Framework (FEMA 2011)

Considerations of radioactive waste management in nuclear events

(1) The approach to waste characterization and volume estimation: **debris and soil remediation**
(2) Various species of radionuclides
(3) Establishment of temporary waste storage criteria and treatment strategies
(4) Waste packaging and transport decisions
(5) Considerations of options for treatment and final disposal selection, and
(6) Strategy toward risk-informed waste disposition approach

Issues affecting the waste characterization and management

- Ownership of LLRW would be in question (waste such as generated from terrorism such as RDDs or INDs)
- Waste generated may not be suitable for commercial disposal (such as under 10 CFR 61 regulations)
- Waste volume could range in the order from a few 1,000 m^3 to a few million m^3. By comparison Class A waste has been generated at around 900 m^3/y in routine operations (NA/NRC 2006)
- LLRW disposal capacity (commercial) will be seriously constrained
- Information on alternative disposal options (hazardous or municipal landfilled) is hampered by lack of open information (over 8,300 sites with “proprietary” information) (***Directory of Waste Processing and Disposal Sites***)

Low-level radioactive waste (LLRW) waste characterization and volume estimation

Definition by **exclusion** - LLRW is defined (10 CFR 61.55) **not by *what it is***, but rather by ***what it is not***. LLRW is radioactive waste that is **not *high-level radioactive waste, transuranic waste, spent nuclear fuel, or 11e(2) byproduct material (uranium and thorium mill tailings and wastes)***.

LLRW consists of a wide range of wastes having various physical and chemical characteristics and concentrations of radioactive isotopes. Disposal of commercially generated LLRW is regulated by the U.S. Nuclear Regulatory Commission (NRC), and must be done in a controlled manner to protect human health and the environment.

The U.S. radioactive waste system is *origin-based* but *not risk-based* *(NA/NRC 2006)*.

Current regulations does not contain lower limits

Radionuclide	Concentration, curies per cubic meter		
	Col. 1	Col. 2	Col. 3
Total of all nuclides with less than 5 year half-life	700	([1])	([1])
H-3	40	([1])	([1])
Co-60	700	([1])	([1])
Ni-63	3.5	70	700
Ni-63 in activated metal	35	700	7000
Sr-90	0.04	150	7000
Cs-137	1	44	4600

(i) If the concentration does not exceed the value in Column 1, the waste is Class A.
(ii) If the concentration exceeds the value in Column 1, but does not exceed the value in Column 2, the waste is Class B.
(iii) If the concentration exceeds the value in Column 2, but does not exceed the value in Column 3, the waste is Class C.
(iv) If the concentration exceeds the value in Column 3, the waste is not generally acceptable for near-surface disposal.
(v) For wastes containing mixtures of the nuclides listed in Table 2, the total concentration shall be determined by the sum of fractions rule

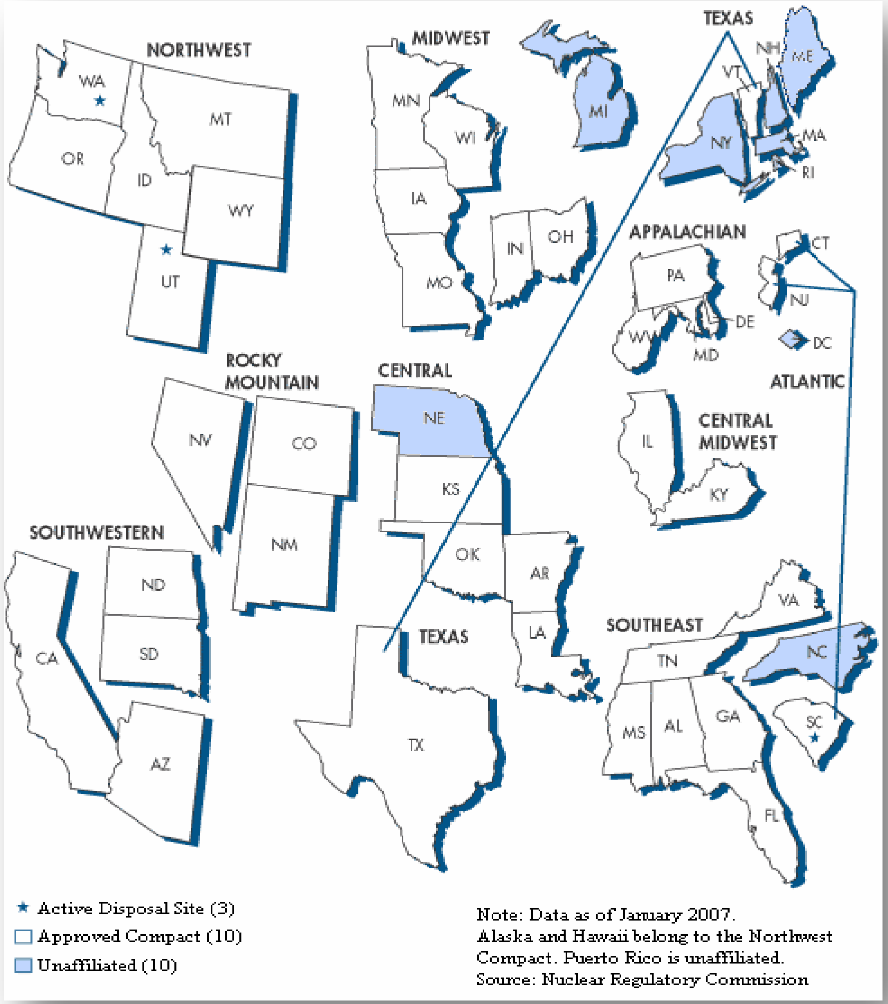
Existing U.S. commercial low-level radioactive waste disposal capacity has serious limitations

Disposal Facility	Wastes Allowed	Various States Access	Capacity
Energy Solutions--Barnwell, SC	Class A, B, C	Atlantic Compact (CT, NJ, SC)	15,000 ft^3 y^{-1}
Energy Solutions--Clive, UT	Class A, and mixed LLRW	Open to all states	41 million ft^3 with plans to more than double capacity
U.S. Ecology--Richland, WA	Class A, B, C	Northwest and Rocky Mountain Compacts (11 states)	25 million ft^3
Waste Control Specialists--Andrews, TX, west Texas near NM border	Class A, B, C, and mixed LLRW	Texas Compact (VT, TX; Texas Compact Commission considering providing access to out-of-compact states)[a]	2.3 million ft^3 for commercial use and 26 million ft^3 for Federal (DOE) use

[a] Waste Control Specialists intends to construct and operate a separate federal (DOE) disposal capacity in conjunction with its commercial facility.

Additional uncertainty about the LLW compacts

Low-Level Radioactive Waste Policy Act (LLRWPA) of 1980 and subsequent amendments direct states to take care of their own LLW either individually or through regional groupings, referred to as compacts. The states are now in the process of selecting new LLW disposal sites to take care of their own waste. The selection process for these new sites is complex and varies because of many factors including the regulations for site selection.



Related issues: waste treatment and staging (1/2)

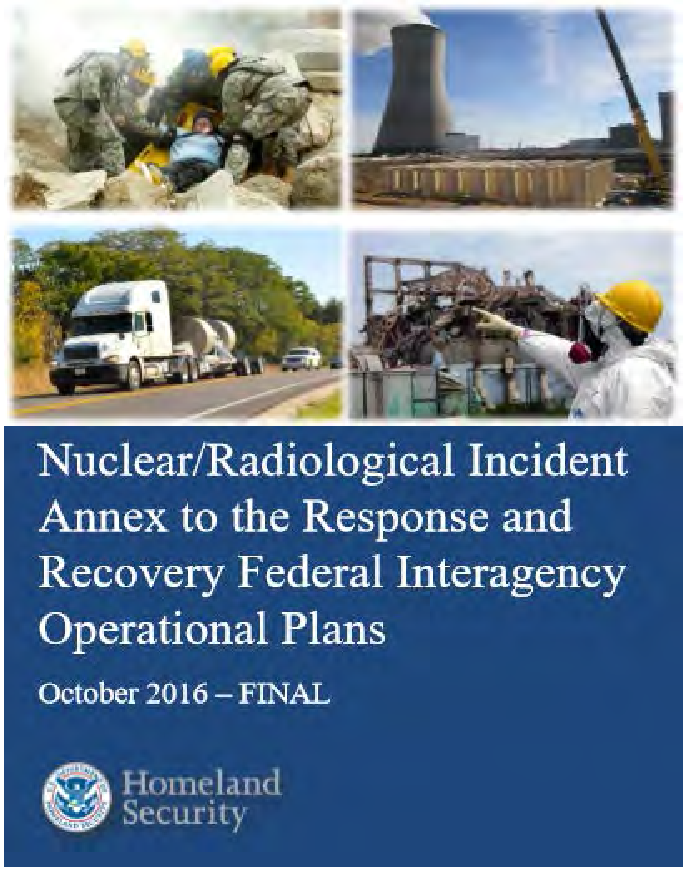
- Large volumes of waste with varying levels of contamination (mostly Class A or lower but higher level wastes may be generated such as by neuron activation in an IND event): building materials, soils, asphalt, concrete, trees/shrubs, decontamination residues, thus treatment strategies will need to be closely coordinated
- Methods of treatment may include: stabilization, removing contaminants, volume reduction (evaporation, grinding, crushing, shredding)
- Meet waste acceptance criteria (e.g., RCRA land disposal restrictions)
- Waste staging areas to be chosen, preferably close to the incident site
- Staging criteria to be developed during planning process

Related issues: waste transportation and packaging (2/2)

Given the large quantities of wastes, transportation effort may turn into a major campaign both locally to the staging areas and regionally to the final disposal sites. For planning purposes, one must ensure:

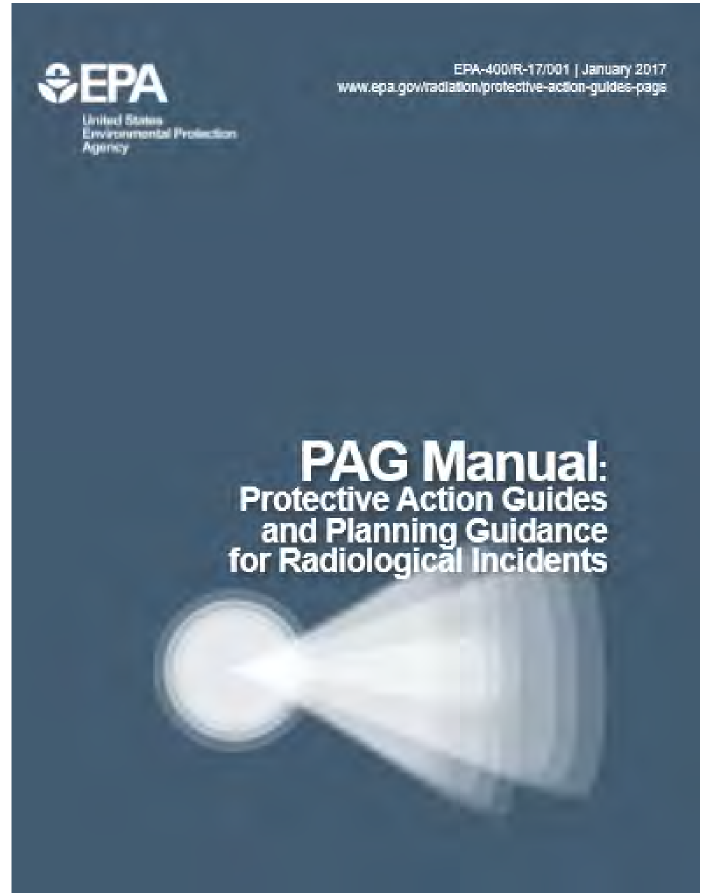
- Sufficient quantity of waste containers (appropriate type, size, and integrity specifications)
- Appropriate packaging requirements for transportation through various transportation routes and modes (highways, railways and waterways)

Current emergency guidance sheds little light on waste management



10 CFR § 61.55 – Waste Classification

10 CFR 61.55 provides the classification of low-level radioactive waste according to its radiological hazard. The classes include Class A, B, and C, with Class A being the least



An effective response to a large-scale radiological incident will involve consideration of the entire range of potential disposal options. The precise mix of disposal options employed will depend on the nature of the specific incident (e.g., location, waste volumes). The process selected to plan and conduct the long-term decontamination and remediation should identify and make provisions for using the different available disposal options.

Out of several disposal options there is no exempt level to clear the majority of the waste that is largely uncontaminated (EPA PAG 2017)

COMPARISON OF ATTRIBUTES OF EXISTING DISPOSAL OPTIONS

- Licensed Commercial LLRW Disposal Facilities—
  - Can manage most anticipated waste types within license conditions.
  - Highest degree of public acceptance.
  - Significant bulk disposal volume possible.
  - Access restrictions may require special approval for waste from certain states.
  - Management of mixed radioactive and hazardous waste will need to ensure proper disposal and long-term groundwater monitoring.
- Solid and Hazardous Waste Landfills—
  - May offer local disposal option for expected large volumes with limited contamination.
  - May offer a disposal option at hazardous waste landfills for mixed wastes (mixtures of hazardous and radioactive wastes); hazardous waste landfills have specified construction and engineering requirements.
  - Need to consider the location of the units in proximity to large or sensitive populations, sensitive ecosystems, and sole source aquifers.
  - May require design modifications to ensure that the waste can be managed protectively over time.
  - Difficulty in obtaining public acceptance, although some hazardous waste landfills have accepted waste with limited radionuclide content with state approval.
  - Requires additional demonstration of suitability to ensure protectiveness for radiological material (e.g., groundwater monitoring, additional engineering controls); many solid waste landfills have not been evaluated for disposal of radioactive material and may not be suitable for radiological material.
  - May require longer-term/special monitoring, as well as institutional controls.
- DOE Disposal Sites—
  - Could potentially handle high-activity waste if insufficient commercial access or capacity.
  - May be suitable for some problematic waste types (e.g., whole vehicles).
  - DOE disposal facilities generally accept only DOE-owned or DOE-generated waste. Disposal of non-DOE waste requires additional review and agreements involving the host state, consistent with DOE's authorities, particularly where existing agreements limit DOE's waste disposal activities.

In need of a risk-based waste disposal system and strategy

Multi-levels for waste disposal options based on risk

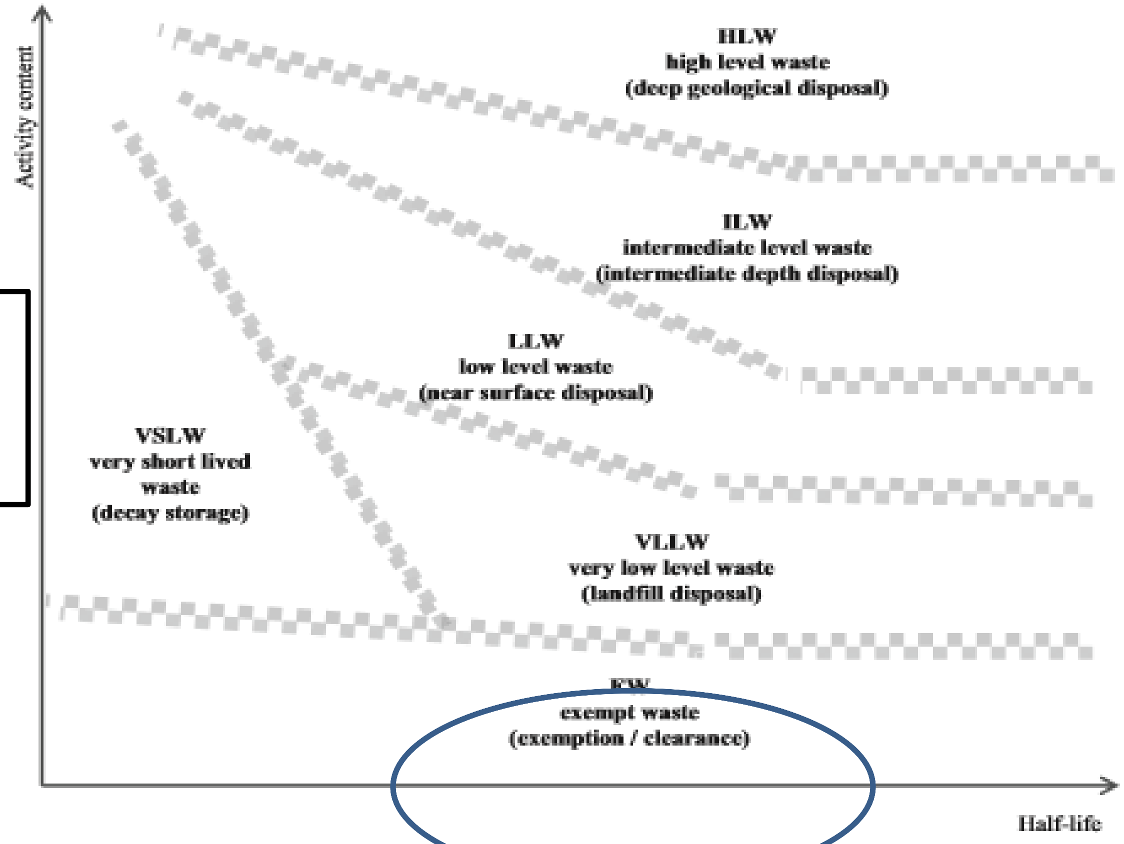
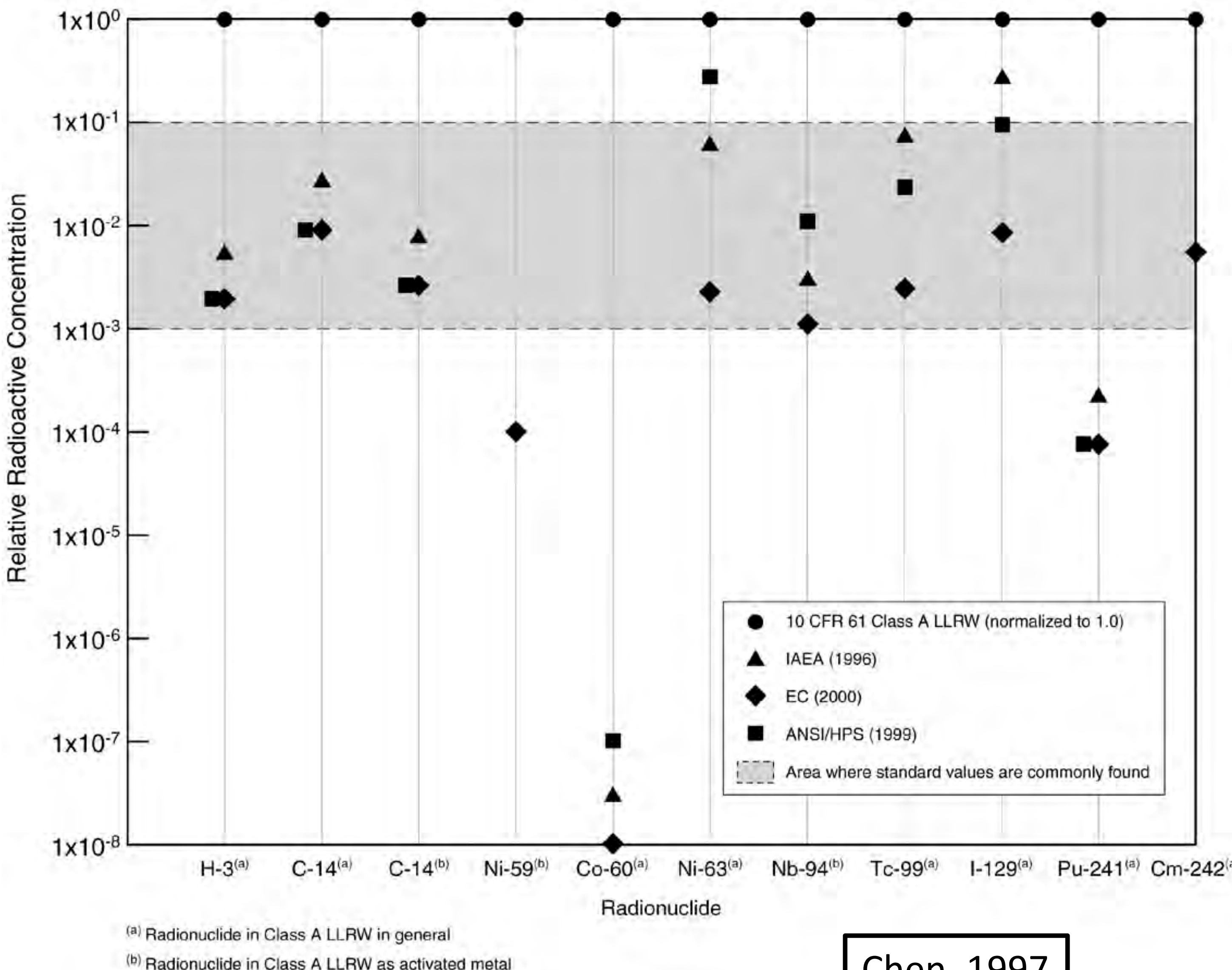


FIG. 1. Conceptual illustration of the waste classification scheme.

An example of the IAEA waste disposal system: IAEA GSG 1 Classification of Radioactive Waste (2009)

The clearance levels are within the 10 CFR 61 standards



Chen, 1997

Current cleanup efforts allow residual activities to remain in soils

Radionuclide	Screening Value* (pCi/g)	Screening Value* (Ci/m^3)	Upper Limit of Class A LLW** (Ci/m^3)
C0-60	3.8	6.08×10^{-6}	7×10^{2}
Ni-63	2,100	3.36×10^{-3}	3.5
Sr-90	1.7	2.72×10^{-6}	4×10^{-2}
Tc-99	19	3.04×10^{-5}	3
I-129	0.5	8.00×10^{-7}	8×10^{-2}
Cs-137	11	1.76×10^{-5}	1
U-238	14	2.24×10^{-5}	0.16 (100 nCi/g)***
Cm-242	160	2.56×10^{-4}	32 (20,000 nCi/g)

Note: *Soil screening value taken from NUREG-1757, Vol. 2, Appendix H. Assume soil density is 1.6 g.cm^3. **Values taken from 10 CFR 61.55 Table 1&2. ***For alpha-emitting transuranic radionuclides.

NRC proposed final rule for low-level radioactive waste disposal (10 CFR 61) offers a <u>performance-based</u> provision

09/19/2017

On September 8, 2017, the U.S. Nuclear Regulatory Commission (NRC) issued a **Staff Requirements Memorandum (SRM)** in response to SECY-16-0106, which sought Commission approval to publish a final rule in the *Federal Register* that would amend Title 10 of the Code of Federal Regulations (10 CFR) Parts 20, "**Standards for Protection Against Radiation," and Part 61,** "Licensing Requirements for Land Disposal of Radioactive Waste." *(https://www.nrc.gov/docs/ML1725/ML17251B147.pdf)*

A move toward performance-based assessment approach for LLW:

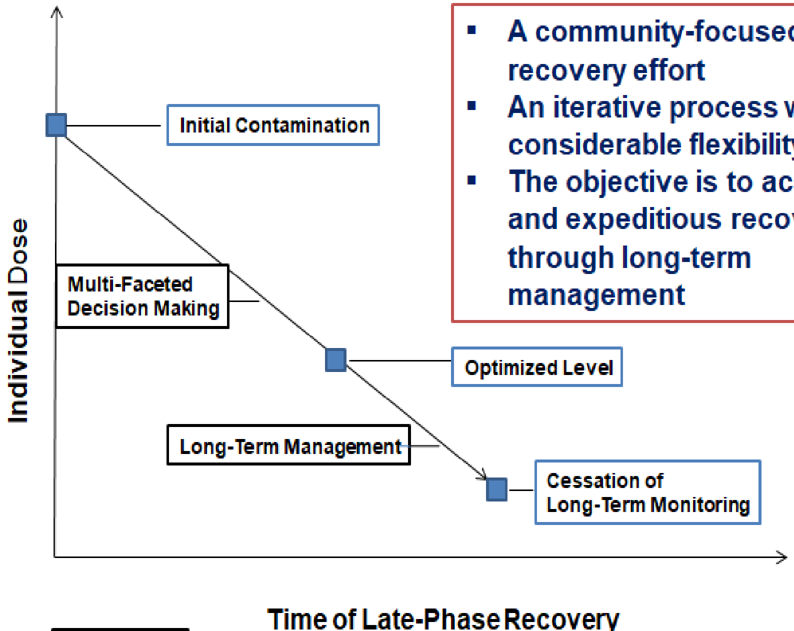
- Reinstate the **1,000 year compliance period** from the proposed rule with a specific dose limit of **25 mrem/year** and adopt **a longer period of performance assessment**—the period of which would be based on site-specific considerations and a "reasonable analysis," as defined in SRM-SECY-13-0075…..

Disposal options should cover a wide range of alternatives

- **Exemption**
  - Materials (e.g., soils) that can be left in place with acceptance criteria (much like site remediation)
- **Commercial disposal sites**
  - Commercial LLRW disposal sites
    - Limited disposal capacity
  - RCRA Subtitle C (hazardous) landfills
    - Possibility of accepting "low activity" wastes (EPA 2003)
  - RCRA Subtitle D (municipal) landfills
    - Possibility of accepting wastes with "clearance"
- **Government disposal sites**
  - Possibility of disposal at DOE sites may require Executive Orders

ISSUES:
1. RCRA landfills have not been systematically compiled by their accessibility and availability. Waste acceptance criteria unknown.
2. Site remediation concept is yet to be developed for the contaminated areas.

A long-term recovery strategy toward remediation via continued monitoring and management



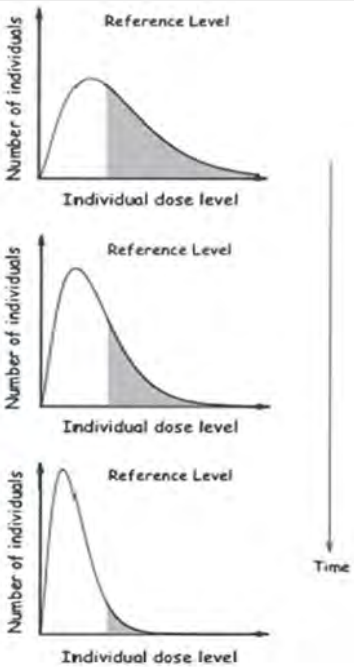
- A community-focused recovery effort
- An iterative process with considerable flexibility
- The objective is to achieve and expeditious recovery through long-term management

(NCRP 2014)

A continuing effort to control exposure in the long term

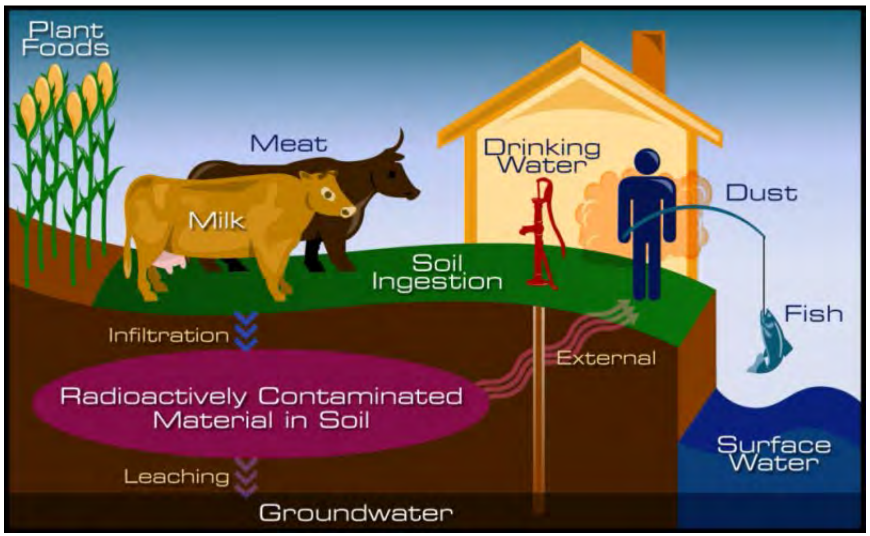
Aim to control the doses to the *Individuals* over the long term

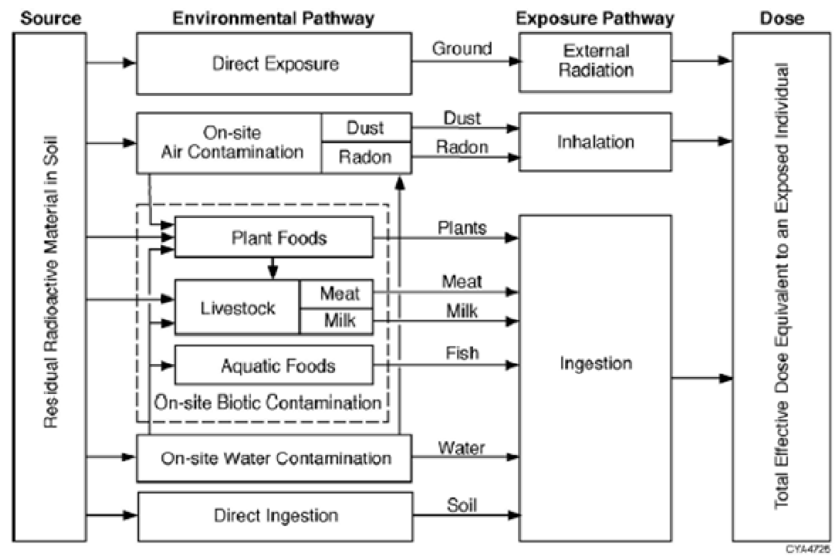
(ICRP Report 111)



Long-term remediation approach is part of the waste management strategy in the wide-area contamination

Use of pathway analysis (a risk-based) approach to determine how much residual contamination can be allowed in site remediation





Example: use of RESRAD Moidel to determine acceptable soil cleanup levels. Source: Argonne National Laboratory. This has been a practice in US environmental cleanup regulations. Soils left behind is not considered as radioactive waste under 10 CFR 61 regulations. Applicable approaches apply to NRC (License Termination), EPA (Superfund) and DOE (Nuclear Complex Cleanup).

Piecing together a holistic waste management strategy

NCRP 175: Adaptive and responsive cleanup strategies should be developed that facilitate the optimization process.

- Waste management and environmental remediation are both integral parts of wide-area response effort during a major nuclear event
- A risk-based approach is justified and proven to be successful
- Developing a harmonized strategy and approach is essential to addressing radioactive waste management in the wide-area cleanup

- Develop cleanup scenarios
- Adaptive approach
- Iterative process
- Achieving holistic waste management

A strategy toward radioactive waste management

Develop a risk-informed approach toward radioactive waste management throughout various phases of response

- **Early phase**: removal of initial high activity radioactive contamination and debris (such as from explosions) for storage or disposal to facilitate first responders actions in search and rescue
- **Intermediate phase**: removal of high level radioactive contamination (such as from plume deposition) for storage or disposal to facilitate initial restoration and recovery effort
- **Late phase (long-term recover)**: long-term remediation of the contaminated lands toward the existing exposure situations (a risk-based approach)

Summary and conclusions

- Radioactive waste characterization and management is one key issue in planning and managing recovery from nuclear or radiological incidents
- Current policy and regulatory provisions are ill equipped to properly respond to a large scale incident
- Response planning needs to accommodate the large quantities of waste with miniscule radioactivity
- Current system requires a risk-informed framework that incorporates an adaptive strategytoward a unified approach for waste management in the event of a major nuclear incident

Waste Management Challenges Facing Fukushima's Long-Term Recovery

Sang Don Lee*, Paul Lemieux, Timothy Boe, Anne Mikelonis

US Environmental Protection Agency
National Homeland Security Research Center

Earthquake and Tsunami

- Earthquake
  - March 11, 2011
  - 9.0 magnitude earthquake (5th strongest ever recorded)
- Tsunami
  - Inundated 260 mi^2 of coastline, reaching up to 3 mi inland
  - Inundation height as high as 50 ft
- Disaster caused
  - 15,882 deaths, 2,668 missing, 6,142 injuries
  - Damaged more than 1.2 M buildings

- Bird and Grossman. Envr. Hea. Pers. 2011, 119, a290-a301
- Ishigaki et al. Tohoku J. Exp. Med., 2013, 229, 287-299
- http://news.nationalgeographic.com/news/2011/03/pictures/110311-tsunami-earthquake-japan-hawaii-science-world-waves/

Relevant Documents

- US Embassy Science Fellow Report

http://josen.env.go.jp/en/documents/pdf/workshop_july_17-18_2013_04.pdf

- IAEA report: The Fukushima Daiichi Accident Technical Volume 5/5 Post-accident Recovery

http://www-pub.iaea.org/MTCD/Publications/PDF/AdditionalVolumes/P1710/Pub1710-TV5-Web.pdf

- MOEJ report: FY2014 Decontamination Report - A compilation of experiences to date on decontamination for the living environment conducted by the Ministry of the Environment

http://josen.env.go.jp/en/cooperation/pdf/decontamination_report1503_full.pdf

- MOEJ Decontamination Guidelines

http://josen.env.go.jp/en/framework/pdf/decontamination_guidelines_2nd.pdf

- JAEA report: Remediation of Contaminated Areas in the Aftermath of the Accident at the Fukushima Daiichi Nuclear Power Plant: Overview, Analysis and Lessons Learned

http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Review-2014-051.pdf

http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Review-2014-052.pdf

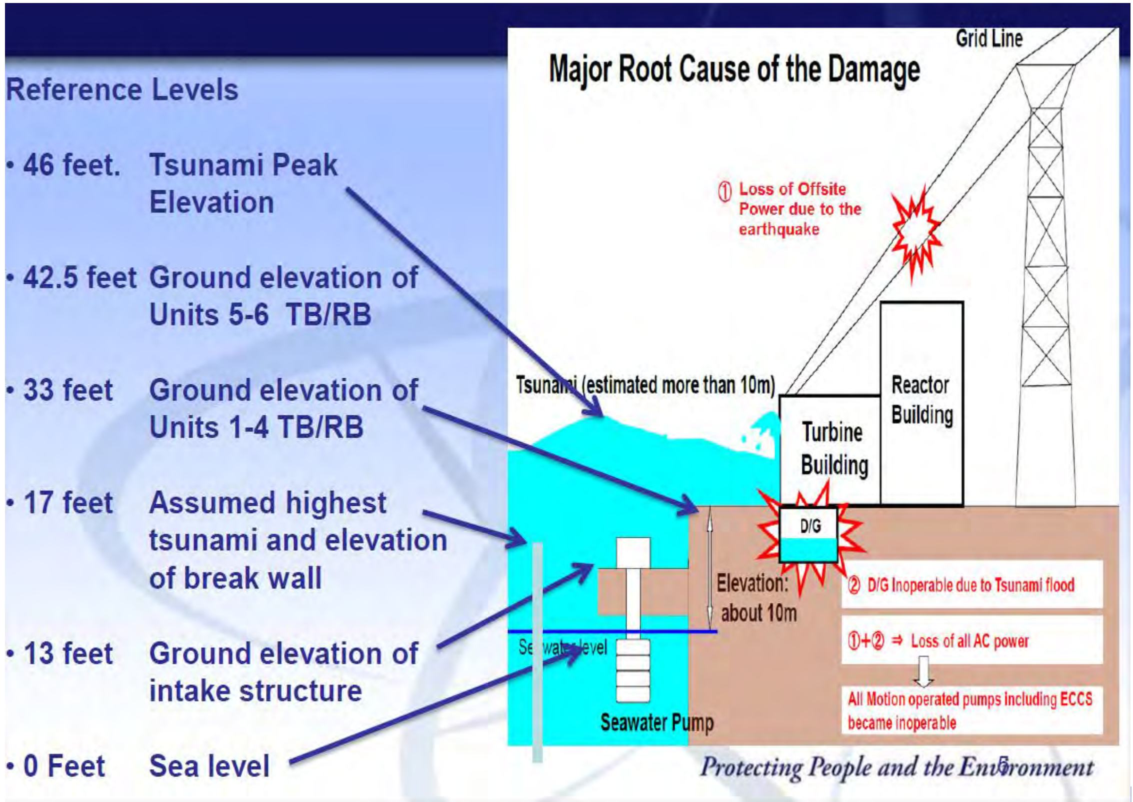
- EPA report: Current and Emerging Post-Fukushima Technologies, and Techniques, and Practices for Wide Area Radiological Survey, Remediation, and Waste Management

https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=528638

Fukushima Dai-ichi NPP

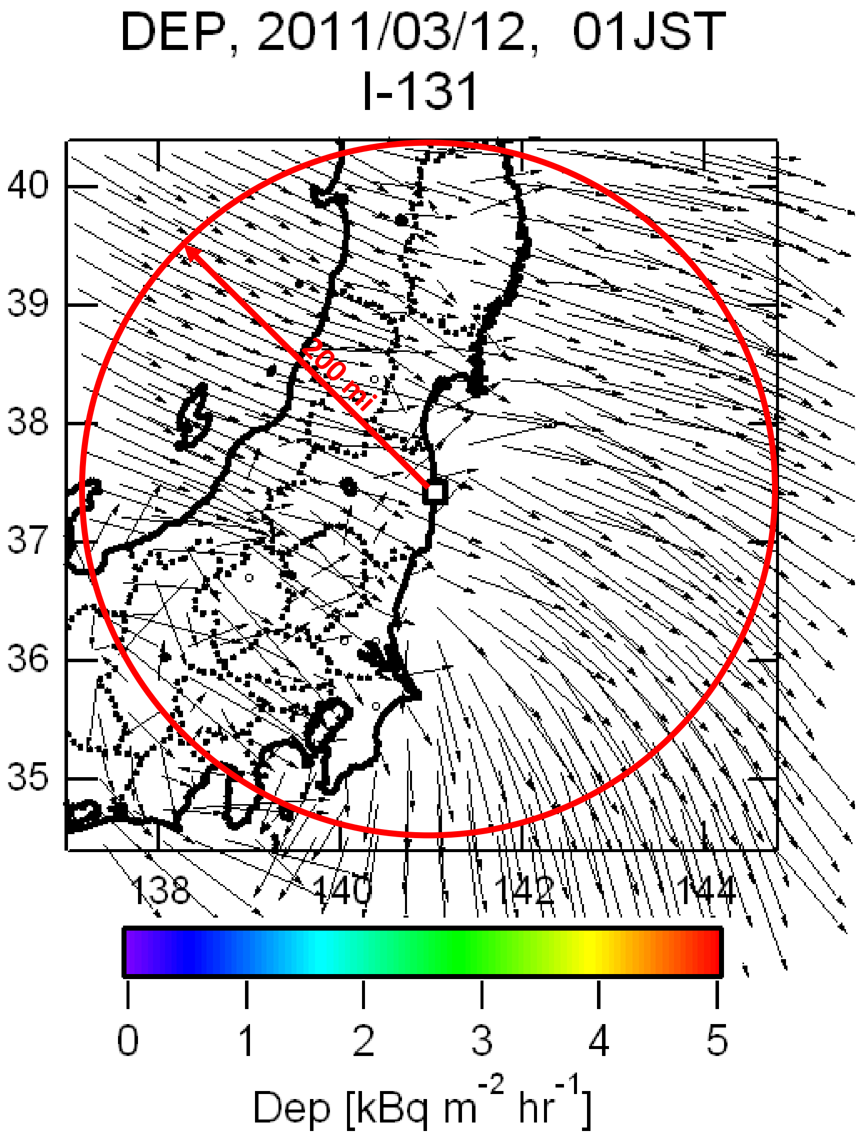
- Following the earthquake
  - Reactors shut down
  - Emergency diesel generators supplied power
  - Plant conditions stable

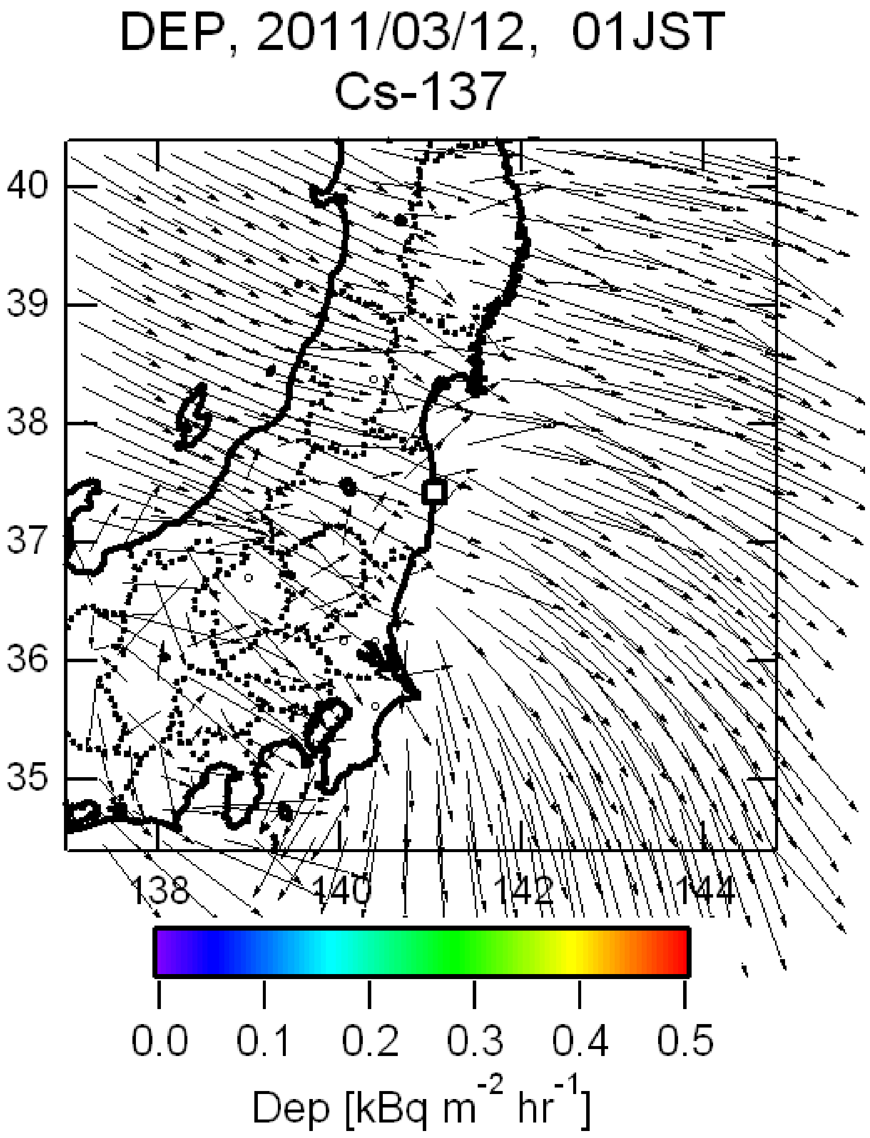
- Following the Tsunami
  - Core and fuel melt and damaged
  - Hydrogen generation and explosions
  - Radioactive material offsite release



Steven West, US NRC, NSTC subcommittee on disaster reduction, May 1 2014

Nuclides Fallout Simulation（From March 12 to 23, 2011）

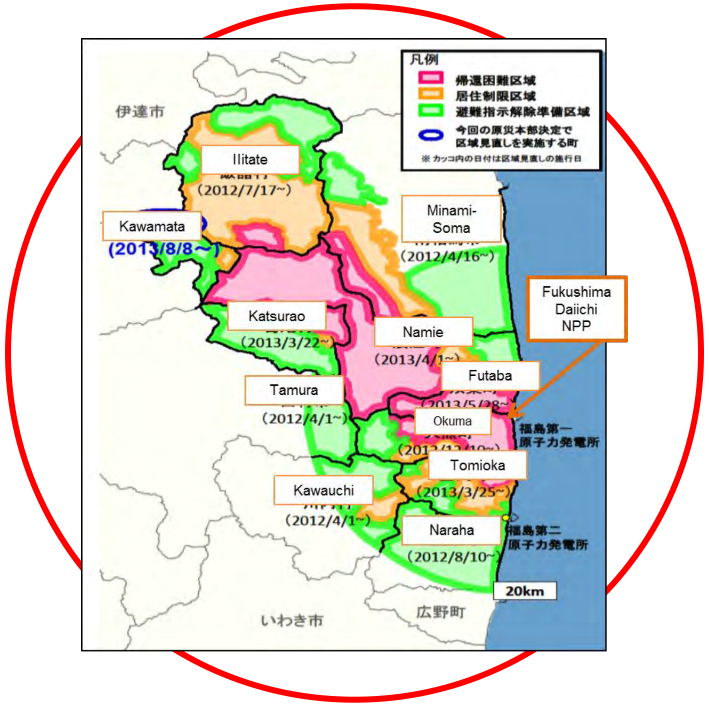




Radionuclides are scattered by wind and rain in total East Japan.

From Dr. Yamada's presentation at EPA-DHS First Responder Workshop in DC on April 3rd 2014

Offsite Contamination by Nuclear Power Plant Incident



Area 1: <20mSv/yr
Evacuation orders are ready to be lifted:

Area 2: 20 – 50 mSv/yr
Residents are not permitted to live:

Area3: >50 mSv/yr
Residents will have difficulties in returning for a long time:

- Onsite: NPP
- Offsite: outside NPP
- Evacuation order: >20 mSv/year
- Evacuees: ~160,000
- Long term clean up goal: 1 mSv/year
- Decontamination required offsite area: ~5,000 mi^2
- Special Decontamination Area (>20 mSv/year): ~425 mi^2

http://josen.env.go.jp/en/documents/

Current Progress of Remediation

- Special Decontamination Area: planned decontamination is complete for all municipalities by March 2017
  - Avg. dose rate before decontamination: 1.27 uSv/hr
  - Avg. dose rate post decontamination: 0.63 uSv/hr
  - Avg. dose rate 6 months after decon: 0.44 uSv/hr

- Intensive Contamination Survey Area: 84 municipalities out of 92 completed decontamination and 8 municipalities in progress

Completion of the Decontamination in SDA (as of the end of March 2017)

Decontamination works in the following municipalities have been completed by the end of March 2017

Municipality	Residential area	Farmland	Forest	Road	Evacuation order was lifted on
	Number of implementated houses	Implemented area ha	Implemented area ha	Implemented area ha	
Minamisoma	4,500	1,700ha	1,300ha	270ha	July 12, 2016
Namie	5,600	1,400ha	390ha	210ha	March 31, 2017
Tomioka	6,000	750ha	510ha	170ha	April 1, 2017
Iitate	2,000	2,100ha	1,500ha	330ha	March 31, 2017
Futaba	97	100ha	6.2ha	8.4ha	————
Kawamata	360	600ha	510ha	71ha	March 31, 2017
Katsurao	460	570ha	660ha	95ha	June 12, 2016
Okuma	180	170ha	160ha	31ha	————
Kawauchi	160	130ha	200ha	38ha	Former Areas to which evacuation orders are ready to lift up: October 1, 2014 Former Areas in which residents are not permitted to live: June 14, 2016
Naraha	2,600	830	470ha	170ha	September 5, 2015
Tamura	140	140ha	190ha	29ha	April 1, 2014
Total Number	22,000	8,500ha	5,800ha	1,400ha	

- "Forest" refers to those close to residential areas
- The MOE will continue decontamination if we get new consent from the residents

3rd MOE-IAEA meeting 4/19/2017

Progress in Intensive Contamination Survey Area ③

Within Fukushima Pref. (as of January 2017)	Ordered			Achievement		
	Ordering ratio (%)	Number of ordering	Number of planning	Achievement ratio (%)	Number of achievement	Number of planning
Residential houses	**99.9**	420,399	420,901	**97.8**	411,746	420,901
Public facilities	**99.7**	11,696	11,728	**93.8**	11,006	11,728
Roads (km)	**96.2**	18,353	19,071	**77.7**	14,822	19,071
Farmland / meadows (ha)	**92.6**	31,521	34,058	**89.7**	30,537	34,058
Forests in living area (ha)	**90.6**	4,162	4,591	**76.0**	3,490	4,591

[Source] Survey conducted by Fukushima Prefecture
Note: The number of planning might be revised in future.

Outside Fukushima Pref. (as of December 2016)	Ordered			Achievement		
	Ordering ratio (%)	Number of ordering	Number of planning	Achievement ratio (%)	Number of achievement	Number of planning
Residential houses	**100**	147,688	147,699	**100**	147,682	147,699
Public facilities	**100**	1,591	1,591	**100**	1,591	1,591
Parks / sport facilities	**100**	3,945	3,945	**100**	3,945	3,945
Other facilities	**100**	6,273	6,273	**100**	6,268	6,273
Roads (km)	**100**	5,400	5,400	**100**	5,400	5,400
Farmland / meadows (ha)	**100**	1,588	1,588	**100**	1,588	1,588
Forests in living area (ha)	**100**	300	300	**100**	300	300

Note: The number of planning is the total number as of the end of December 2016, which might be increased in future depending on each municipality's status.

Fukushima Decontamination Guidelines

Radioactive materials settled on soil, vegetation, and buildings

Radioactive materials consolidated and shielded

Decontamination of paved roads

Road Decontamination

	Technique
A	Street sweeping
B	Ride-on sweeping
C	Water-jet vehicle
D	Manual high-pressure water washing
E	Hydro-blast ultra-high pressure water washing
F	Dry-ice blasting
G	Sand-blasting
H	Medium-scale shot-blasting (iron balls)
I	Large-scale shot-blasting (iron balls)
J	Asphalt planing/shaving
K	Mechanical digger asphalt removal
L	Top-soil removal from unpaved road or soft-shoulder

Residential Decontamination

Techniques Used for Decontamination ①

- Houses, buildings
  Removing deposits from the roof, deck , and gutters
  Wiping off roofs and walls, high-pressure washing etc.
- Gardens and trees
  Mowing, removing fallen leaves, topsoil stripping etc.
- Roads
  Removing deposits in ditches, high-pressure washing etc.

Decontaminating paved surfaces
(by a collective type high-pressure water cleaner)

Decontaminating roofing tiles (by wiping)

Decontaminating gardens (by removing soils etc.)

Photos provided by: Date City

High-pressure water washing

Brushing

Decontamination adsorbent

Wiping gutters

High-pressure water jet washing

Manual brushing of walls

Figure 2-20: Examples of decontamination techniques for houses

Public Facility Decontamination

Figure 2-25: Decontamination methods for play equipment

Figure 2-26: Decontamination of swimming pools

Vegetation, Forest, Lawn Decontamination

Techniques Used for Decontamination ②

Vacuum vehicles

High-pressure water washing with a tower wagon

s)

Photo provided by: Japanese Society of Turf grass Science

Photo provided by: JAEA

Removal of litter (vacuum)

Removal of litter and humus

Pruning (vehicle mounted platform lift)

Pruning (ladder & chainsaw)

Bamboo thinning (chainsaw)

Felling (mechanical harvester)

Figure 2-16: Illustration of forest decontamination techniques

Farmland Decontamination

Hammer knife mower

Cultivator and mower

Stripping topsoil

Stripping subsoil

Topsoil stripping (mechanical digger)

Manual topsoil stripping

Thin layer topsoil stripper

Reversal tillage with plough

Fixation agent application

Solidified soil separation and recovery machine

Figure 2-18: Various soil treatment methods applied to agricultural land

Other Decontamination Activities

Removal of litter and moss

High pressure water washing of pebbles

Removal of debris from drains

Scale of Decontamination Project

The MOE has budgeted approx. 2.6 trillion yen (= USD 24 billion) until FY2016 for decontamination of both the SDA and the ICSA. 16,000,000㎥ of contaminated soil and wastes is estimated to have been removed.

Decontamination in SDA

- Total number of labor:
  approx. 13,000,000 workers
- Budget: approx. USD 12billion
  ※ MOE's budget until FY2016 (excluding unnecessary cost)
- Volume of the generated soil:
  approx. 8,400,000㎥

  From the above volume of soil already transported from TSS*: approx. 1,000,000㎥
  (as of the end of January 2017)

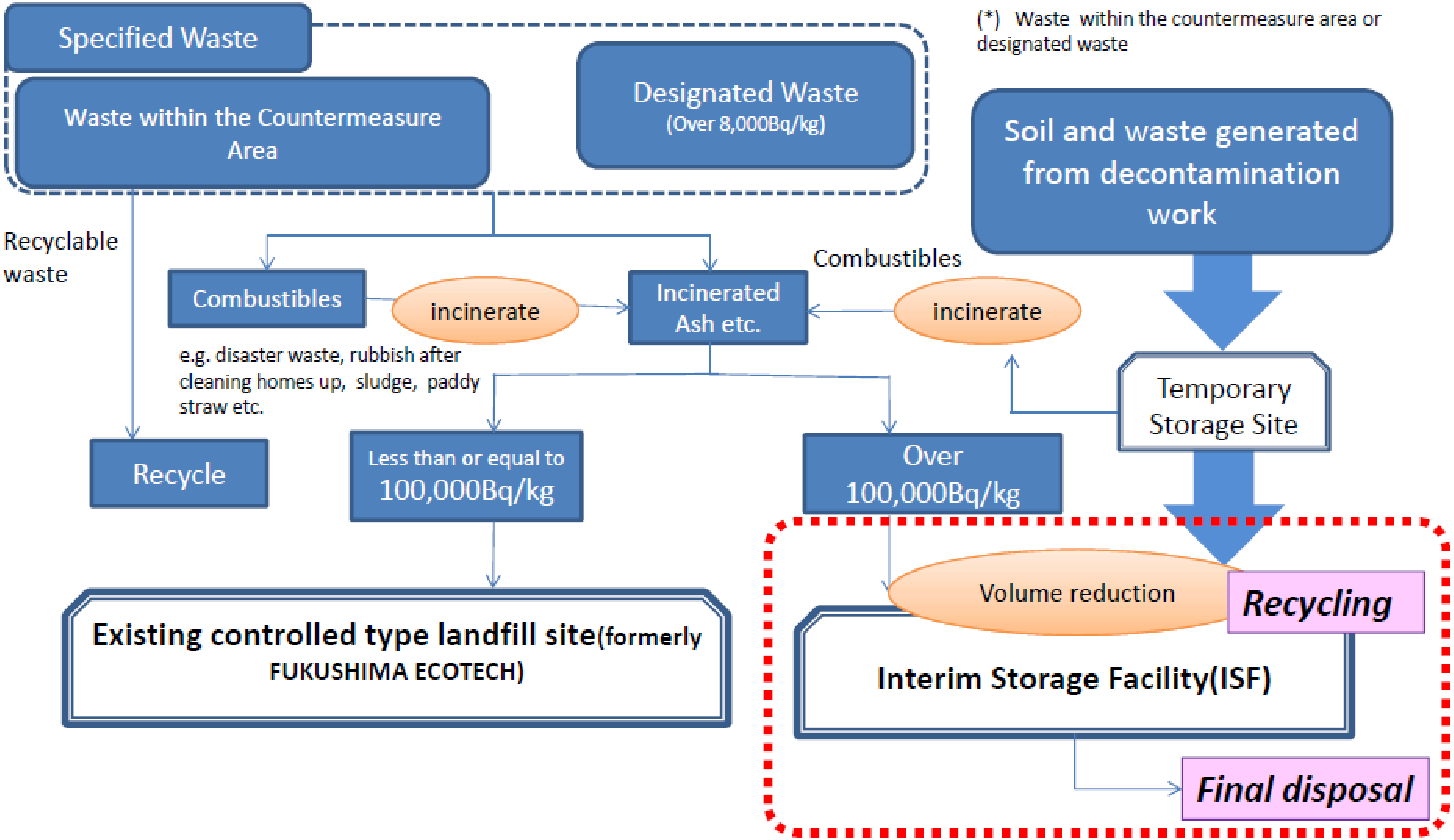
* Volume transported either to the ISF or to Temporary incineration facility

Decontamination in ICSA

- Total number of labor:
  approx. over 17,000,000 workers
  ※ estimated from the hearing among relevant municipalities
- Budget: approx. USD 12billion
  (within Fukushima Pref. : approx. JPY 1.2trillion,
  outside Fukushima Pref. : approx. JPY 0.5trillion
  ※MOE's budget until FY2016 (excluding unnecessary cost)
- Volume of the generated soil:
  approx. 7,200,000㎥ (estimation)
  (within Fukushima 6,800,000㎥,
  outside Fukushima 400,000㎥, both are estimation)

  From the above volume of soil already transported from TSS*: approx. 1,100,000㎥
  (as of the end of January 2017)

(Review) Flow Diagram for Treatment of Specified Waste(*), Soil and Waste Generated from Decontamination (Fukushima Pref.)



Waste Management: Temporary Storage Sites

Naraha Town Rice Field – On-Site Storage

Okuma Town Baseball Field – Temporary Storage Facility

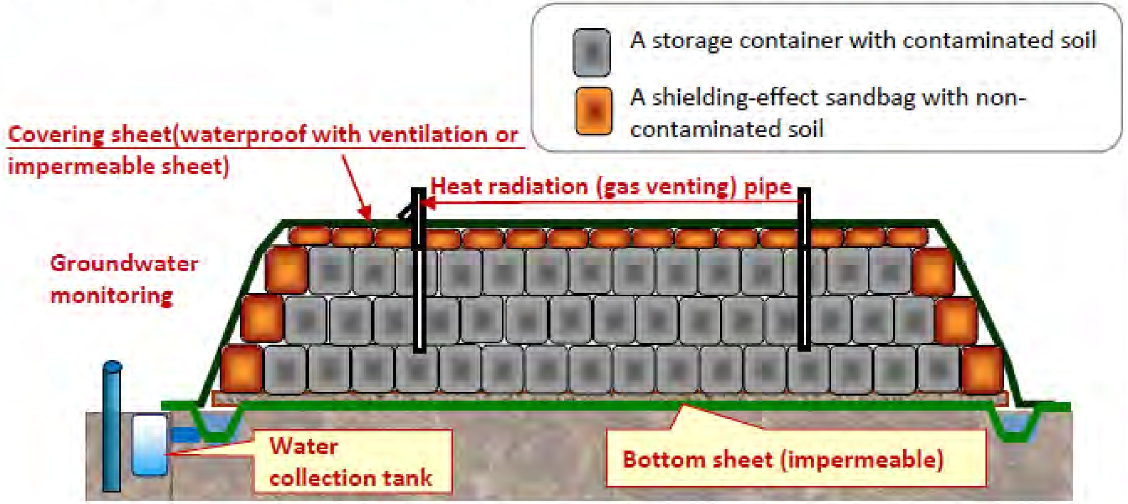
Tomioka Town Sports Complex – On-Site Storage

Tomioka Town Park – Temporary Storage Facility

Fukushima City Private Residence – On-Site Storage
Above ground, not buried on-site

Continuation of Storage and Land Lease in Temporary Storage Sites (TSS)

◆Basic structure of a TSS / Routine management & checkup (A case in the SDA)



< Checkup points >

Routine checkup/ weekly	・Visual check ・Air dose rate measurement
Routine checkup / monthly	・Groundwater measurement
If necessary	・Leachate measurement and treatment in water collection tank
Emergency inspection in unusual weather and earthquake	・Visual check ・Air dose rate measurement

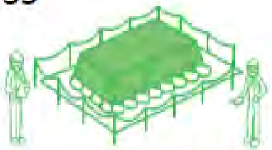
◆Number of TSS and the volume of removed soil

* The number in the SDA is as of the end of March 2017 and the number in the ICSA is only in Fukushima Prefecture as of the end of December 2016

	Number of TSS	Number of storage site	Volume of removed soil
SDA	269	—	7,556,007 bags
ICSA	864	149,330	6,086,979 ㎥

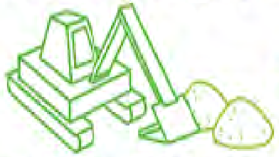
◆Storage in TSS～Transfer～Restore to original form～Return of land and extension of storage period

TSS

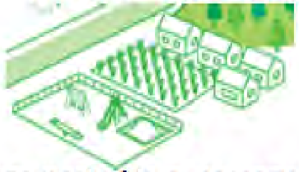


Transfer to ISF

Restore to the original form



Return of the land



《At first》 The delivery will be completed within 3 years* upon delivery

《Current status》 Continuation of storage period is necessary. Process of the ISF delivery largely depends upon land acquisition, construction status, and transportation plan, etc.

Continuation of the storage

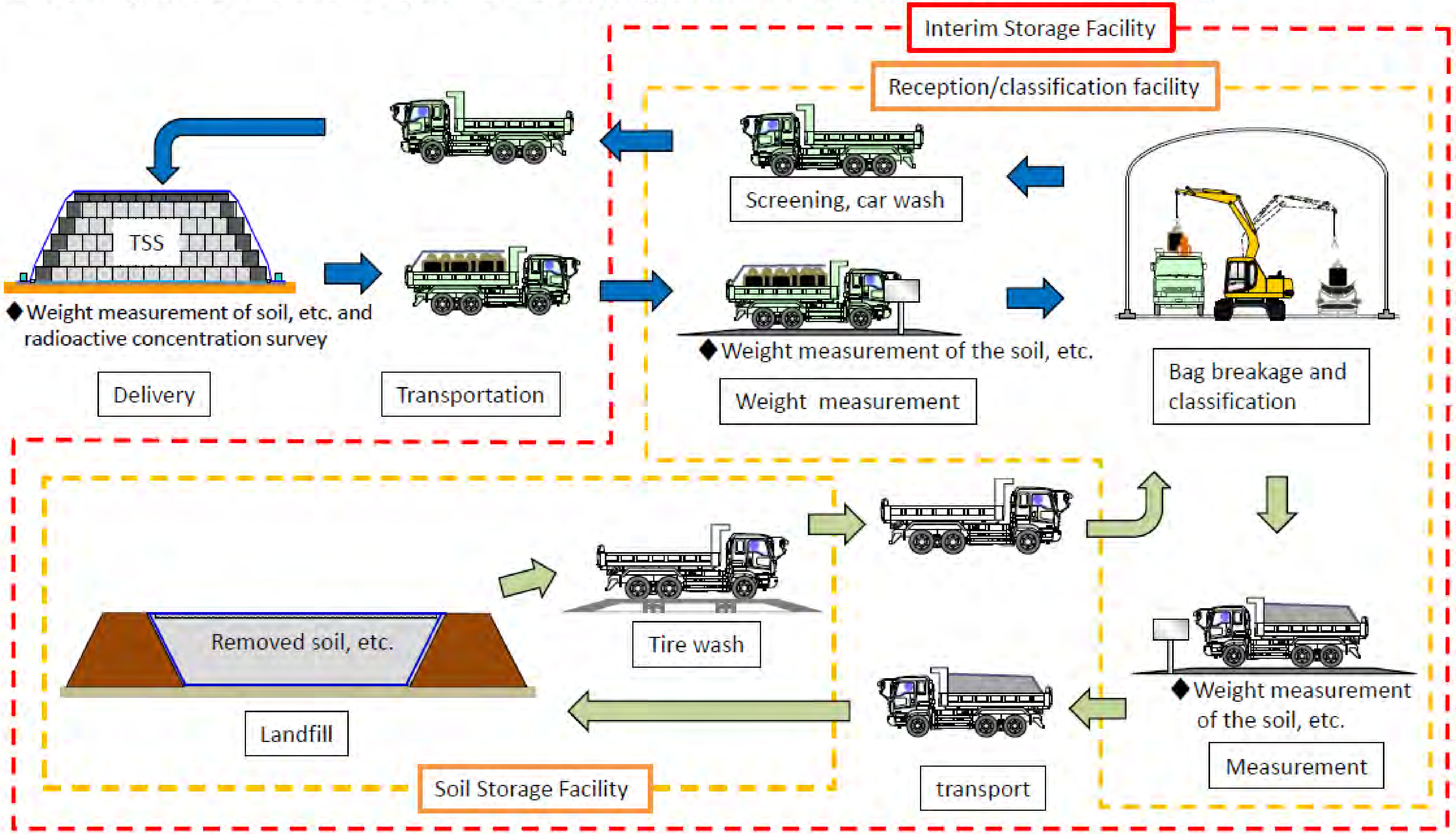
Continuation of the land lease

* Basic Policy of ISF (Oct. 2012): The national Government will make utmost efforts to start operating the ISF in about 3 years after the full-scale delivery of soil from the TSS

Overview of the Construction of Interim Storage Facility in FY2016

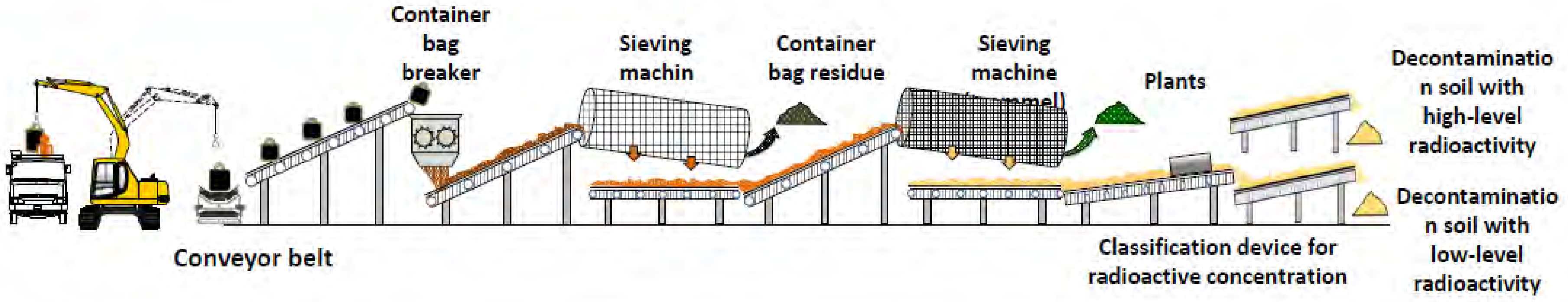
Image of the soil flow

Removed soil will be transported from temporary storage site to the soil storage facility after breaking the container bags and classifying in the reception/classification facility



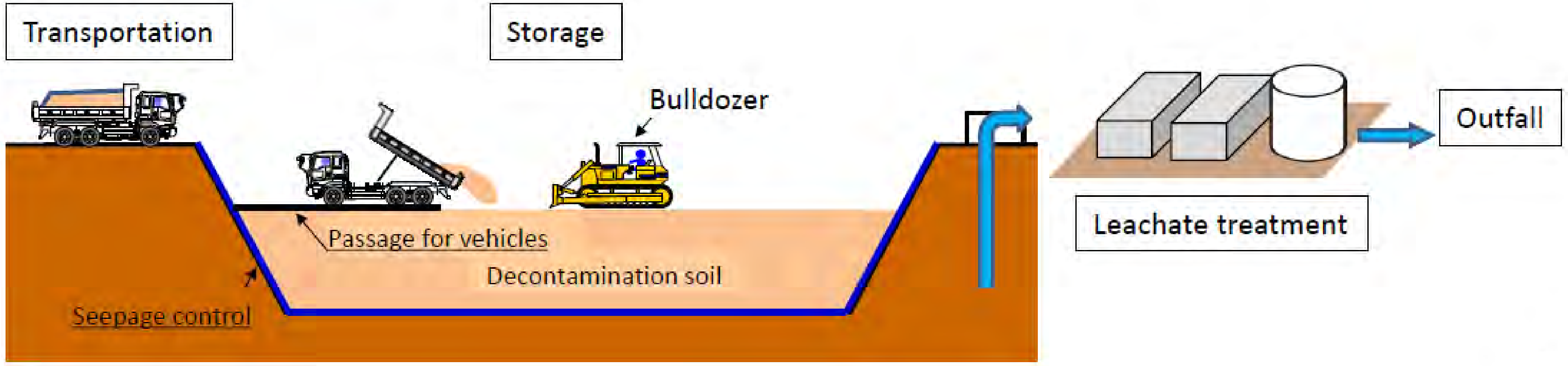
Imaginary Picture of Reception / Classification / Soil Storage Facility

Reception / Classification Facility



Unloading equipment	Equipment for container bag breaker	Equipment for primary classification	Equipment for secondary classification	Equipment for classification of radioactive concentration

Soil Storage Facility



Waste Management: Volume Reduction

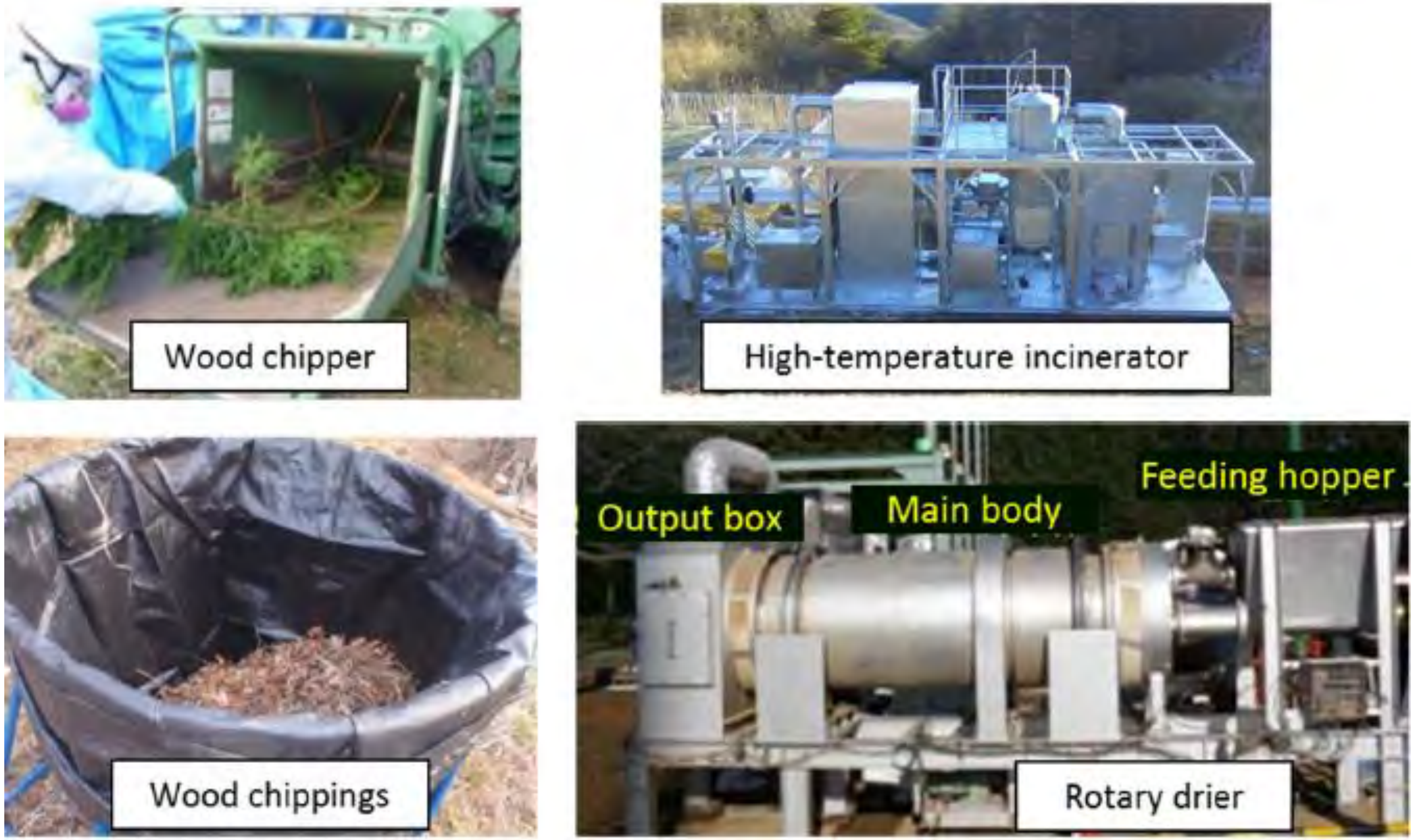


Figure 2-28: Illustration of some volume reduction methods for solid organic waste

Waste Management: Tracking

Figure 2-30: Flexible container and labelling system for packages and transport vehicles

Containment of Wastewater: treatment

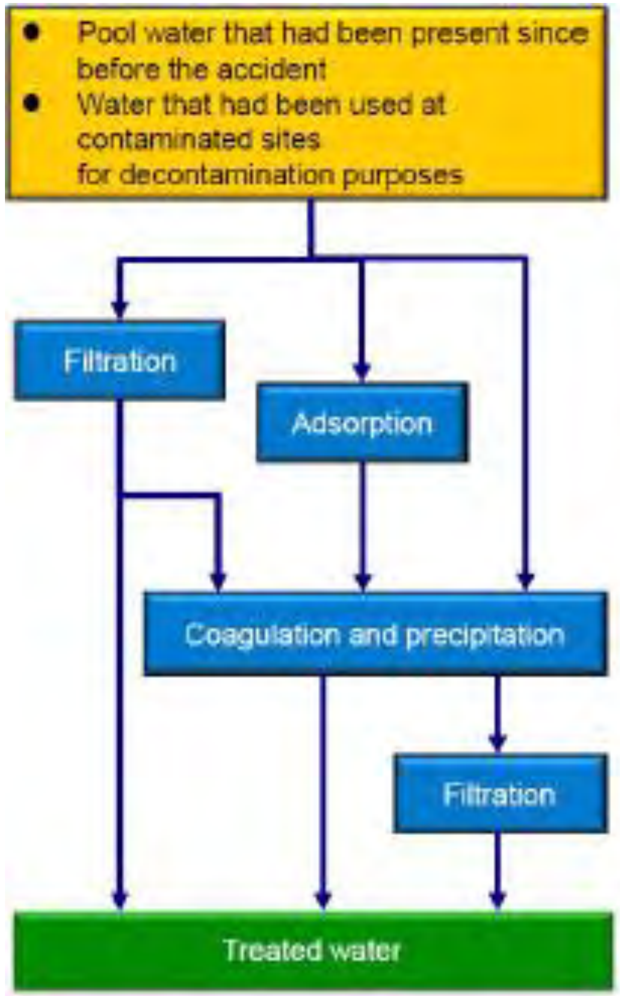


Figure 2-27: Decontamination of liquid waste: flow chart and equipment

Containment of Wastewater

Removal of sediment in side ditches, etc.

Transfer of water from vacuum tanker to treatment tank

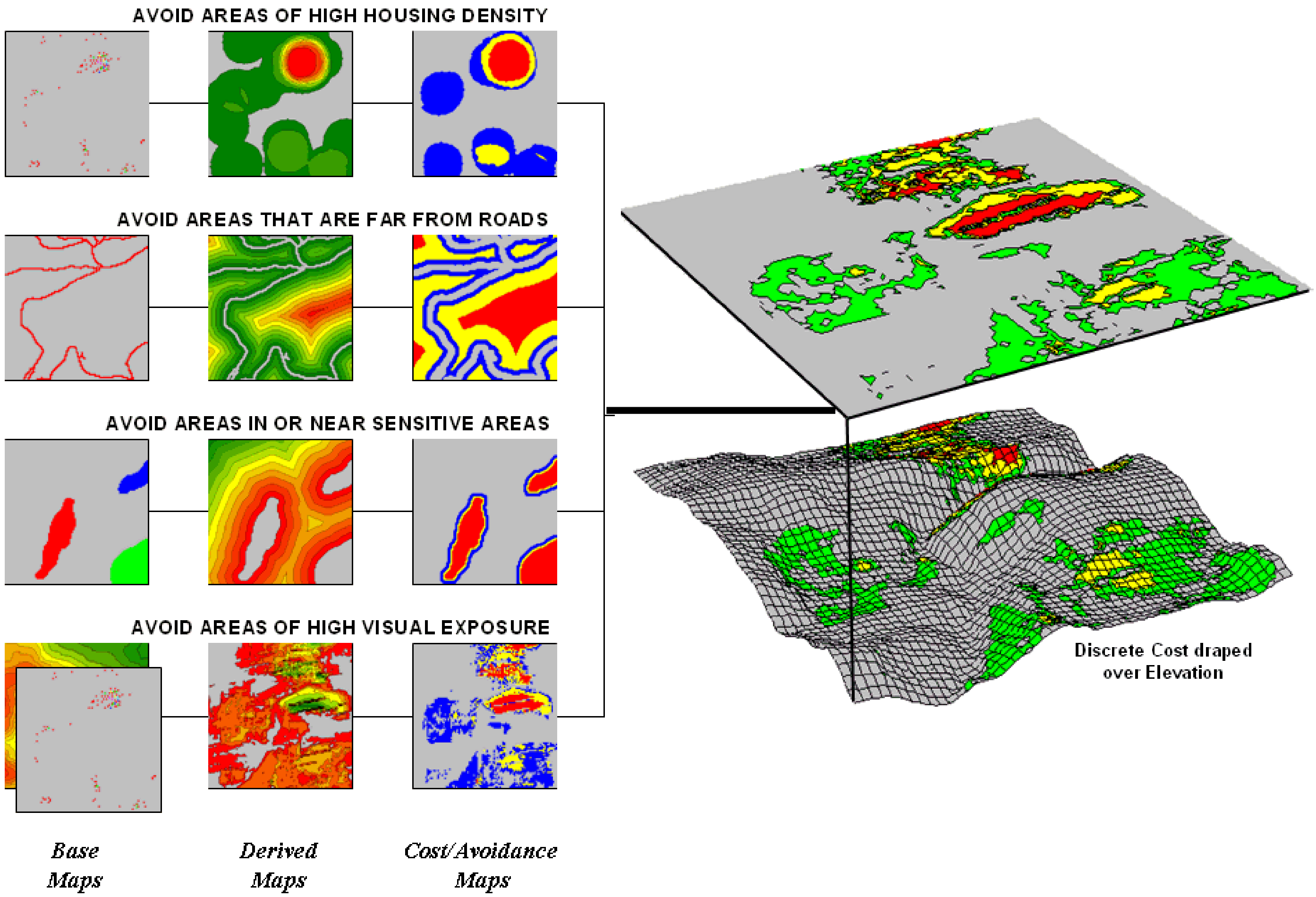
Sludge remaining after treatment

Current Challenges

- Decontamination waste is approximately 16 million m^3
  - Need storage and disposal sites
  - Need to transport all waste to ISF and Disposal site
  - Require waste volume reduction
- Disposal site is not available yet and should be ready in 30 years
  - All wastes need to move out of Fukushima prefecture
- Interim Storage Facility construction is still in progress
  - Delayed land acquisition in the evacuated area
- Transport of waste bags to ISF from TSS
  - Local governments are pushing to accelerate the transportation to ISF
  - Widely dispersed locations of TSSs
- Attempt to recycle/reuse decontamination waste for volume reduction
  - Conflicting policies: 5000 Bq/kg for farmland soil, 8000 Bq/kg for designated waste, no limit for decontamination waste
  - Some local governments want to reuse decontamination waste for construction

Preparation for the US

- Assessment of available and potential disposal and temporary storage sites and optimal transportation options



Preparation for the US

- Waste volume reduction
    - Effective survey strategy before decontamination
    - Prediction of contaminant fate and transport
    - Choice of decontamination methods
    - Timely decontamination
    - Waste sorting
    - Is incineration a viable option for US?

- **Sang Don Lee**
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  - **919 541 4531**

Tradeoffs Between Decontamination Methods and Waste Management During Response to a Wide-Area Radiological Incident

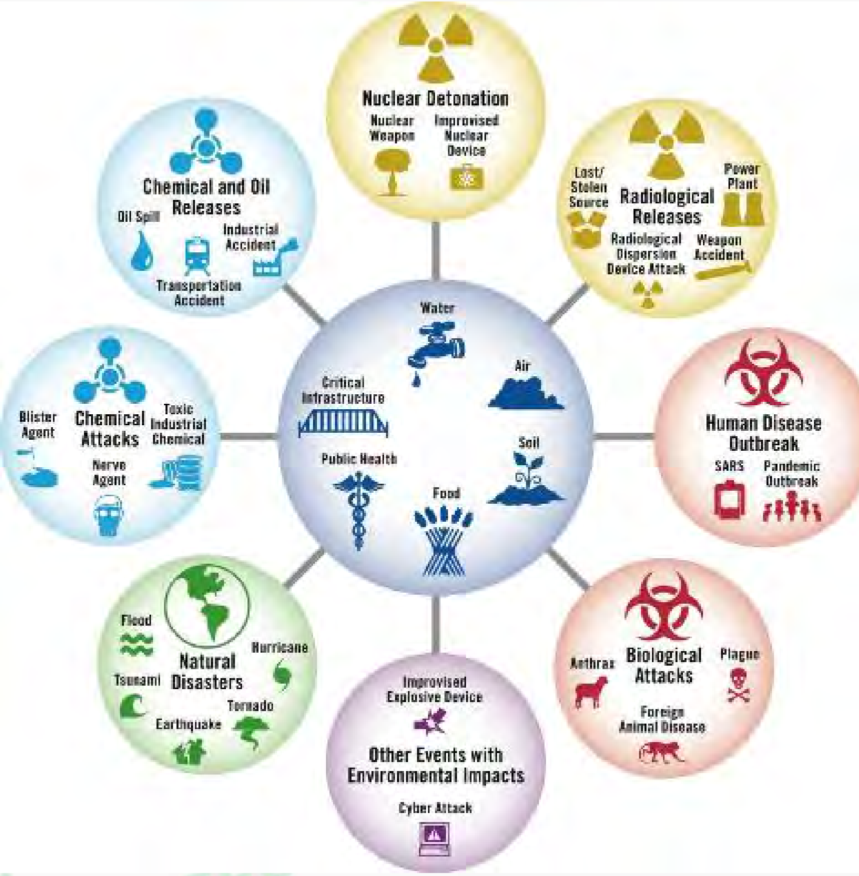
Paul Lemieux, Sang Don Lee, Timothy Boe, Anne Mikelonis

US Environmental Protection Agency

Outline of Presentation

- EPA All-Hazards Approach
- Wide-area Radiological Incidents
- Decision Making Needs
- Potential Waste Generation
- Decontamination Approaches and Waste Tradeoffs
- Potentially Useful Tools

EPA's "All Hazards" Universe

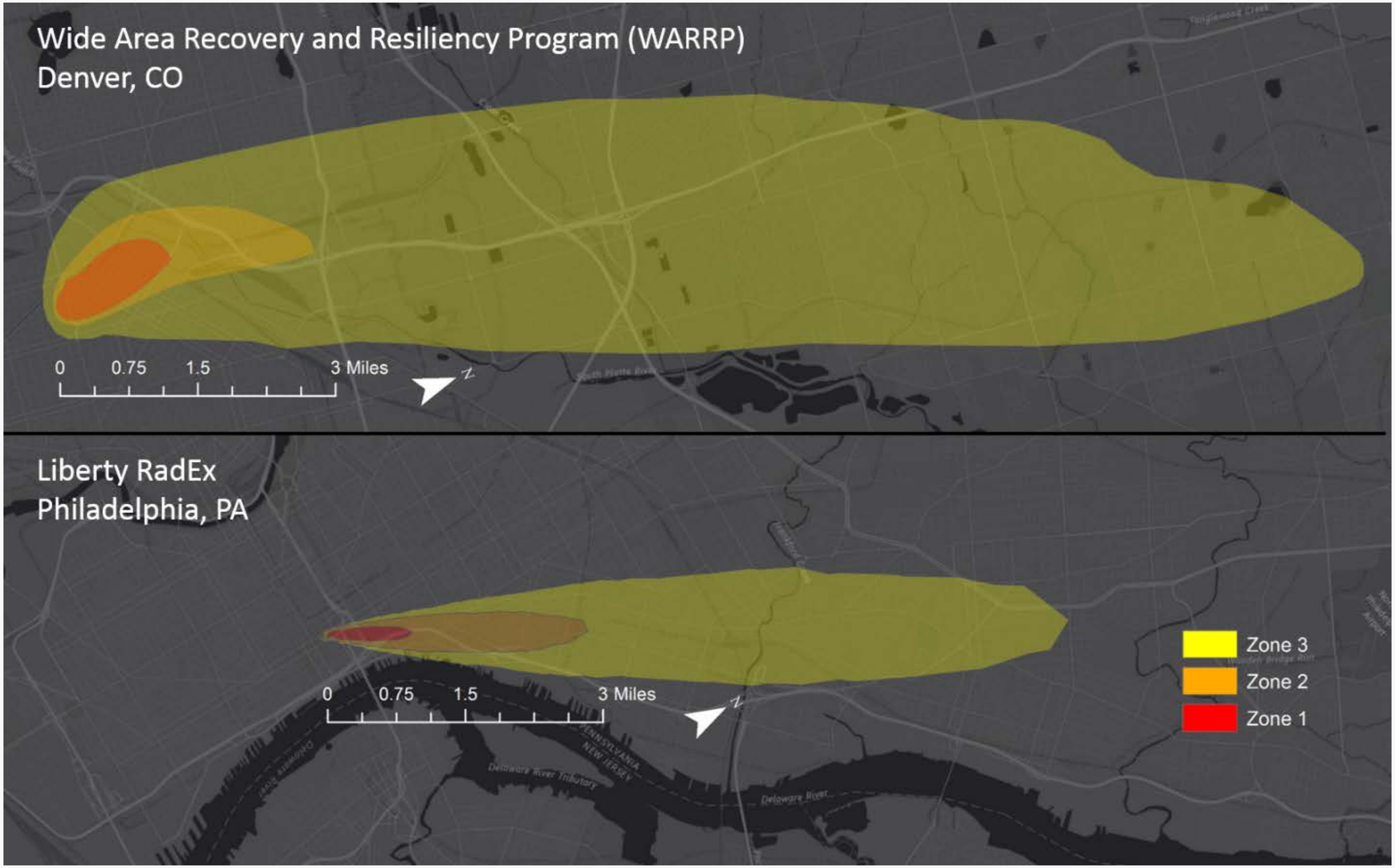


Refining EPA's Approach to Homeland Security, Office of Homeland Security (2011)

Wide-Area Radiological Incidents

- Nuclear Power Plant (NPP) Accident
  - Diverse radionuclides
  - Multiple deposition mechanisms
- Radiological Dispersal Device (RDD)
  - Limited number of radionuclides
  - Deposition largely contaminated fallout
  - Mostly surface contamination
- Improvised Nuclear Device (IND)
  - Diverse radionuclides
  - Contamination of irradiated materials near epicenter
  - Deposition of contaminated particles in dangerous fallout zone
  - Mostly surface contamination (except near epicenter)

Example Scenarios



Estimated Building Distribution Based on Building Count

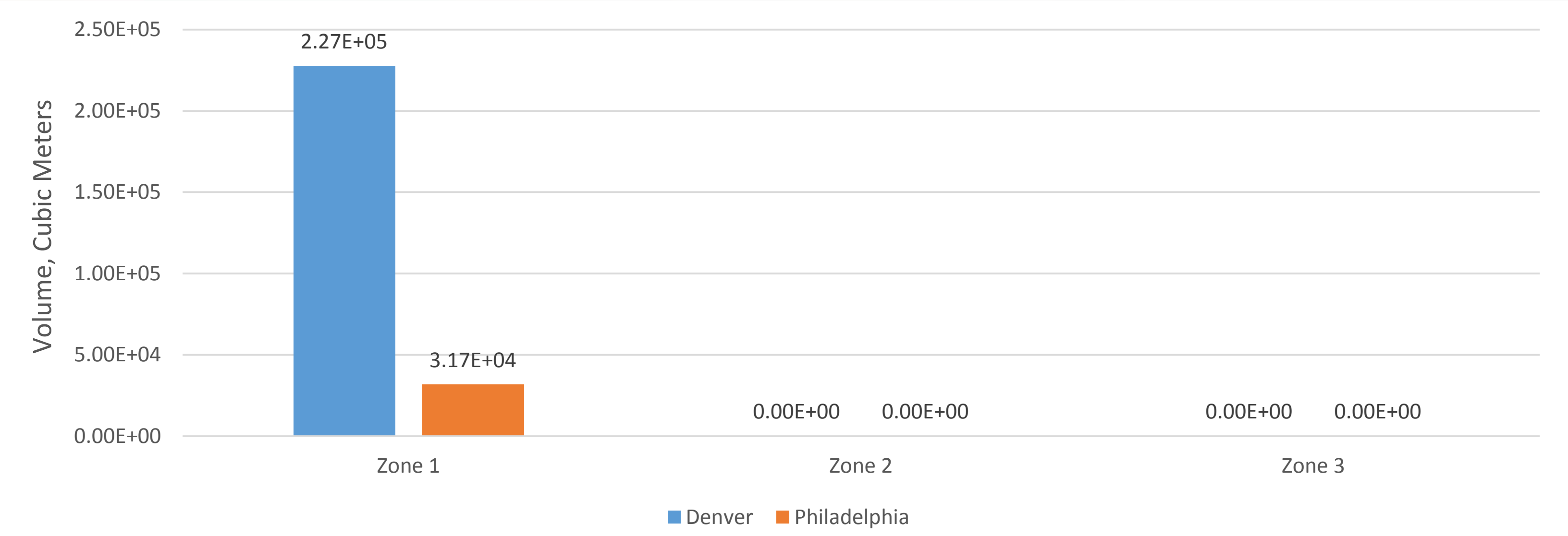
WEST Building Type	Denver			Philadelphia		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 1**	**Zone 2**	**Zone 3**
Agricultural	0.5%	0.2%	0.1%	0%	0%	0.003%
Multi Family	29.4%	7.4%	1.7%	8.2%	1.3%	1.0%
Medical	11.3%	1.6%	0.1%	3.4%	0.2%	0.1%
Entertainment	22.7%	6.7%	1.0%	7.3%	1.0%	0.6%
Parking	0.8%	0.1%	0.01%	0%	0%	0.003%
Educational	0.3%	0%	0.02%	0%	0%	0.01%
Emergency	0.5%	0.1%	0.01%	0.9%	0.1%	0.02%
Industrial	4.9%	1.8%	0.6%	1.5%	0.3%	0.4%
Single Family	15.7%	74.9%	92.9%	67.7%	94.8%	95.8%
Multi Use	13.9%	7.3%	3.5%	11.0%	2.3%	2.1%

Extensive Decontamination Approach Parameters

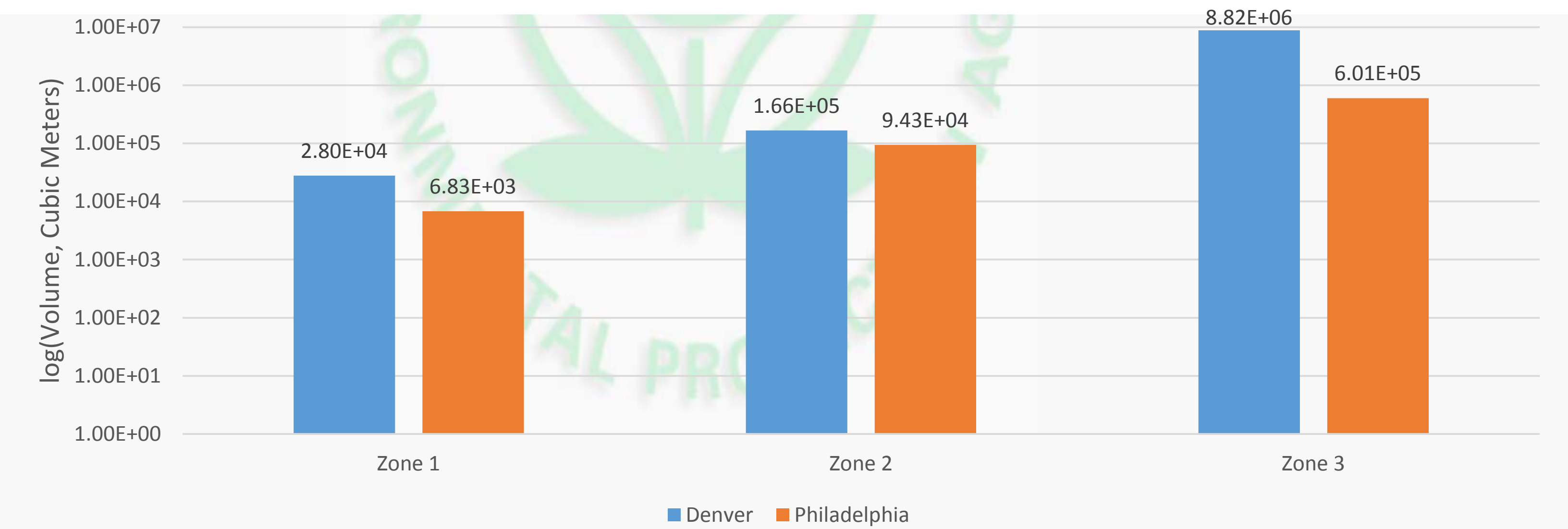
	Zone 1	Zone 2	Zone 3
Buildings	90 % demolition 10 % decontamination	0 % demolition 100 % decontamination	0 % demolition 100 % decontamination
Asphalt	2.5 cm removal – 50%	2.5 cm removal – 50 %	2.5 cm removal – 25 %
	Wash – 50 %	Wash – 50 %	Wash – 75 %
Concrete	2.5 cm removal – 50%	2.5 cm removal – 50 %	2.5 cm removal – 25 %
	Wash – 50 %	Wash – 50 %	Wash – 75 %
Soil	15 cm removal – 100 %	15 cm removal – 100 %	15 cm removal – 100 %
External Walls	Wash – 100 %	Wash – 100 %	Wash – 100 %
Roofs	Wash – 100 %	Wash – 100 %	Wash – 100 %
Interior Walls	Strippable Coating– 100 %	Washing – 50 % Strippable Coating – 50 %	Washing – 100 %
Floors	Material Removal – 100 %	Material Removal – 100 % Mop – 100 %	Mop – 100 %

Example of Demolition and Decon Solid Waste

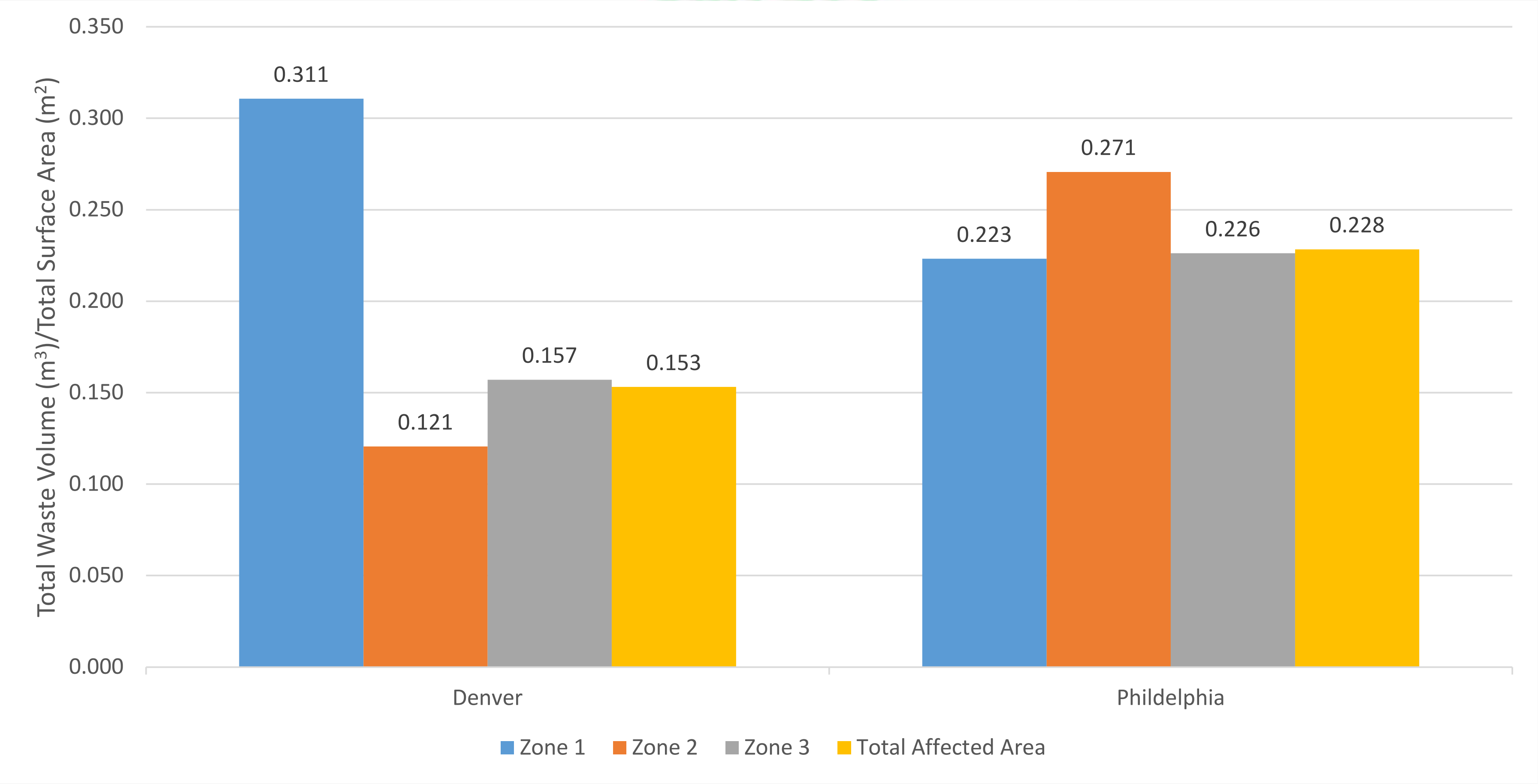
Demo Waste



Decon Waste

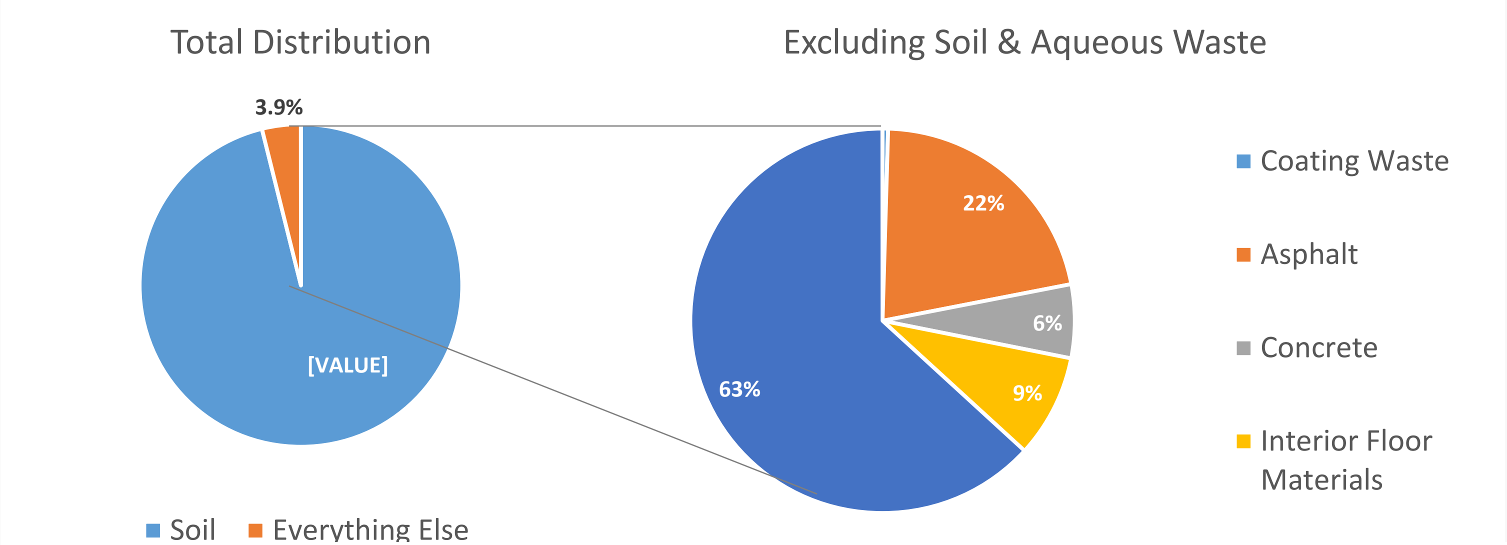


Total Solid Waste Generated per Unit Affected Area (m^3/m^2)

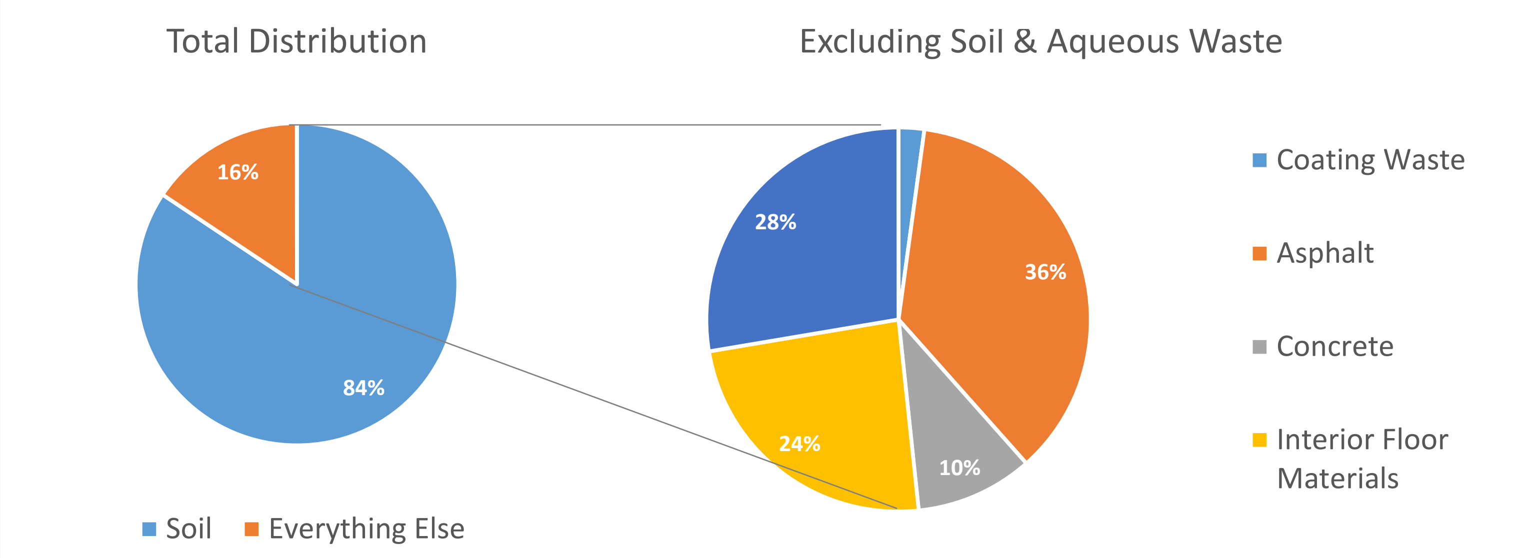


Distribution of Est. Total Solid Waste between Denver and Philadelphia

Denver



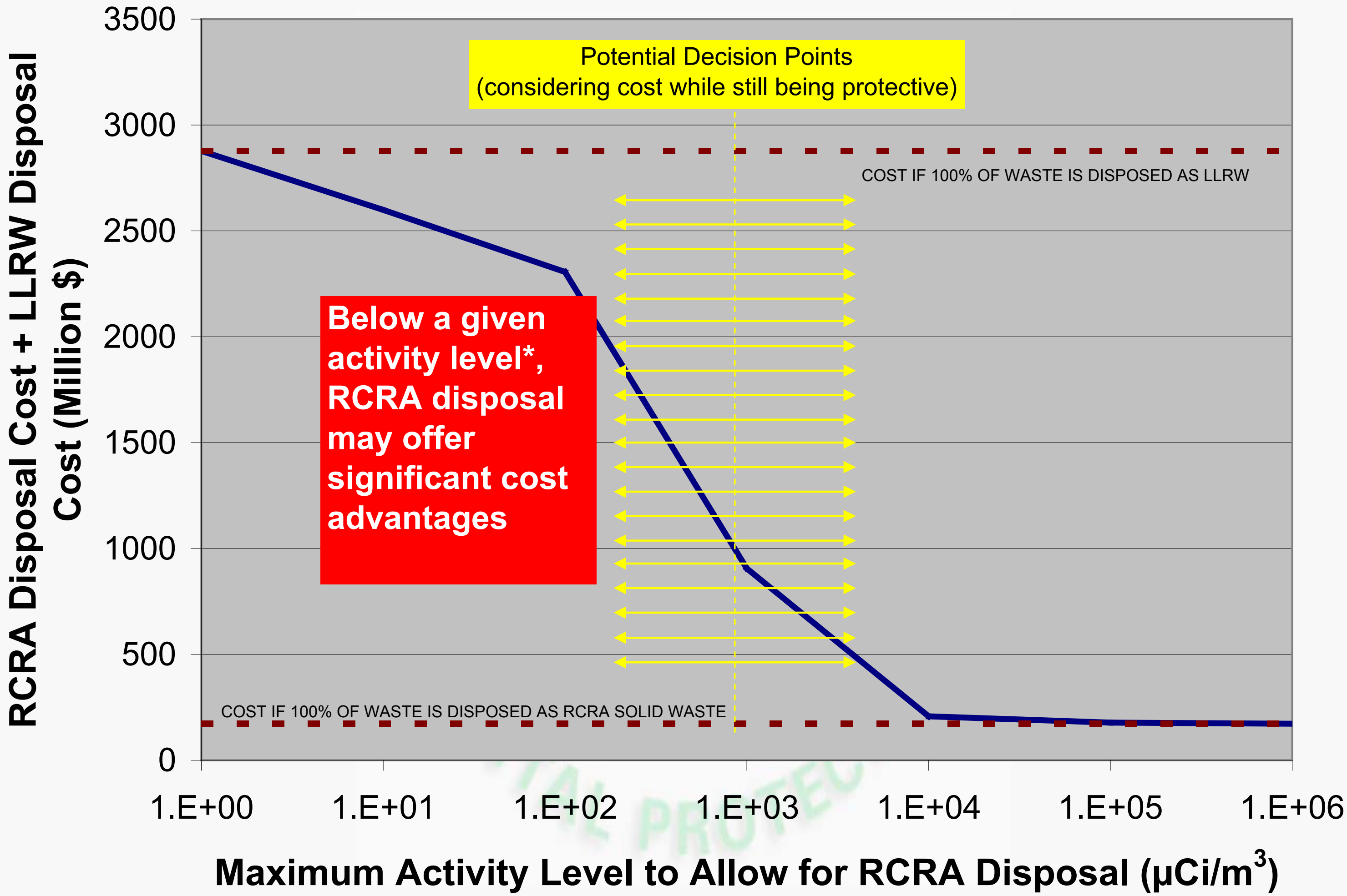
Philadelphia



Decision Making Information Needs for Waste

- Waste quantity and characteristics
  - Sampling and analysis of waste
- Relevant regulatory requirements (local, state, federal levels)
- Key decision makers
- Potential waste treatment/disposal facilities
  - Waste acceptance criteria
- Potential transportation issues/routes
- Impact of remediation/decontamination decisions on waste management and vice-versa

Cost vs. Disposal Option

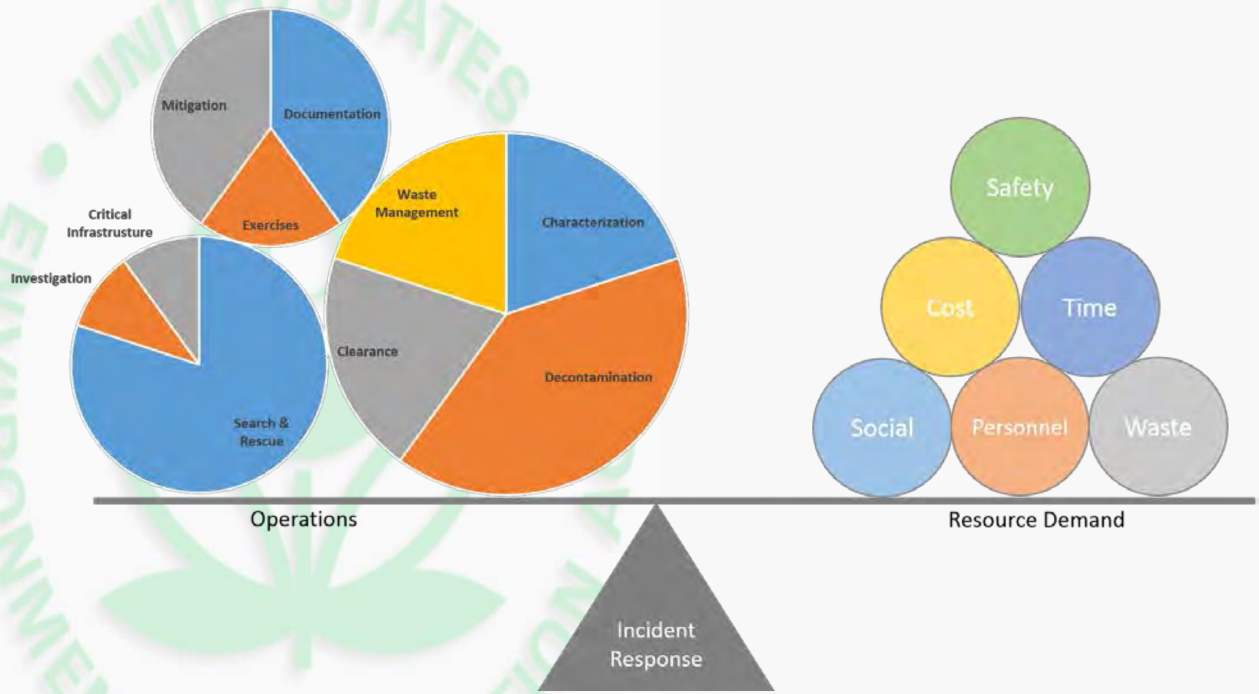


NOTE: Assumed \$300/m³ for RCRA disposal and \$5000/m³ for LLRW disposal

* Where RCRA disposal is protective of public health and safety

Resource Demand

- Cost and time factors directly impact resiliency
- Decon approach and/or waste management plan may be viable, but too costly or untimely
- All of these options must be weighed during planning and response



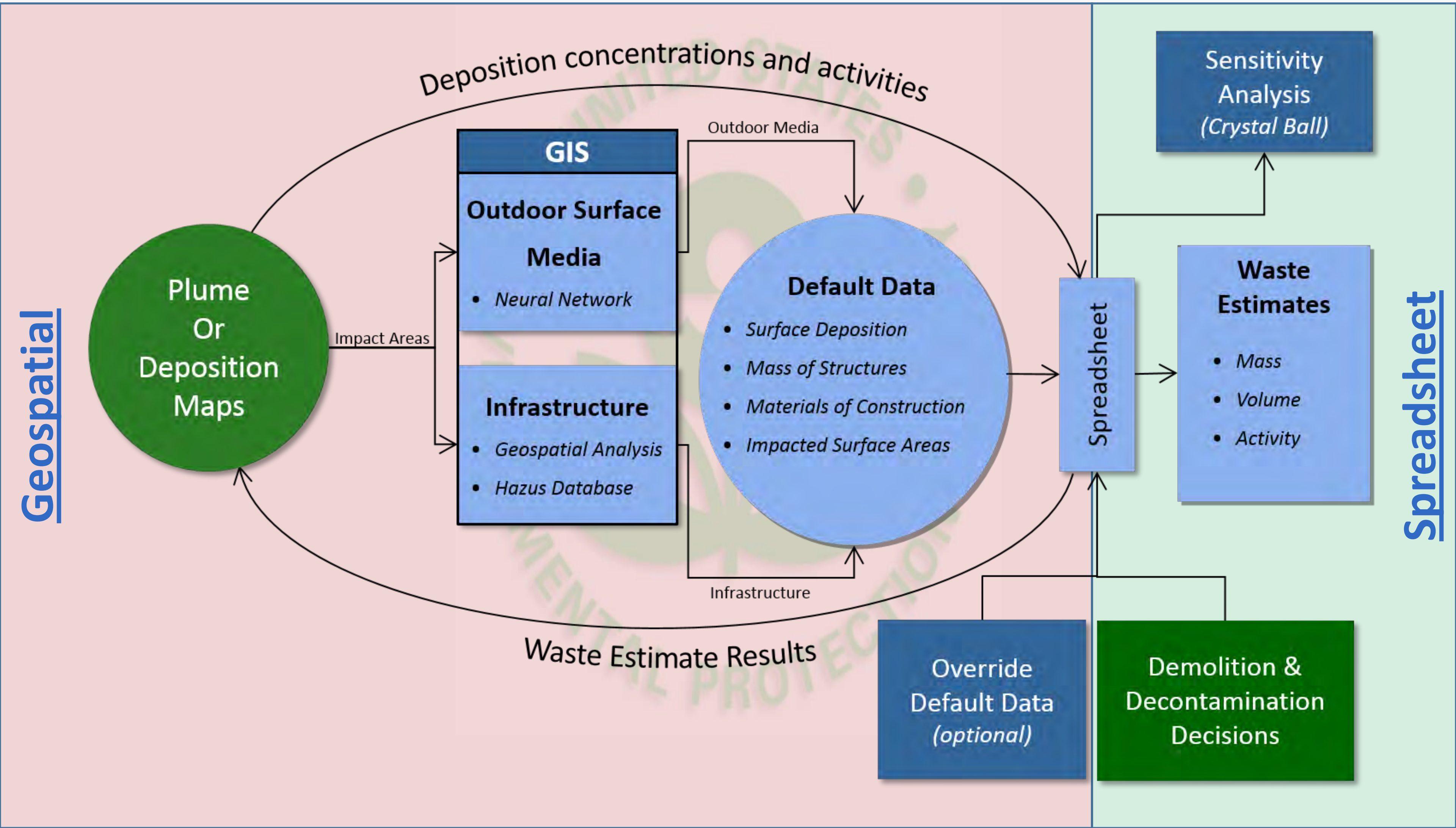
Tools to Help Manage Wide-Area Response

WEST Description

- GIS-based tool that can assist in planning/preparedness activities at all levels of government
  - Radiological Dispersal Device (RDD) waste management issues linked with decontamination and restoration timeline
  - Waste management decisions need to be made early

- Waste Estimation Support Tool (WEST) Facilitates
  - First-order estimate of waste quantity and activity
  - Pre-selection of disposal options
  - ID of potential triage/staging/storage within each zone or surrounding area
  - Assessment of impact of decontamination strategies on waste generation
  - Assessment of impact of waste management strategies on decontamination decisions
  - Identify starting points for policy discussions

WEST Methodology

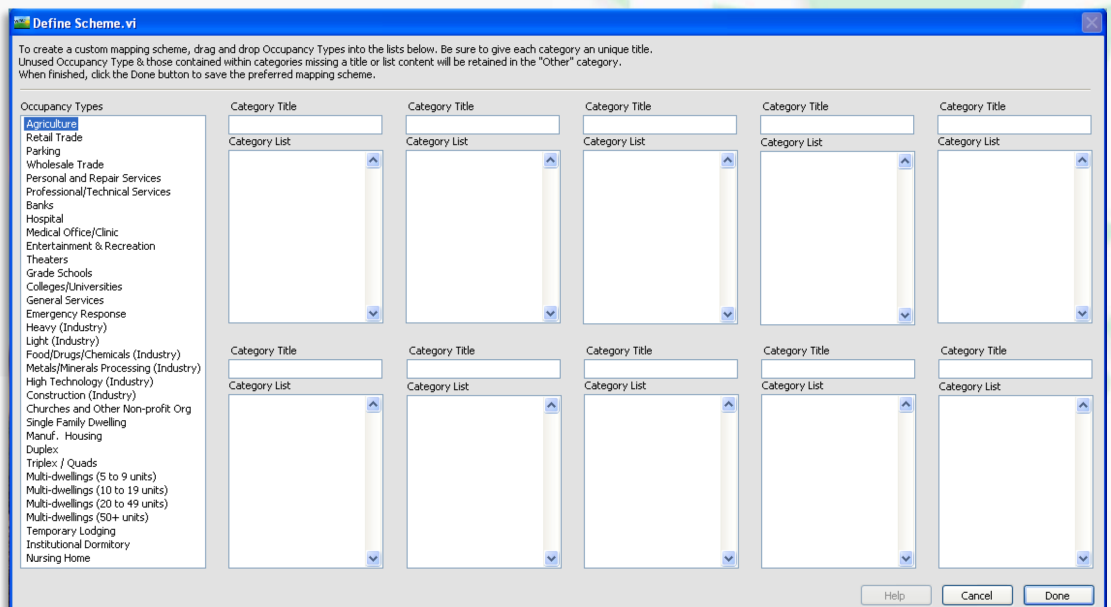


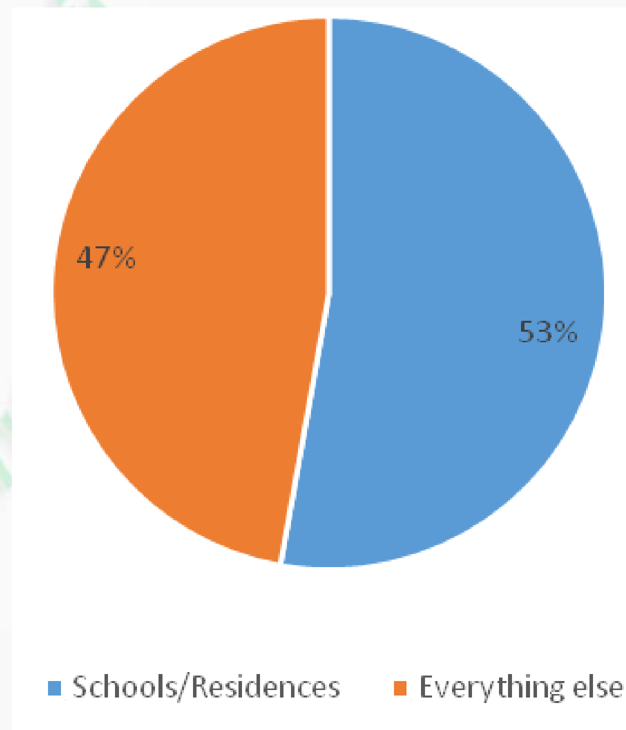
Adjustable Parameters

- Demolition/decontamination decisions
  - Default % for all buildings within each zone
  - Custom based on 28 user specific occupancy types (e.g., single family homes, industrial buildings, etc.)
- % Distribution of decontamination technologies (includes solid/aqueous waste, removed material per unit area)
  - Water Washing
  - Abrasive removal
  - Strippable coatings
  - 2 optional "generic" decontamination technologies
  - "No decontamination" option

Occupancy Type Distribution

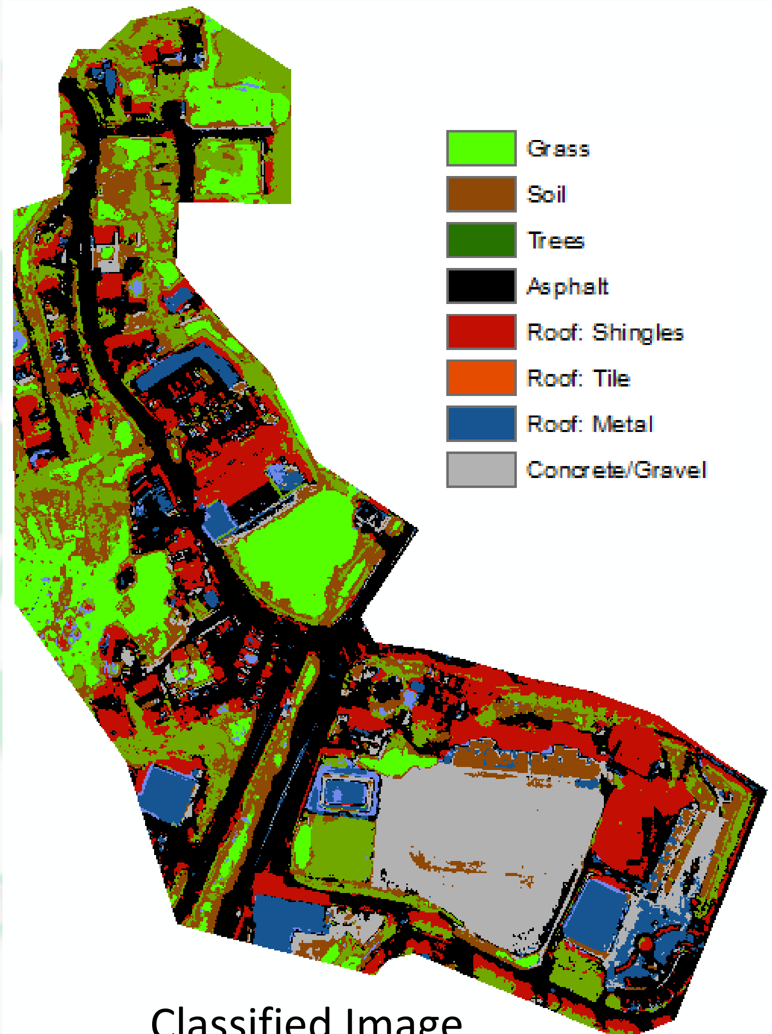
- Target susceptible populations by specific infrastructure types (e.g., schools or residences)
- Potentially an important consideration for determining the most effective decontamination strategy
- Roughly half of infrastructure within the WARRP scenario consisted of schools and residences





Surface Classification

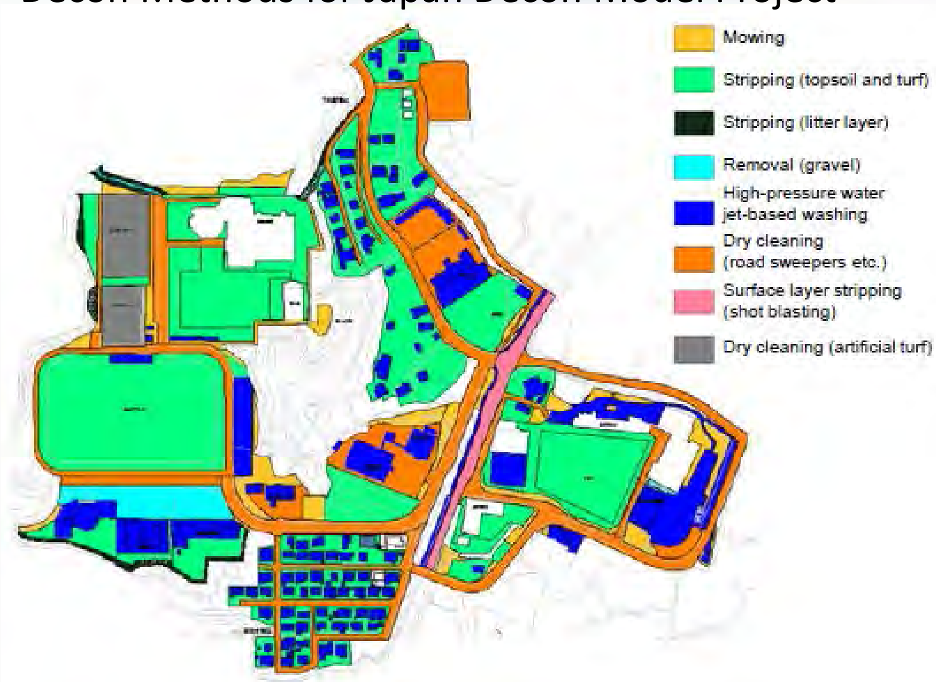
Satellite Image



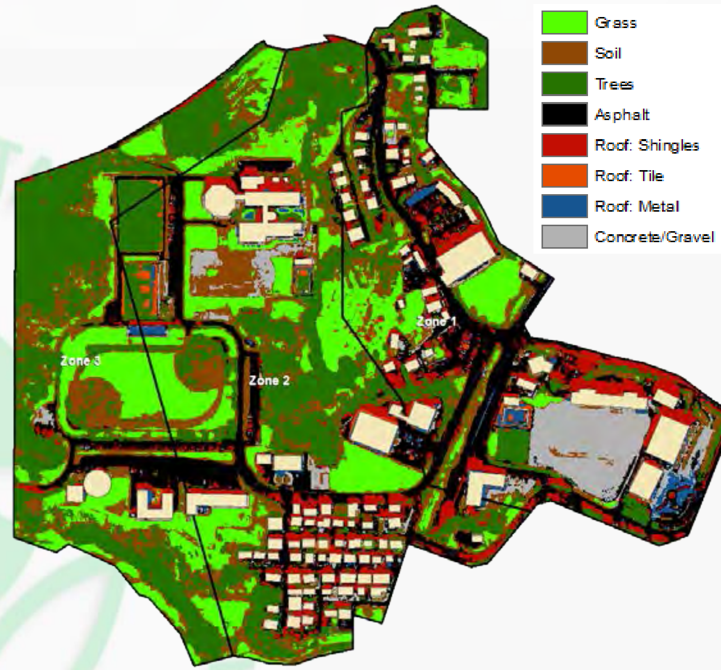
Classified Image

Example WEST Inputs

Decon Methods for Japan Decon Model Project



Enhanced WEST Surface Classification



Decon Methods for Japan Decon Model Project

Decontamination Method	Solid Waste Volume per Unit Area	Solid Waste Mass per Unit Area	Liquid Waste Volume per Unit Area	Liquid Waste Mass per Unit Area	Decon Method Distribution	Relative Surface Type
Mowing	12	1.4	None	None	17%	Grass
Stripping (turf)	50	70	None	None	17%	Soil
Stripping (litter)	50	7	None	None	27%	Trees
Removal (gravel)	30	48	None	None	6%	Concrete/gravel
Pressure Wash	None	None	20	20	15%	Roof
Shot Blasting	3	7.22	None	None	0%	NA
Dry Cleaning	1.5	2.6	None	None	18%	Asphalt
Artificial Turf	20	NA	None	None	0%	NA

Converted to WEST Method

Current classification method	Decon method	Decon Method Distribution
Soil	Stripping (turf)	62%
Concrete	Removal (gravel)	6%
Asphalt	Dry Cleaning	33%
Roof	Pressure Wash	100%

Implications Identified by the Tool

- Highlights benefits of considering waste when selecting decontamination options
- Further define decontamination strategy based on infrastructure, time, & radionuclide activity
- Advantages of on-site treatment to reduce waste
  - Soil is prime candidate for on-site treatment and waste minimization activities
- Aqueous waste found to constitute a large fraction of the overall waste generated
- Identifies starting point for policy discussions
  - Use of conventional or haz. waste landfills for minimally-contaminated materials
  - Use of low-level radioactive waste disposal capacity for materials contaminated at higher levels

I-WASTE

What Problem/Gap Does This Tool Address?

- Management of waste from all-hazards incidents is tightly coupled with other aspects of the response (i.e., system of systems)
- Decisions on waste management issues are made at the local/state/federal level, and include private sector
- Chemical/Biological/Radiological/Nuclear (CBRN) waste is not explicitly addressed in many regulations
- Waste management decisions for CBRN-generated waste are closely tied to decontamination decisions
- Need for easy access to information to make informed decisions

http://www2.ergweb.com/bdrtool/login.asp

I-WASTE Background

- Natural or man-made disasters
- Preparedness planning
- Multi-stakeholder: EPA, inter-agency, state, local, industry, NGOs
- Audience: EPA response community, state/local agencies, waste management facility operators
- Potential applications
  - Training, planning, exercises
  - Starting point for post-incident clean-up

I-WASTE Overview – Current Features

- Web-based tool with restricted access
- Series of inputs defining scenario
- Calculators available to estimate mass & volume of disaster-generated waste and debris (offices, schools, theaters, shopping malls, residences, hotels, hospitals)
- Database of treatment/disposal facilities (location, technical information, permits, geolocation)
- Access to contaminant and decontaminant information
- Guidance for worker safety, packaging and storage, and transportation

http://www2.ergweb.com/bdrtool/login.asp

Key Functions

Incident Waste Decision Support Tool (I-WASTE DST)

Provide feedback

Planners, emergency responders, and other individuals responsible for making disposal decisions can access technical information, regulations, and guidance to work through important disposal issues to assure safe and efficient removal, transport, treatment and/or disposal of debris and waste materials. Guidance and information contained in EPA's Incident Waste Decision Support Tool is accessible from this home page. You can navigate through applicable guidance and information presented in a logical framework, quickly produce an order of magnitude waste estimate, and access the treatment and disposal facility database and/or other guidance and information.

Access the Quick Start Guide or the Overview Tutorial for a brief overview of key functionality. Access the Waste Materials Estimator Tutorial for detailed demonstration of key features of the WME. More detailed instructions for using the tool are contained in the Help System. If you are a first-time user, or would like information on the Background, Status and Future Plans of the tool, and a discussion of the Design Philosophy and Technical Approach we have applied to the development of the tool, you may want to read Before You Begin.

Incident Planning & Response

Create a record of incident planning exercises or incident response decisions. Navigate through applicable guidance and information presented at each step in the decision process. Records may be saved and retrieved for future reference.

Waste Materials Estimator

Use the **Waste Materials Estimator** to produce an order of magnitude estimate for the weight and volume of materials that may require disposal. Base estimates on default values contained in the tool, or refine estimates based on more specific user-defined values.

Treatment & Disposal Facilities

Locate treatment and disposal facilities. Choose one or more filter criteria to generate a list of treatment and disposal facilities. Note: The facilities presented in the tool are not endorsed by EPA, nor have any facility owners agreed to accept any material. A facility's ability to accept incident waste is case specific and determined by the facility and its regulators. Facility contact information is provided to facilitate the initiation of treatment and disposal discussions.

Guidance & Information

Access guidance and information compiled to assist with disposal decisions. View guidance, reports, and websites organized by events or topics, view contact information, and access other useful tools.

It is important to understand that the information provided here does not override existing regulatory or legal requirements that apply to the disposal of waste materials. This information should be used as a starting point for understanding some of the options available for disposal of these materials.

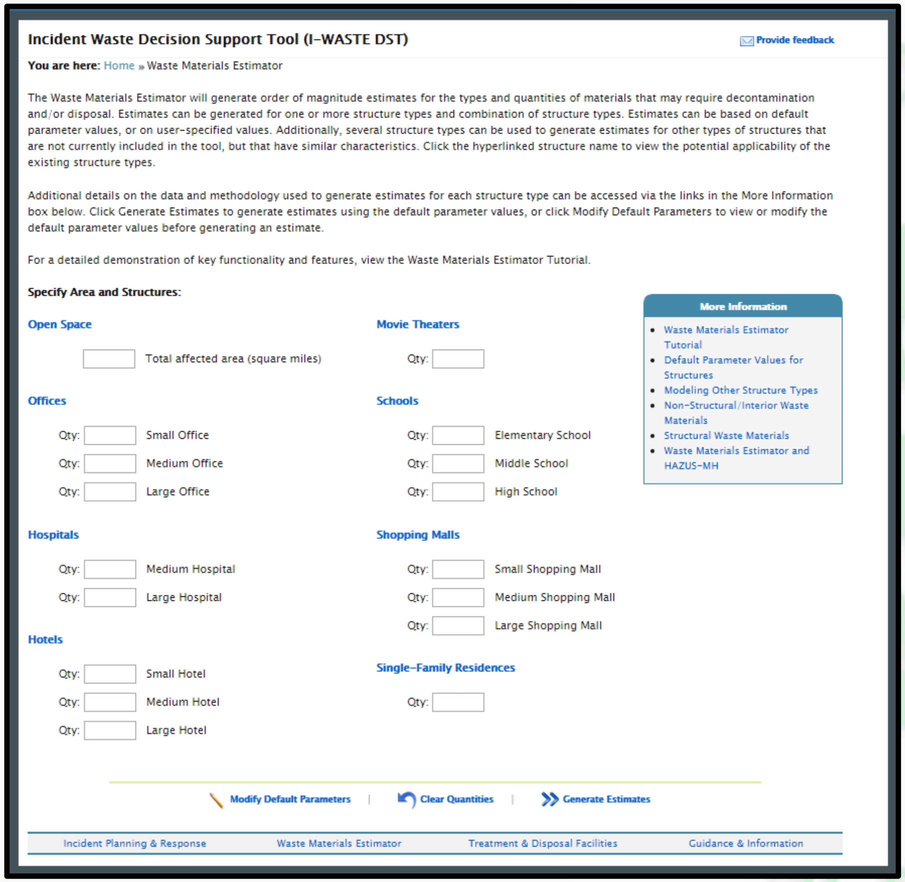
***Note that you will be required to re-login after 30 minutes of inactivity.**

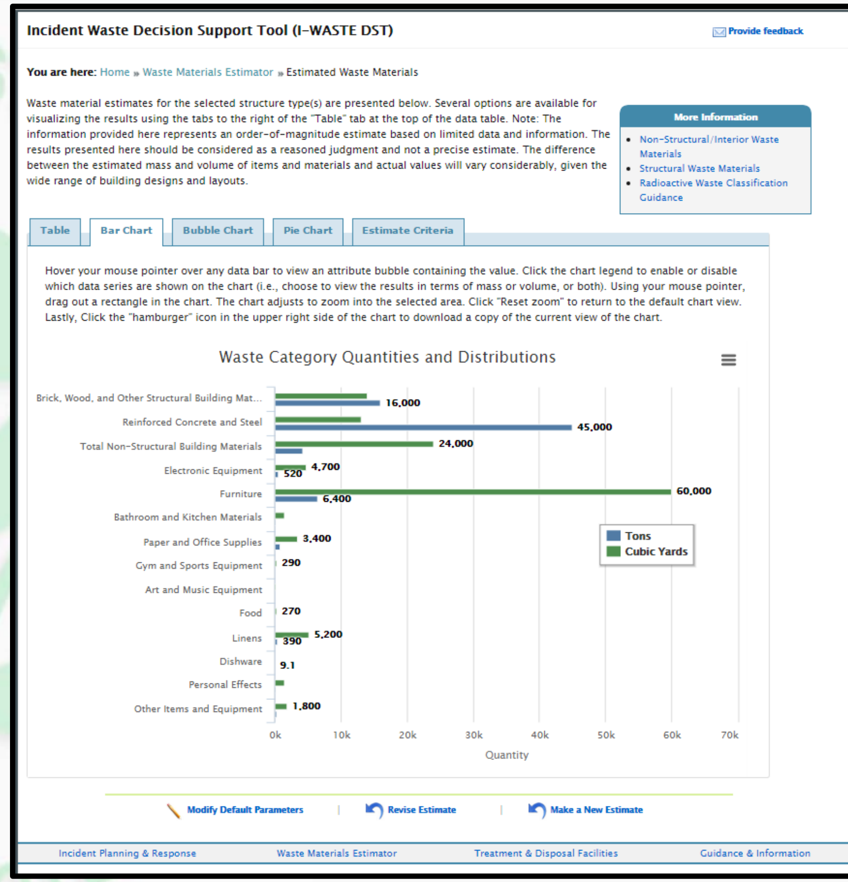
I-WASTE Facility Databases

- Landfills
  - MSW
  - Construction & Demolition Debris
  - Hazardous Waste
- Combustion Facilities
  - Municipal Waste Combustors (Waste-to-Energy)
  - Hazardous Waste
  - Medical/biohazardous Waste
  - Industrial combustion facilities (e.g., boilers, smelters, etc)
- Decontamination Wastewater Disposal Facilities
  - Publicly-Owned Treatment Works (POTWs)
  - Federally-Owned Treatment Works (FOTWs)
  - Liquid Hazardous Waste Combustion Facilities
- Other Disposal Facilities
  - Centralized Waste Treatment (CWT) Facilities
  - Commercial Medical Waste Autoclaves
  - Commercial and Federal Radioactive Waste Disposal Facilities

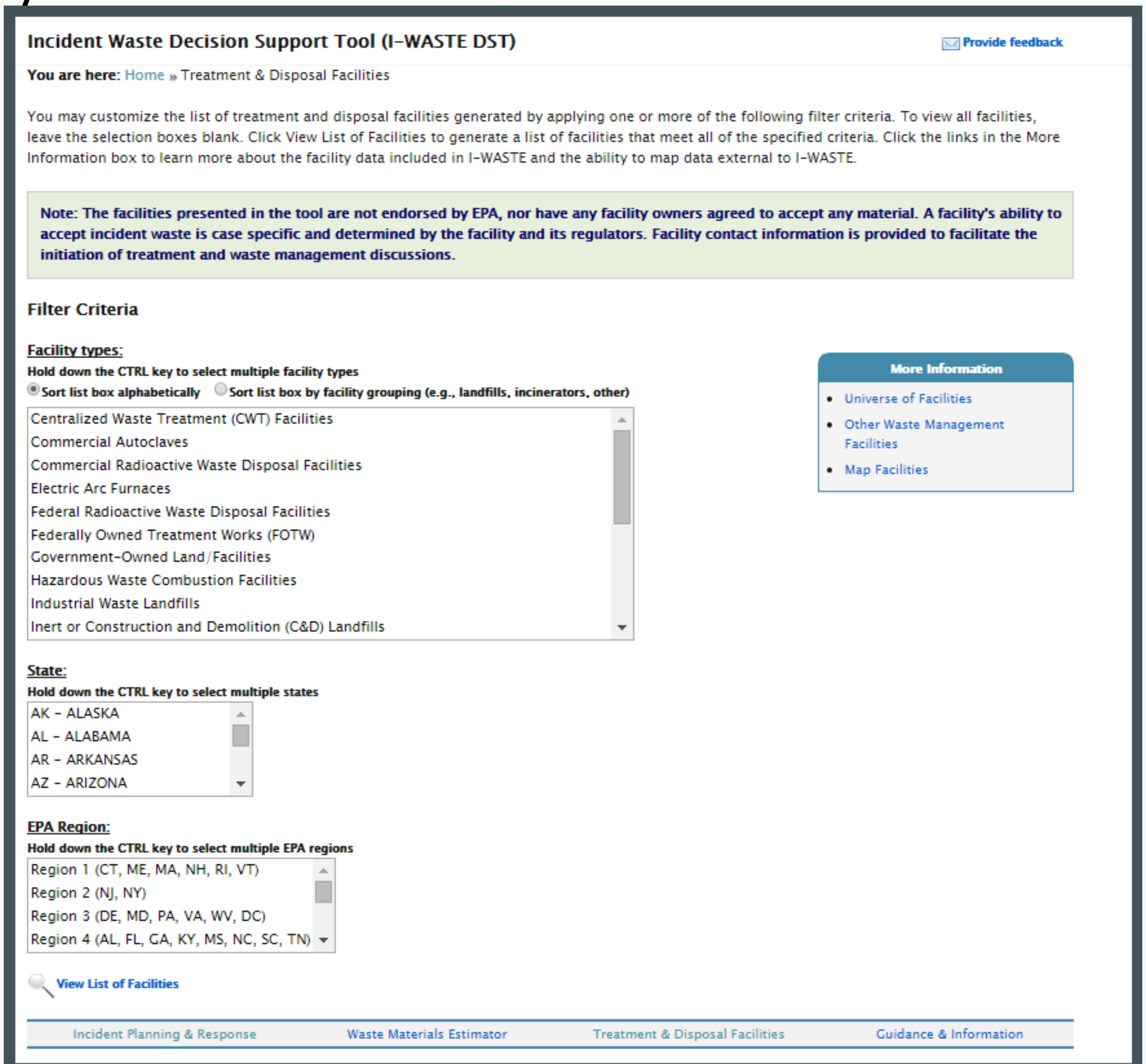
http://www2.ergweb.com/bdrtool/login.asp

Waste Quantity Estimator





Facility Databases



Incident Waste Decision Support Tool (I-WASTE DST)

Provide feedback

You are here: Home » Treatment & Disposal Facilities

You may customize the list of treatment and disposal facilities generated by applying one or more of the following filter criteria. To view all facilities, leave the selection boxes blank. Click View List of Facilities to generate a list of facilities that meet all of the specified criteria. Click the links in the More Information box to learn more about the facility data included in I-WASTE and the ability to map data external to I-WASTE.

Note: The facilities presented in the tool are not endorsed by EPA, nor have any facility owners agreed to accept any material. A facility's ability to accept incident waste is case specific and determined by the facility and its regulators. Facility contact information is provided to facilitate the initiation of treatment and waste management discussions.

Filter Criteria

Facility types:

Hold down the CTRL key to select multiple facility types

Sort list box alphabetically **Sort list box by facility grouping (e.g., landfills, incinerators, other)**

Centralized Waste Treatment (CWT) Facilities
Commercial Autoclaves
Commercial Radioactive Waste Disposal Facilities
Electric Arc Furnaces
Federal Radioactive Waste Disposal Facilities
Federally Owned Treatment Works (FOTW)
Government-Owned Land/Facilities
Hazardous Waste Combustion Facilities
Industrial Waste Landfills
Inert or Construction and Demolition (C&D) Landfills

More Information

- Universe of Facilities
- Other Waste Management Facilities
- Map Facilities

State:

Hold down the CTRL key to select multiple states

AK - ALASKA
AL - ALABAMA
AR - ARKANSAS
AZ - ARIZONA

EPA Region:

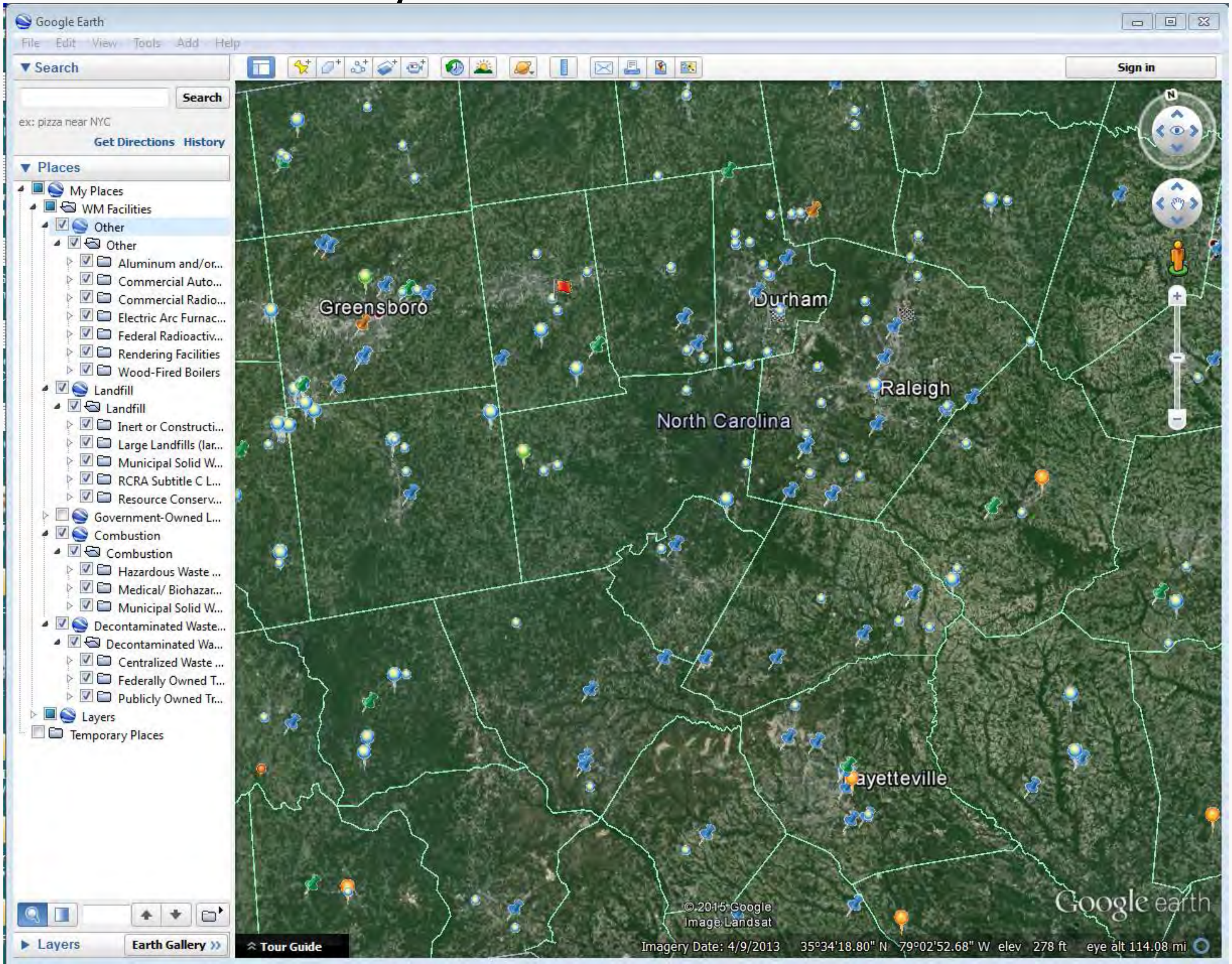
Hold down the CTRL key to select multiple EPA regions

Region 1 (CT, ME, MA, NH, RI, VT)
Region 2 (NJ, NY)
Region 3 (DE, MD, PA, VA, WV, DC)
Region 4 (AL, FL, GA, KY, MS, NC, SC, TN)

View List of Facilities

Incident Planning & Response | Waste Materials Estimator | Treatment & Disposal Facilities | Guidance & Information

Geocoded Facility Databases



Relevant Guidance

Incident Waste Decision Support Tool (I-WASTE DST)

Provide feedback

You are here: Home » Guidance & Information

Guidance and information contained in the Incident Waste Decision Support Tool is accessible from this page. You can access features and information that is tailored to specific categories of events. Other guidance and information that is broadly applicable to more than one event is accessible via the quick links on the right.

Expand all descriptions

Chemical/Biological

- Basic Information
- Chem/Bio & Decon Agent Information
- Create Building Waste Inventory
- View Saved Building Waste Inventories
- View Building Waste Characteristics

Natural Disaster

- Basic Information
- Waste & Debris Fact Sheets
- Debris Management Equipment
- Planning Documents

Agricultural Incidents & Foreign Animal Disease

- Basic Information
- Disposal Guidance
- Case Studies
- Pathogen Information
- Training Modules

Radiological/Nuclear

- Basic Information
- Incident Response & Cleanup Information
- Radiological Dispersal Device (RDD) Information
- Low-Level Radioactive Waste Compacts
- Radionuclide Information
- Radioactive Materials & Waste Regulations

Critical Infrastructure

- Basic Information
- Water Systems (Chem/Bio Contamination)
  - Drinking Water Treatment Plant Decon Disposal
  - Water Supply Distribution System Decon Disposal
  - Drinking Water System End User Items Disposal
  - Wastewater Treatment Plant Decon Disposal

Quick Links

- Treatment & Disposal Facilities
- Disposal Guidance
- Size Reduction Guidance
- Packaging/Container Guidance
- Hazardous Waste Transportation Regulations
- Waste Transportation Guidance

Browse Documents and Reports

Select an event

Then select a topic

Go

Browse Guidance

Select an event

Then select a topic

Go

Other Resources

- Key Terminology
- Response Management Jurisdictional Boundaries
- Regional, State, and Local Contacts
- Other Planning & Response Tools
- Laboratory Information

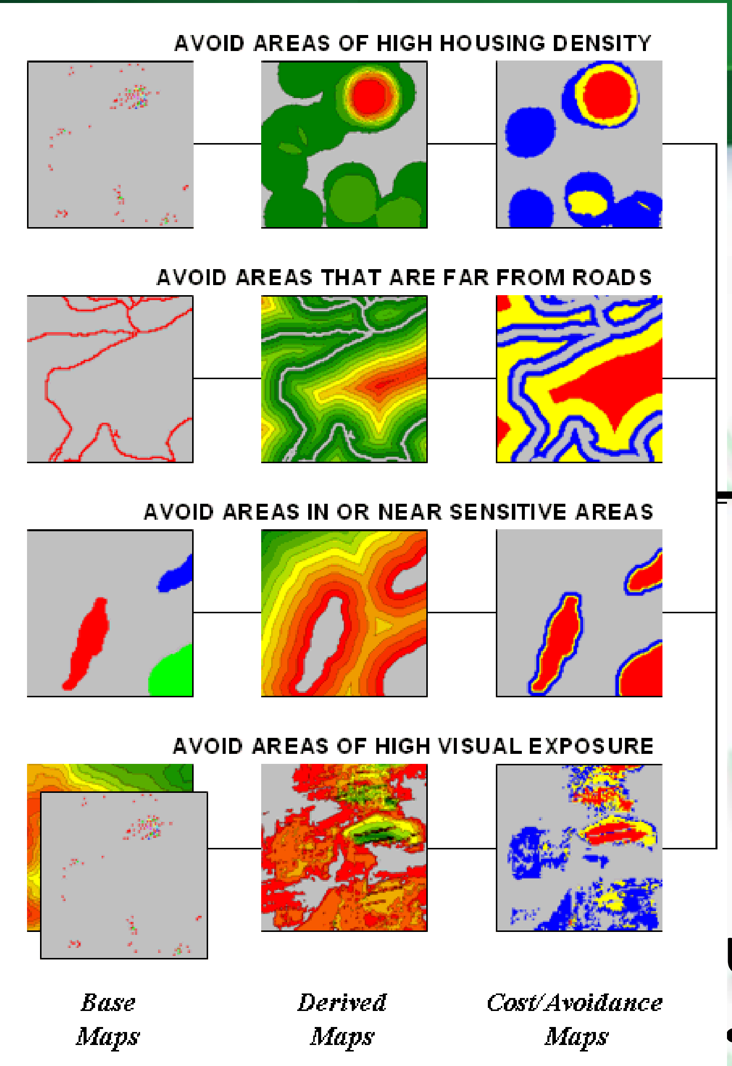
Access

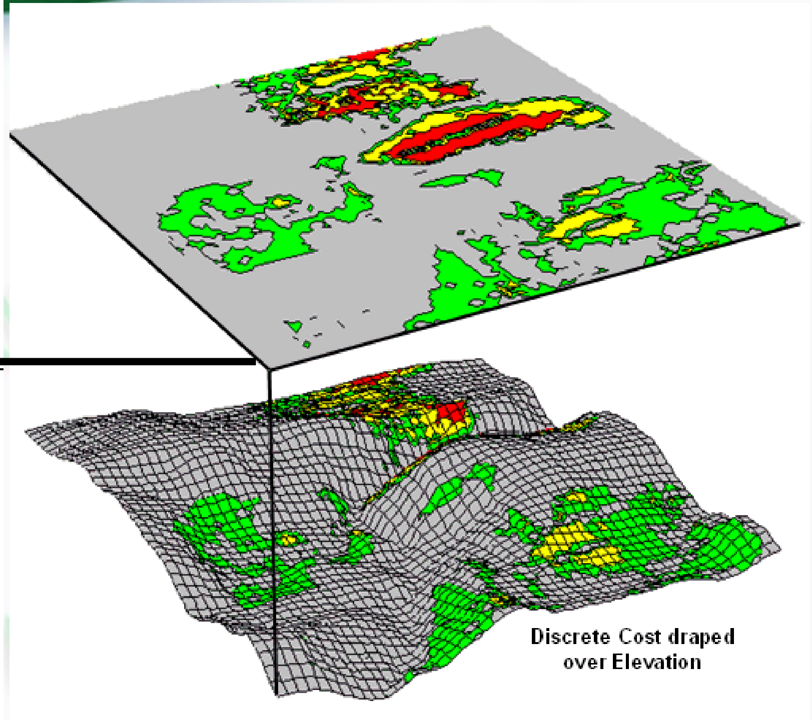
http://www2.ergweb.com/bdrtool/login.asp

- First-time users will need to request a user ID and password – the link above has directions for making the on-line request
- When your request is approved, your login ID and initial password will be emailed to you.

Logistical Planning and Site Identification Tool for Transporting Large Volumes of Waste

Logistics/Site Analysis





Use GIS to:

- Identify most optimal routes
- Recommendations on where to locate, expand, or consolidate waste staging and temporary storage locations

Benefits of using such a tool…

Automatically establish routes to avoid sensitive areas

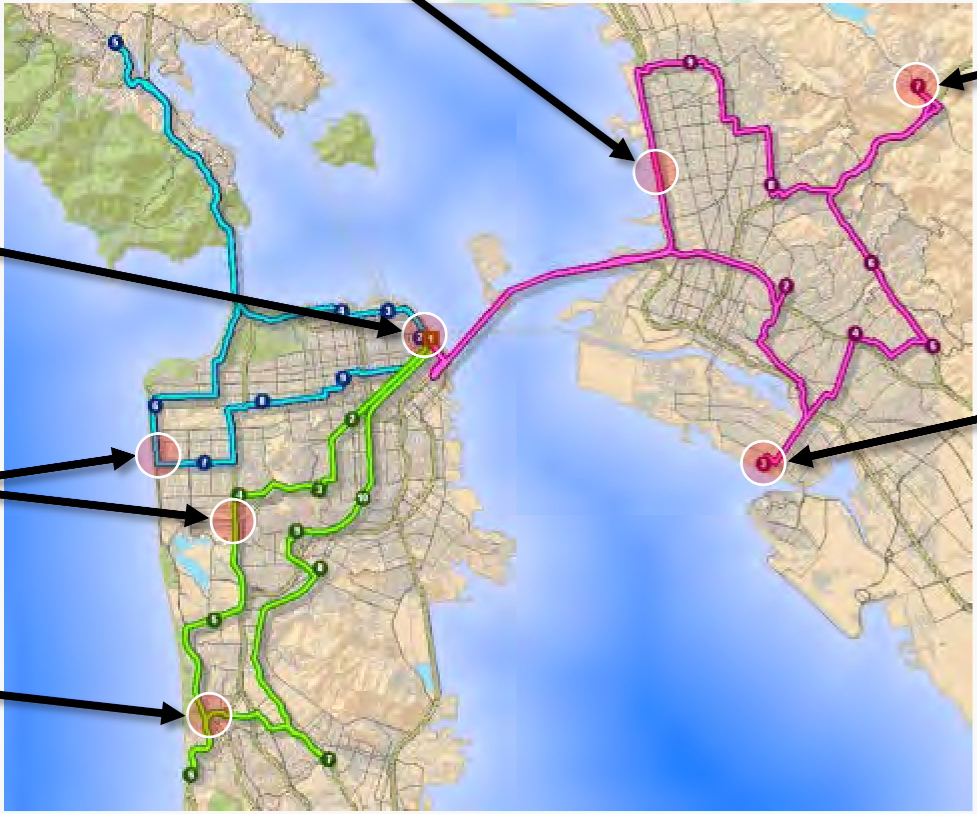
Identify potential storage sites based on certain criteria

Define staging locations for waste pickup

Split routes according to contract or service

Estimate the most optimal route with consideration to time, cost, and personnel

Define triage/sorting locations for specific waste type/characteristics



Thank You

- Contact Info:

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Waste Management and Decontamination of UK Po-210 Incident in 2006

John Cardarelli II, PhD, CHP, CIH, PE
CBRN Consequence Management Advisory Team

for
NCRP Workshop
51^{st} Midyear Meeting
Denver, Colorado

February 5, 2018

Disclaimer

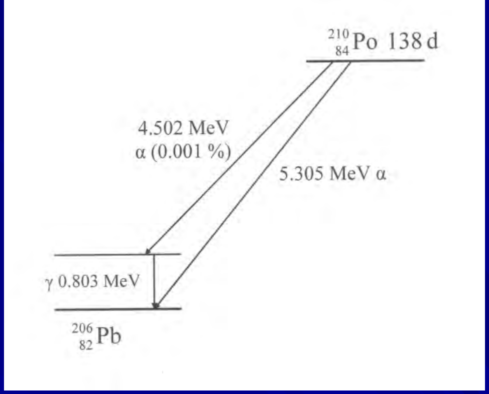
The opinion expressed in this technical presentation are those of the author and do not necessarily reflect the views of the US EPA.

Outline

- What is Polonium-210?
- Polonium Incident & recovery timeline
- Responsible Authorities
- Instruments & Equipment
- Decon Operations & Risk Assessment Factors
- Disposal
- General Observations (Po-210)
- General Recovery Issues
- Public Health Impact

What is Polonium-210 (Po-210)?

- Both man-made and naturally occurring
- Alpha emitter 99.999% (5.3 MeV)
- Gamma emitter 0.001% (803 keV)
- Easily airborne
- Specific Activity = 166 TBq/g (4492 Ci/g)
- 1 µg ingestion delivers about 20 Gy (2,000 rad); 10% absorbed by blood.
- Half-life = 138 days
- Typical Use: Static eliminators
- Eliminated via urine, feces, perspiration, & hair



Po-210 Timeline

(Terrorist attack using a Radiological Dispersal Device)

- Nov 23, 2006: Death of A. Litvinenko
  - ✓ Poisoned October 2006 (40 MBq, based on hair analyses; 4 MBq to blood; 3 Gy)
  - ✓ Poisoned again on November 1, 2006
  - ✓ 4 GBq resulting in a dose ranging between 20 Gy to 100 Gy (Harrison et al., 2017)
- Nov 24, 2006:
  - ✓ Confirmation of Po-210
  - ✓ UK GDS contacted
  - ✓ First five contaminated venues identified
- Nov 26, 2006:
  - ✓ Recover Working Group established

Analysis of samples taken from the patient identified Po-210 through its characteristic (803 keV) but weak (1.2E-5) **gamma emission**. (Nathwani et al., 2016)

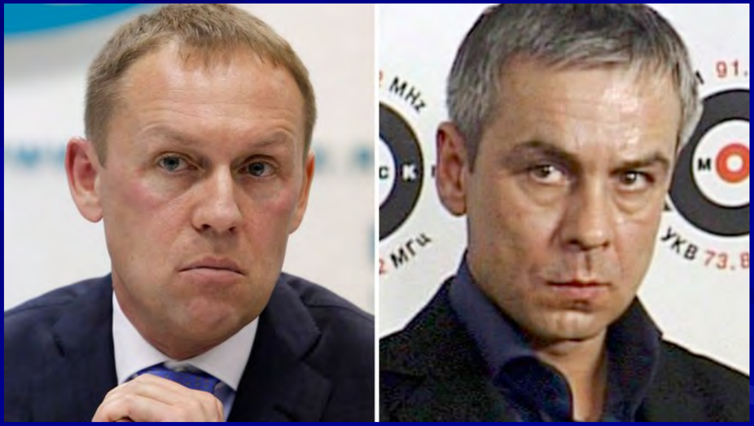
Po-210 Timeline con't

(Terrorist attack using a Radiological Dispersal Device)

- Nov 27, 2006:
  - ✓ GDS facilitated decon arrangements following the post mortem
- Jun 10, 2007:
  - ✓ 40+ venues affected/contaminated
  - ✓ 10 to 11 venues monitored, deconned, and returned for public use.

Present: Ongoing criminal investigation to bring Andrey Lugovoy and Dmitri Kovtun to trial

http://news.met.police.uk/news/statement-following-inquiry-report-into-the-death-of-alexander-litvinenko-147118



http://www.itv.com/news/update/2015-01-28/ex-kgb-agents-remain-main-suspects-over-spys-death/ Photo credit: Reuters

Responsible Authority & Clean Up Guidance

- Westminster City Council

- Health Protection Agency recommended clean-up level for fixed contamination of **10 Bq/cm^2** (i.e.,no doses exceeding **1.0 mSv / year**).

"Levels of contamination below this value do not need remediation on health grounds, although it is good practice to remove contamination where this is easily achievable."

http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947411630

Instruments/equipment

- Personal Contamination Monitor (PCM5) or “Electra” rate meter with AP2, DP2R, or DP6 alpha probes.
- Static Air Samplers (L100 or L60)
- Portable counter / scalars
  - 100 second count times
  - accounted for radon
- HEPA vacuums
- Custom made brush to decon laundry chute.

Thermo Electron Corp, Electra ratementer with alpha proble

Characterization

"Monitoring would normally only be carried out in areas and for surfaces where there is credible reason to believe there may be contamination. Where significant contamination is found in such areas, it may be prudent, for reassurance purposes, to sample other locations within the premises that are not expected to be contaminated."

http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947411630

Decon Operations

- Avoided abrasive decon technique to prevent reaerosolization.
- Fixative agents preferred for items of low monetary or personal value, then disposed.
- Used full PPE and respiratory protective equipment
  - ✓ Coveralls, overshoes, gloves, FF respirator or air hood
- Air sampling

Decon Operations

- PVC sheeting to minimize reaerosolization
- Non-porous Surfaces
  - ✓ Tacky wipes
  - ✓ ALARA DECON solution
  - ✓ Soft and abrasive cloths
  - ✓ Scrapping paint

- Porous Surfaces
  - ✓ HEPA vacuuming
  - ✓ Physical removal (i.e., carpet)
  - ✓ Cutting out contaminated areas

Risk Assessment Factors

- Degree to which contamination level exceeded 10 Bq/cm^2
- Ease of removal
- Extent of contamination (widespread vs. local)
- Whether the item could be covered or sealed in place.
- Dose implication for all contractors.
- Implications for the environment and waste.
- The wishes of key stakeholders, in particular the owners.

Options for items above 10 Bq/cm^2

- Disposal
- Temporary Storage (half-life 138 days)
- Covering the surface to prevent re-mobilization
  - ✓ Bag the items
  - ✓ Paint (e.g., varnish)
- Additional decontamination
  - ✓ Wiping
  - ✓ Washing
- Additional long-term monitoring to ensure integrity of remedial action.

Disposal

- Subject to UK regulations
  - ✓ Class 1 Waste <0.37 Bq/g (<10 pCi/g) (No packaging needed)
  - ✓ US Regs: radioactive waste = >74 Bq/g (>2,000 pCi/g)
- No exemptions provided
- 4.8 tons in total waste / 400 packages (one venue)
- Six 200L drums (another venue)
- 40+ venues surveyed / 10 venues were deconned

General Observations

- Clean-up level (10 Bq/cm^2) was practical to implement.
- Contamination found to be “patchy” rather than widespread.
- Clearance done with field instruments
- Minimal laboratory analyses (air samples)
  - ✓ No wet chemistry analyses
  - ✓ No alpha spectrometry analyses
- Multiple decon treatments needed in some areas, particularly on carpet.
- Separate teams for characterization/decon and clearance (independent surveys).
- Characterization criteria may present challenges in the US.

General Recovery Issues

As identified by Dr. Dudley Hewlett, Head of Science, UK GDS (2008)

- Who will pay for decontamination?
- Lack of adequate insurance coverage
- Waste management, ownership, consignment and final disposal
- Multi-agency information sharing
- Media handling
- Tolerability of residual hazards
- Management of expectations around the decontamination process, cost, and timeframe
- Communications
- Logistics
- Staffing resource

Public Health Impact

- Large epidemiologic and bio-assay component (Maguire et al. 2006)
  - ✓ 1,029 residents identified (11 venues)
  - ✓ 974 interviewed; 787 offered bioassay
  - ✓ 139 (18%) showed evidence of internal contamination
  - ✓ 53 (57%) had assessed doses between 1 mSv to 10 mSv

Estimated Risk of Death from acute exposure (Scott, B.R. 2007)

Systemic burden (MBq/kg-body-mass)*	Central estimate of the risk (%)	Expected survival time (days)
> 1	100	1 to 28
0.4 t0 1	100	50 - 250
0.03 to 0.3	1 to 100	300 - 500
0 to 0.02	<1	Normal lifespan for most

*1 MBq ≈ 0.6 μg

References

- Harrison, et al., Polonium-210 as a poison. *J. Radiol Prot.* 27:17-40. 2007.
- Harrison, et al., The Polonium-210 poisoning of Mr. Alexander Litvinenko, *J. Radiol Prot*. 37:266-278. 2017.
- Maguire, et al., Assessing public health risk in the London polonium-210 incident*. Public Health*. 124:313-318. 2006.
- Nathwani, et al., Polonium-210 poisoning: a first-hand account. *Lancet*. 388:1075-1080. 2016.
- Scott, B.R. Health risk evaluations for ingestion exposure of humans to polonium-210. *Dose Response.* 5:94-122. 2007.

Managing Waste from a Radiological Incident

Considerations for Decision-Making

February 6, 2018

Presented by:
Dan Schultheisz
U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
Radiation Protection Division

Presented to:
Health Physics Society Mid-Year Meeting
Session TAM-A.5
Denver, CO

Overview of Presentation

Waste Management Challenges

U.S. Policy Framework for Incidents

Waste Management Phases

Case Studies

Planning and Preparedness

- Decision Support Tools
- Technical Documents
- Guidance
- Exercises/Workshops
- Other Planning Activities

Waste Management Challenges

Wide-scale radiological incidents present significant and unique circumstances for waste management

- Significant waste volumes
- Time and public pressures for action (days vs. years)
- Logistical and resource limitations (e.g., sampling)
- Coordination of multiple agencies/activities

Planning ahead will help identify

- Options that are available (or not available)
- Potential resource constraints/bottlenecks (e.g., water)
- Who needs to be involved and when (e.g., public)
- How decisions will be made

U.S. Policy Framework for Incidents

The National Response Framework (NRF) describes the responsibilities for chemical, biological, radiological, and nuclear (CBRN) incidents

- Nuclear/Radiological Incident Annex assigns lead roles:
  - NRC for release from licensed materials or facilities
  - DOE/DOD for DOE/DOD facilities or nuclear weapons
  - DHS for deliberate attacks involving nuclear facilities/materials
  - EPA for incidents of foreign origin

EPA is the coordinating agency for oil and hazardous materials response (i.e., long-term cleanup) under NRF Emergency Support Function #10

- Events as disparate as 9/11, anthrax, Katrina, BP spill

Putting It Into Perspective

What can be learned from non-radiological events?

- World Trade Center (2001)
  - ~1.3 million metric tons (~76 million cubic feet)
  - Small urban footprint – local disposal possible
  - Barging to staging area at closed landfill on Staten Island
- Hurricane Katrina (2005)
  - 2-3 billion cubic feet of debris over ~230,000 km^2
  - 350,000 automobiles and 60,000 vessels
  - Opposition to local disposal from overburdened communities

Additional considerations for planners

- Decontaminating very tall buildings
- Wash water – capture, recycle, treat, release?
- Size of source term and contaminated area

What's Involved in Managing Debris/Waste?

Multiple steps need to be integrated:

- Initial debris management
- Waste staging (and storage)
- Waste characterization
- Waste segregation
- Waste treatment and packaging
- Waste disposal

Waste volumes will drive decision-making

- Could overwhelm existing capacity (see Japan)
- Need to be considered in early planning

Initial Debris Management

Debris management is an immediate step taken to facilitate emergency response

- Clearing transportation routes
- Allowing access for life-saving measures
- Allowing access to restore critical infrastructure

Part of overall waste management strategy

- Limit number of movements (facilitate staging)
- Avoid cross-contamination (some characterization)
- RDD debris most likely in limited area (blast zone)
- Fukushima debris primarily from tsunami, not NPP

Staging (and Storage) of Waste

Staging areas allow for more methodical management of waste, perhaps for extended times

- Could be inside or outside affected area
- Ideally large areas strategically located
- Paved or lined sites that can be controlled
- Access to transportation routes (road, water, rail)
- Examples include
  - Rail yards
  - Industrial parks
  - Military installations
  - Warehouses/hangars
- Citizens Advisory Panel effective at Liberty RadEx

Characterization of Waste

Disposition of waste depends on what it is, so need to characterize both for waste form and hazard

- Waste form:
  - Asphalt/concrete
  - Building materials
  - Organic material (soil, shrubs, trees)
  - Vehicles can be problematic
- Hazard:
  - Radiological/hazardous materials
  - More flexibility for slightly contaminated waste

Characterization in both field and staging areas

- Field surveys using meters, wipe samples (data quality)
- More extensive characterization with lab sampling

Segregation of Waste

Consider ahead of time how to avoid mixing things that are different in either waste form or hazard

- Leads to most restrictive management path
- Smaller cleanups may effectively treat everything as radioactive waste for efficiency
  - Larger waste volumes make this a problematic approach
- Preliminary waste management plan can help scope
  - What types of waste might be generated
  - Whether they contain hazardous materials
  - What radiation levels might be used to separate them
  - Where to locate staging areas
  - How to process the waste
- EPA Standard Operating Guideline on field technologies that could be used to segregate/minimize waste (2013)

Treatment of Waste

Some types of treatment can be done at staging areas, particularly volume reduction

- Grinding
- Shredding
- Soil washing
- Ion exchange/reverse osmosis (decon liquids)

Treatment vendors may be able to provide other services, including packaging

- Consideration of bulk waste (e.g., soil)

Transportation requirements and routes

Disposal of Waste

Waste will range from radiologically uncontaminated to highly contaminated, so be aware of all options

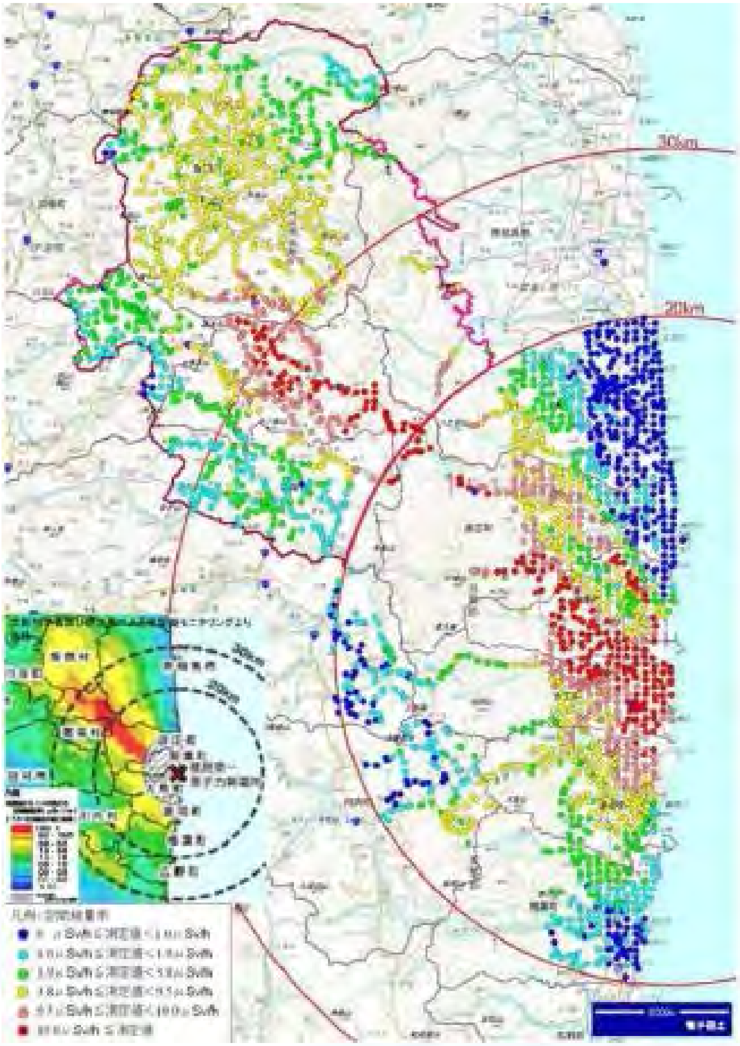
- Solid waste landfills
- Hazardous waste landfills
- Licensed low-level radioactive waste facilities
- Waste characterization will need to be sufficient

State and local officials have to consider

- Local disposal – under what conditions? How much?
- Is constructing new disposal capacity an option?
  - 2011 EPA workshop convened experts to examine issues
- Other states may object to accepting the entire burden

Case Studies

Case Study – Fukushima



Wide-area Radiation Monitoring Map

Aerial Dose Rate (μ Sv/h)

- 0 – 1.0
- 1.0 – 1.9
- 1.9 – 3.8
- 3.8 – 9.5
- 9.5 – 19.0
- 19.0 –

1 μ Sv/h = 8.76 mSv/y

Description of Waste Streams

Management of radioactive waste significantly complicated by earthquake and tsunami

- Buildings destroyed, infrastructure damaged
- Agricultural areas flooded and contaminated
- Toxic/hazardous substance mixtures widespread
- Accumulation of waste from treating NPP effluents
- Significant ocean releases (re-contamination)
- “Hot spots” found across the country

Japan relies heavily on incineration of solid waste

- Precautions to avoid re-suspension of radionuclides
- Concentration of radioactive material in ash

Management of Decontamination Waste

Initial waste estimates ranged ~ 0.5-1.5 billion ft^3

Three-part management strategy defined

- Temporary storage (~3 years)
  - At or very close to the point of generation (or residents)
  - Many small facilities
- Interim storage facility (~30 years)
  - Fukushima Prefecture only
  - Consolidated storage at one or a small number of facilities
- Final disposal facility
  - To be located outside Fukushima Prefecture
- Challenge: local community acceptance
  - March 2012: 86% of municipalities reluctant to accept waste

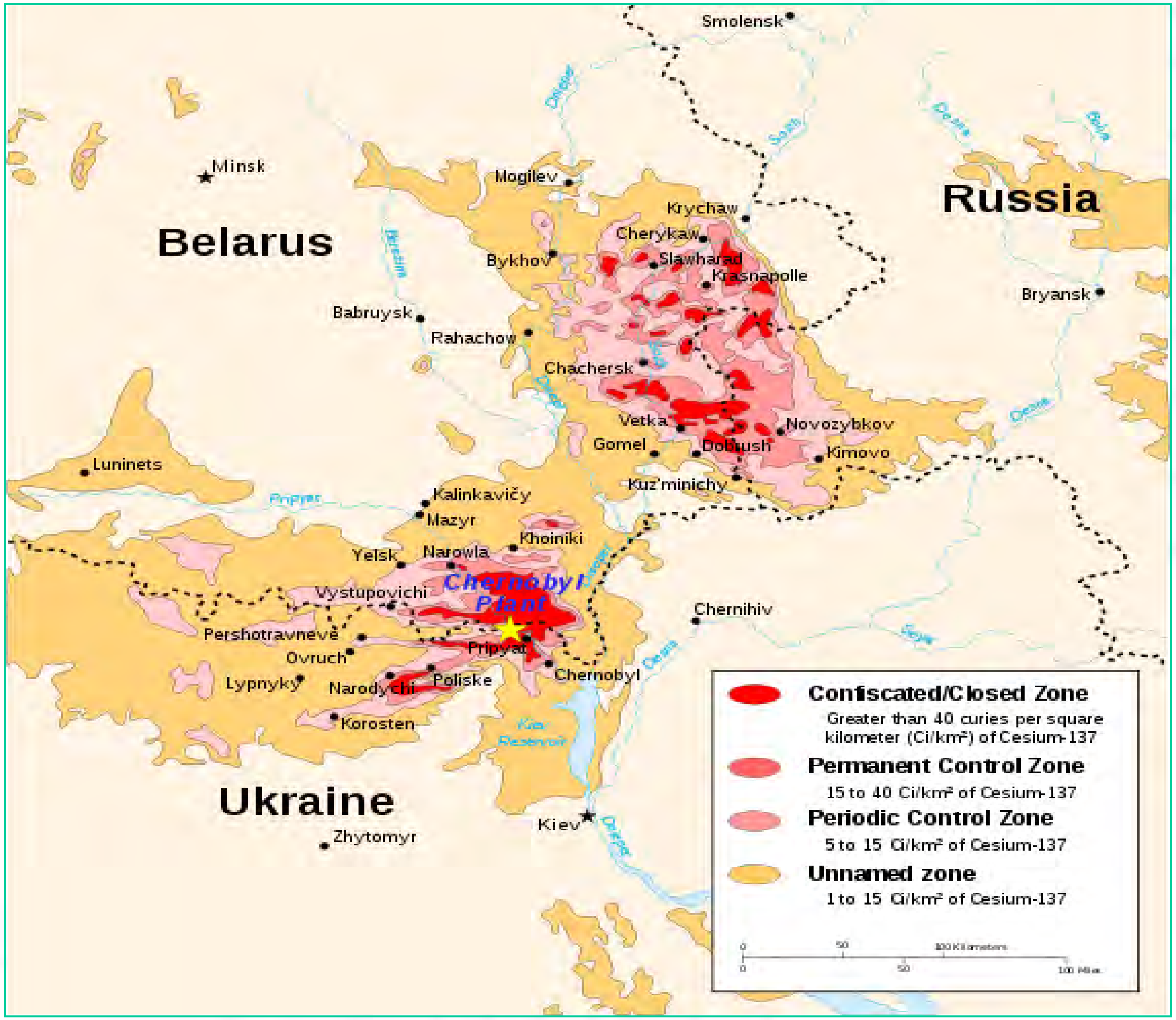
Landfill Disposal of Incinerator Ash in Japan

	8,000 Bq/kg or under		8,000～100,000 Bq/kg	Exceeding 100,000 Bq/kg
	Other (Criteria of Waste Management Act)	Specified Domestic Waste & Specified Industrial Waste[※2]		
Structure of landfill site	Controlled type landfill site[※1](Landfill site equipped seepage control work and drainage treatment)			Isolated type landfill site (Landfill site equipped outer intercept)
Preventive measures against leaching of radioactive material	None	*Installing the soil layer *Prevention of rainwater penetration into fly ash	*Cement solidification *Installing the soil layer *Establishing the impermeable soil layer	None (No Leaching of Radioactive Material due to Water Blocking)
Monitoring of radioactive material	None	*Discharged water *Groundwater *Air dose rate in the vicinity		*(Non-existence of discharged water) *Groundwater *Air dose rate in the vicinity

Source: Ministry of Environment

*1 Isolated type of landfill site is possible to be used.
*2 Generated from areas with possible accident-origin radioactive materials near 8,000 Bq/kg

Case Study – Chernobyl



Extent of Contamination

Exclusion zone:

- 2040 km^2 in Ukraine
- 2100 km^2 in Belarus
- 170 km^2 in Russia
- ~4300 km^2 total

Contaminated area (>1 Ci/km^2 of Cs-137) totals ~140,000 km^2

Significant areas taken out of production

- ~8,000 km^2 agricultural land
- ~7,000 km^2 timber land

Decontamination and Waste Management

Limited effort to decontaminate except to support reactor decommissioning (even where populated)

- Several million m^3 of waste from rubble, debris, soil
- Trees bulldozed and buried
- ~800 burial areas in Ukraine exclusion zone, largely without characterization or segregation
  - "These facilities were established without proper design documentation and engineered barriers and do not meet contemporary waste disposal safety requirements"
    -- Chernobyl Forum
  - *Vector* site to provide upgraded treatment, sorting, packaging, disposal for long- and short-lived waste
- Belarus reviewing disposal areas for potential upgrade

Additional Challenges

Initially, there was a lack of

- Information
- Detailed planning
- Technical equipment
- Engineered storages
- Experience

Ongoing

- Lack of funding
  - Exacerbated by collapse of Soviet system
- No demand for remediation
- Necessity for reburial of waste

Case Study – Goiania

Scenario and Consequences

September 1987 – abandoned teletherapy source was breached and resulted in contamination of people and property

- 1,375 Curies of Cesium-137
- Created 3,500 m^3 of waste (~150,000 times original vol.)

Two near-surface repositories opened in 1995

- Located ~23 km from accident site
- Waste classified based on time to decay to 87 Bq/g
- 40% of the total volume could have been released
- More extensive engineered barriers for higher activity

Waste Categorization

Waste from the incident was categorized and segregated for disposal (time to decay to 87 Bq/g)

Table D.6. Waste from Goiânia Accident

GROUP (Time - years)	Number Metallic Boxes	Volume (m^3)	Number of Drums	Volume (m^3)	Storage Activity * (TBq)	Total Volume (m^3)	Current Activity (TBq)
I (t=0)	404	686.8	2710	542	0,06	1228,80	0,03
II (0 < t < 90)	356	605.2	980	196	0,476	801,20	0,250
III (90 < t < 150)	287	487.9	314	62.8	1,44	550,70	0,76
IV (150< t <300)	275	467.5	217	43.4	13,67	510,90	7,19
V (t > 300)	25	42.5	2	0.4	30	42,90	15,80
Total	1347	2289.9	4223	844.6	45,71	3134,50	24,03

*NOTE: * Storage Activity: at the time of storage / ** Current Activity: as of March 2008.*

Source: National Report of Brazil for the Third Review Cycle of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

Planning
And
Preparedness

Decision Support Tools – WEST/I-WASTE

Waste Estimation Support Tool (WEST) can generate first-order estimates of potential waste volumes

- Can be used for rad incident planning and response
- Use commercially available software/databases
- Adjust parameters based on decontamination strategy

I-WASTE can assist in managing incident waste

- Multiple scenarios available, including radiological
- Calculators to estimate mass and volume of waste
- Databases of building contents and disposal facilities
- Guidance on worker safety, packaging, transportation
- Applied for natural disasters (e.g., Hurricane Katrina)

Technical Documents

Chemical-Biological-Radiological Disposal (2012)

- A significant incident is likely to result in waste volumes exceeding current disposal capacity
  - Can new CBR capacity be developed quickly?
- EPA workshop convened experts to consider CBR technical issues to support policy decisions (e.g., siting)

Field Technologies (2013)

- EPA developed a standard operating guideline for application of decon/cleanup technologies in the field
  - Subject matter expert workshop to evaluate and assign qualitative rankings of selected attributes (e.g., throughput)

See https://www.epa.gov/homeland-security-research, "All publications"

- "Remediating Indoor and Outdoor Environments"
- "Treatment and Disposal"

Technical Documents – Low-Activity Waste

EPA has considered the potential use of hazardous waste landfills for disposal of "low-activity" waste

- Modeling effort over past several years
  - Scenarios include workers, intruders, long-term performance
- Technical reports being revised after peer review
- Provides a technical basis for determining protectiveness
  - Criteria for characterization and disposal over range of options
- Local disposal likely to be controversial
  - State and local officials must have confidence that the proposed action will protect public health
  - Likely to raise equity issues (undue burden)
  - Technical basis for decisions must be transparent and allow examination by stakeholders

Protective Action Guides (PAG) Manual

EPA issued revised PAG Manual in early 2017

- Addresses late phase recovery with planning guidance for cleanup and waste disposal
  - Proposes overall framework for decision-making
  - Involve technical experts, decision-makers, public/stakeholders
  - Work toward consensus where possible
  - Cleanup approach will affect disposal needs
  - States will need to consider their options for waste disposal
    - Conditions for use of certain facilities
    - Waivers or other necessary administrative actions
  - Incorporates guidance for drinking water systems
  - https://www.epa.gov/radiation/protective-action-guides-pags for more information on 2017 revision

Guidance – Contaminated Water

In 2012, EPA issued "Containment and Disposal of Large Amounts of Contaminated Water"

- Support guide for water utilities
- Chemical, biological, toxic, radioactive contaminants
- Five disposal methods discussed
  - Direct discharge to surface water
  - Disposal through wastewater treatment plant
  - Transfer to hazardous or medical/infectious waste facility
  - Disposal in underground injection well
  - Volume reduction and solidification

https://www.epa.gov/waterutilityresponse/containment-and-disposal-large-amounts-contaminated-water

Exercises – Liberty RadEx (2010)

RDD Scenario in Center City Philadelphia

- Post-emergency phase (30-45 days after event)

Interagency team developed waste mgmt. plan

- Worked through issues related to
  - Staging (several sites identified w/help of citizen panel)
  - Characterization (including identifying special waste)
  - Management (logistics – treat, package, transport)
  - Disposal (all potential disposal options considered)
- Produced a draft plan addressing important aspects

State officials forthright about action to be taken

Identified gaps in guidance for decision-making

Workshops – LRE and WARRP

EPA workshop on managing RDD waste (2009)

- Leverage planning for Liberty RadEx
- Separate sessions for Federal, State/local, private
  - Understand current state of preparedness
  - Identify issues/barriers and priorities to address them
  - Transparency, credibility, communication common theme
  - Results presented at 2011 annual WM conference in Phoenix

EPA led workshop in Denver in May 2012

- Wide-Area Recovery and Resiliency Program (DHS)
- Stress importance of preparedness and key issues
- Overview of experience, case studies, planning
  - https://www.epa.gov/homeland-security-waste/summary-2012-wide-area-recovery-and-resiliency-program-warrp-waste

Other Planning Activities

Long-term waste management is receiving more attention/visibility/inclusion on numerous fronts

- Revision of NRF Nuc/Rad Incident Annex
  - Incorporate late phase considerations
- Southern Exposure exercise (2015)
  - Limited treatment of waste management issues
- NCRP Publication 175 (2015)
  - Decision Making for Late-Phase Recovery from Major Nuclear or Radiological Incidents
- IAEA documents emphasizing planning in process
  - Remediation, pre-disposal, disposal

Much more work needed to improve preparedness