HANFORD PUREX TUNNEL 2 EXPERT PANEL REPORT

September 2017

Hanford PUREX Tunnel 2 Expert Panel Report
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Executive Summary:

The Plutonium Uranium Extraction (PUREX) plant at the Hanford Reservation was the workhorse of the nuclear materials production facilities. The facility was built in the early 1950s and went into production in 1956. The PUREX plant operated through 1998. Two rail car tunnels were built to accommodate failed equipment and other contaminated materials that could not be readily disposed of by other means. In May 2017, a 20-foot portion of PUREX Tunnel 1 collapsed. No radioactive materials were released and the collapsed area was backfilled. The Tunnel was covered with a high-density polyethylene tarp to deflect rainwater.

Following the Tunnel 1 collapse, the Department of Energy (DOE) directed contractor CH2M HILL Plateau Remediation Company (CHPRC) to perform a structural analysis of both tunnels (see J.C. Connerly [DOE-RL] to K.K. Dickerson [CHPRC], "PUREX NTE for Recovery/Stabilization," 1701993, May 10, 2017, with clarification May 25, 2017). This analysis indicates that both tunnels do not meet current structural standards. As a result, DOE is proceeding with continuing response actions to stabilize Tunnel 1 by filling it with grout. An Expert Panel was chartered in August 2017 to evaluate Tunnel 2 and to provide recommendations to DOE. This report represents the final recommendations of the Expert Panel.

The Expert Panel was charged to evaluate the current state of Tunnel 2 by reviewing available data and analyses to provide guidance and decision-making criteria for near-term stabilization of Tunnel 2 hazards. The panel consisted of eight subject matter experts (SME) with a broad range of experience in nuclear facility operations, risk-management, industrial hygiene, radiological protection, structural analysis, and decontamination & decommissioning. A series of web-based meetings was held to review the available data on the Tunnel 2 inventory and structural analysis. The panel reviewed the proposed stabilization options and developed a series of criteria to evaluate the various options. The panel concluded that stabilization with grout was the preferred stabilization method. The grout option provides protection to workers, the public, and the environment, while facilitating future options for disposition.

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Introduction:
The Plutonium Uranium Extraction (PUREX) process was the primary means for separating uranium and plutonium from irradiated nuclear fuel for production of nuclear weapons. The PUREX plant was the workhorse of the nuclear materials production facilities at the Hanford Reservation. The facility was built in the early 1950s and went into production in 1956. In order to accommodate failed equipment, rail car tunnels were built at the end of the PUREX plant. Failed equipment was drained and flushed to remove residual contamination and to lower radiation. The equipment was lowered onto rail cars and the rail cars were pushed into the tunnels.

PUREX Tunnel 1 was constructed in 1956. Tunnel 1 is timber beam construction (see Figure 1) and is approximately 360 feet long, 22 feet high, and 19 feet wide. The timbers were 12-inch by 14-inch creosote Douglas Fir and the structure was wrapped in 90-lb mineral-surface roofing (i.e., roofing 'tar' paper) material. An earthen mound of approximately 8 feet was placed over the timber construction to provide additional shielding. Tunnel 1 was used between 1960 and 1965 and contains a total of eight rail cars.


Tunnel 1 under construction.

Figure 1 - PUREX Tunnel 1 under construction (circa 1956)

PUREX Tunnel 2 went into operation in 1964. Tunnel 2 is a steel-and-concrete reinforced Quonset hut construction and is approximately 1,688 feet long, 26 feet high, and 34 feet wide. Two collapses occurred during initial construction, resulting in a redesign to add the concrete and steel reinforcements (see Figure 2).

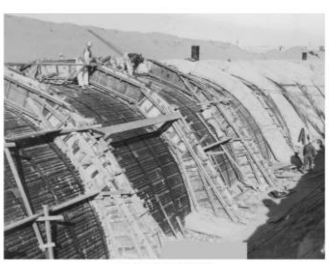
Tunnel 2 under construction.

Figure 2 - PUREX Tunnel 2 under construction (circa 1964)

An earthen mound of approximately 8 feet was placed over the construction to provide additional shielding. Tunnel 2 was used between 1964 and 1996 and contains a total of 28 rail cars (although it has a capacity of 40 rail cars).

May 2017 Event:
On May 9, 2017, a Radiation Controls Technician near Tunnel 1 noticed increased background radiation levels. Upon inspection, workers noticed a depression in the Tunnel 1 earthen mound. The workers promptly exited the area and made the proper notifications. A Site Area Emergency was declared in accordance with Hanford Emergency Operations procedures. Inspection revealed a roof collapse of approximately 20 feet by 20 feet. No airborne contamination was detected and there was no release of radioactive material. Figure 3 shows ground and aerial views of the collapse area.

Figure 3 - PUREX Tunnel 1 collapse area (May 2017)

The exact cause of the collapse could not be determined, but it was likely due to a combination of water loading, due to greater than average snow burden and rainfall during early 2017, combined with a deterioration of the wood timbers over more than 60 years. Over the course of the Tunnel 1 history, the timbers were exposed to normal periodic moisture and prolonged radiation fields. In order to provide immediate protection to workers, the public, and the environment, the breached area was backfilled with soil and a high-density polyethylene (HDPE) tarp was placed over the length of Tunnel 1 to minimize water intrusion. Figure 4 shows a pictorial representation of the contents of Tunnel 1, as well as a current aerial view of it.

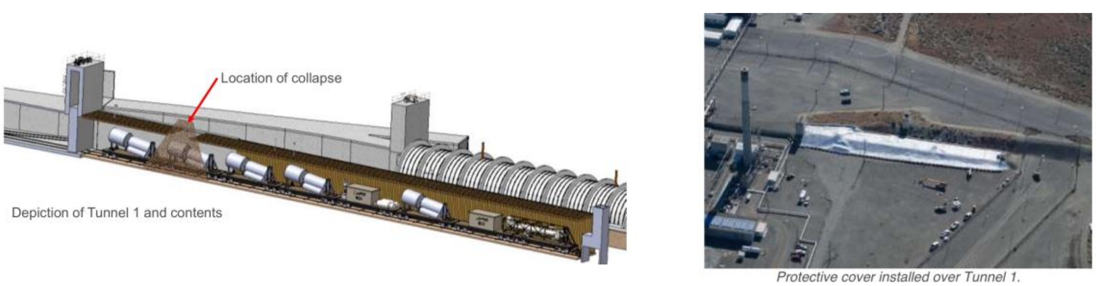

Figure 4 - Pictorial representation of the contents and current aerial view of PUREX Tunnel 1.

Washington State Department of Ecology Administrative Order:
The Washington State Department of Ecology (Ecology) issued an Administrative Order on May 10, 2017, describing three actions to be completed in response to the Tunnel 1 event.

Required Action	Due Date
1. Determine cause of breach, assess future risk and submit structural integrity evaluation.	July 1, 2017
2. Submit draft report detailing corrective actions to ensure safe storage.	August 2, 2017
3. Submit draft permit modifications.	October 2, 2017

The DOE response to Action 2 recommended a phased approach to developing the corrective actions for Tunnel 2. Specifically, DOE proposed enhanced surveillance and monitoring of the Tunnel 2 structure and the creation of an Expert Panel to evaluate stabilization options for Tunnel 2.

PUREX Tunnel 2 Expert Panel:
The Expert Panel was chartered in August 2017 and consisted of eight SMEs with a broad range of experience in nuclear facility operations, risk management, industrial hygiene, radiological protection, structural analysis, and decontamination & decommissioning. The panel developed a Plan of Action (see Attachment 1) and conducted a series of web-based meetings to review available information on the inventory and structural analysis of Tunnel 2. The panel also reviewed proposed stabilization options, developed criteria to assess the proposed options, and developed a recommendation for DOE. The panel members are shown below:

Name	**Affiliation**
Panel Members	
John Marra, Chair	Chief Engineer, DOE Office of Environmental Management (DOE-EM)
Tom Fletcher	Deputy Manager, DOE Richland Operations Office (DOE-RL)
David Kosson	Cornelius Vanderbilt Professor of Engineering, Civil & Environmental Engineering, Vanderbilt University
Craig Benson	Dean, School of Engineering, Hamilton Endowed Chair in Civil & Environmental Engineering, University of Virginia
Kathy Higley	Professor and Head, School of Nuclear Science and Engineering, Oregon State University
Christine Lee	Vice President, ESHQ, CH2M HILL-BWXT West Valley
Kurt Kehler	Vice President, Decommissioning & Waste Management, Canadian Nuclear Laboratories

Name	Affiliation
John Ballantyne	Chief Engineer, Nuclear Structures, CH2M-UK
Observers	
Mark Hasty	Chief Engineer, CH2M HILL Plateau Remediation Company (CHPRC)

Biographies of the panel members are provided in Attachment 2.

Structural Analysis of Tunnel 2:
The CHPRC contractor performed a detailed structural analysis of both tunnels in response to the Ecology Administrative Order. The analysis was performed in accordance with the 2012 International Building Code and used construction drawings, photographs, and other available information as inputs. As-built drawings of the tunnels could not be located and specific properties for the construction materials were unknown, so "best available" information was used. For example, backfill soil properties were those for typical Hanford soils. The analysis used Load and Resistance Factor techniques to calculate Design-to-Capacity Ratios (DCR) to assess the state of Tunnel 2. Figure 5 shows the available design information for Tunnels 1 and 2 and the calculated DCRs for Tunnel 2.

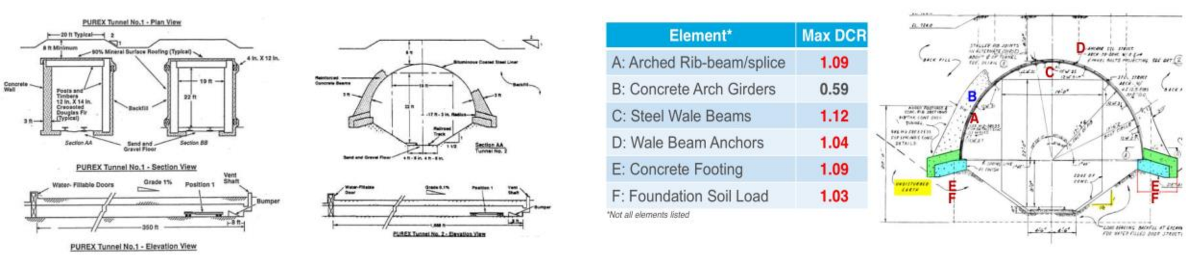

Figure 5 - Cross-sectional design inputs for Tunnels 1 and 2 and DCR for Tunnel 2.

The DCR is based on the ratio of load to capacity, and a value greater than 1 is problematic. As evidenced from Figure 5, the majority of the structural components on Tunnel 2 are greater than 1, and the analysis concluded that Tunnel 2 is at a "high risk" of collapse. It should be noted that design standards at the time of Tunnel 2 construction were not the same as they are presently. It should also be noted that the last view into Tunnel 2 was made in 1996 and, as a result, conservative values were used to calculate the DCR. A manned entry is not considered feasible due to the hazard presented to personnel. This constraint precludes any options that might involve strengthening of the actual tunnel itself. Remote inspection of the tunnel has been considered, but it is unlikely that a remote inspection would provide enough information to provide assurance of the structural stability of Tunnel 2; the structural analysis suggests interim stabilization action is warranted.

PUREX Tunnel 2 Stabilization Options:
As noted above, plans are underway to stabilize Tunnel 1 with grout. Tunnel 2 is much larger than Tunnel 1 and, as a result, additional options have been suggested. Figure 6 shows a pictorial representation of the Tunnel 2 contents.

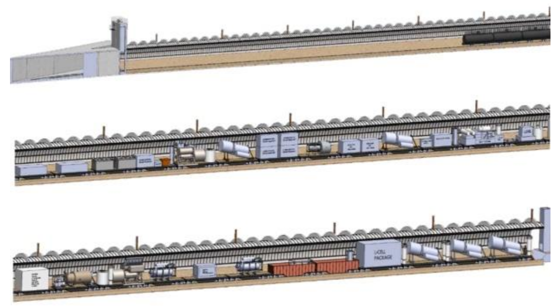

Figure 6 - Pictorial representation of PUREX Tunnel 2 contents.

The stabilization options considered for Tunnel 2, along with a brief description of each, are shown below:

Stabilization Option	Description
No Further Action	Leave the Tunnel and contents as is.
High-Density Polyethylene Cover	Cover the length of Tunnel 2 with a high-density polyethylene (HDPE) cover similar to the cover placed over Tunnel 1.
Soft-Surface Tent Cover	Cover the length of Tunnel 2 with a tarp-like, tent structure with a tubular metal structural frame.
Hard-Surface Tent Cover	Similar to the soft-surface tent structure, but with increased structural integrity (i.e., highly-tensioned fabric cover).
Pre-Engineered Building Cover	Construct a pre-engineered structure (e.g., a “Butler Building”) over the length of Tunnel 2.
Injection of Poly Foam Void Filler	Inject an expanding foam into Tunnel 2 to fill voids and fix contents.
Controlled Collapse in Place	Collapse the structure of Tunnel 2 in place to prevent the risk of failure and/or uncontrolled collapse.
Sand or Clay Void Fill	Fill Tunnel 2 with sand and/or clay to fill voids and to stabilize the structure.
Grout Void Fill	Fill Tunnel 2 with structural grout to fill voids and to stabilize the structure. Note: This is similar to the stabilization option selected for Tunnel 1.
Stored Waste Retrieval	Remove the contents of Tunnel 2 for treatment and disposal elsewhere.

The panel discussed each of these options with an SME from CHPRC to understand the details associated with each, relevant experience with the proposed solution, and other considerations for implementation.

Expert Panel Evaluation of PUREX Tunnel 2 Stabilization Options:
The Expert Panel conducted a parametric evaluation of the proposed Tunnel 2 stabilization options and developed a series of assessment criteria to determine the preferred option. The assessment criteria fell into three broad categories: Safety, Implementation, and Future Options. The criteria are described in additional detail below.

The criteria and rating options were discussed by the panel to ensure common understanding and to refine criteria as necessary. Each panel member completed the assessment criteria independently to ensure proper assessment and to avoid "group think" errors. The eight individual scores were collated and averaged. In circumstances where there was a wide variation in individual scores (i.e., one panel member rated it high and another rated it low), the differences were reconciled. This gave a group opinion. Attachment 3 provides a depiction of how the criteria were rated by the group. Weighting factors were applied, as shown in Attachment 3to distinguish between criteria and to recognize that some took precedent over others (e.g., safety and environmental protection were weighted higher than cost).

Primary Criteria	Secondary Criteria	Description
Safety	Worker Safety	Does the implementation of the stabilization method expose the works to a safety risk?
	Implemented System Safety	How does the implemented stabilization solution protect workers, the public, and the environment in the near-term?
	Long-Term System Safety	How does the implemented stabilization solution protect workers, the public, and the environment in the long-term (i.e., is periodic maintenance or replacement needed?)?
Implementation	Experience	What is the level of experience with the stabilization solution? At Hanford? Across DOE-EM? Internationally?
	Schedule	How much time will the stabilization solution take to implement?
	Cost	What is he relative cost of implementing the stabilization solution?
Future Options	In-Situ Disposition	Does the stabilization solution support in-situ disposition or will further action be required?
	Removal	Does the stabilization solutions support potential removal of the Tunnel contents? Does it make removal more complicated or hazardous?

Preferred Stabilization Alternative:
The panel agrees that, with the data presented, Tunnel 2 is at risk of collapse and stabilization action is warranted. The panel concluded that stabilization with grout was the preferred stabilization method. Grout stabilization was preferred in both the "raw" score data and also when weighting criteria were applied. In the panel's opinion, the grout stabilization provides maximum protection to workers, the public, and the environment. Furthermore, the panel concluded that stabilization with grout facilitates future options for disposition, whether those options involve in-situ disposal or removal of materials.

DOE has a great deal of experience with grout and it has been extensively used by DOE-EM to stabilize and disposition similar facilities. Flowable grout has been successfully used to sequester residual radionuclides in high-level waste tanks at Savannah River (SR) and Idaho, and in stabilization at the Waste Encapsulation and Storage Facility (WESF) and U-Plant at Hanford. Additionally, grout has been used at SR to successfully decommission both P- and R-Reactors. As discussed above, grout is also being used in the interim stabilization of Tunnel 1. These applications demonstrate the suitability of grout for the interim stabilization of Tunnel 2.

Future Panel Actions:
The Expert Panel has fulfilled its charge and will officially move into a "suspension" mode. Panel members are universal in their commitment to supporting successful stabilization of Tunnel 2 and are available to assist in the future during project planning and/or execution or at the discretion of DOE.

Attachment 1
PUREX Tunnel 2 Expert Panel
Plan of Action

Panel Members:

Name	Affiliation
Panel Members	
John Marra, Chair	Chief Engineer, DOE Office of Environmental Management (DOE-EM)
Tom Fletcher	Deputy Manager, DOE Richland Operations Office (DOE-RL)
David Kosson	Cornelius Vanderbilt Professor of Engineering, Civil & Environmental Engineering, Vanderbilt University
Craig Benson	Dean, School of Engineering, Hamilton Endowed Chair in Civil & Environmental Engineering, University of Virginia
Kathy Higley	Professor and Head, School of Nuclear Science and Engineering, Oregon State University
Christine Lee	Vice President, ESHQ, CH2M HILL-BWXT West Valley
Kurt Kehler	Vice President, Decommissioning & Waste Management, Canadian Nuclear Laboratories
John Ballantyne	Chief Engineer, Nuclear Structures, CH2M-UK
Observers	
Mark Hasty	Chief Engineer, CH-Plateau Remediation Company (CH-PRC)

Panel Operation:
The Expert Panel will accomplish its initial activities via a series of web-based conferences to gather data and provide near-term feedback and recommendations to DOE-EM Leadership. Onsite reviews will be scheduled as necessary to complete the panel report and final recommendations.

Web Conference 1 - Panel Charge and Information Gathering (August 25, 2017)

Organization and Charge

- Welcome and Introductions
- Charge and Objective

- Scope
- Schedule - Including Stakeholder Commitments
- Deliverable

Introduction

- Description of May Event
    - Initial Observation
    - Immediate Corrective Actions
    - Current Status
- Washington State Department of Ecology Enforcement Order
    - Proposed Actions
    - Schedules and Commitments

Immediate Actions Taken

- Structural Integrity Evaluations
    - Tunnel 1
    - Tunnel 2
- Enhanced Surveillance Observations
    - Daily Walkdowns
    - Video Surveillance

Summary and Next Steps (Including Next Meeting)

Web Conference 2 - Remediation Options and Evaluation (September 1, 2017)

Tunnel 1 Remediation

- Tunnel 1 Current State and Baseline
    - Tunnel 1 Inventory
    - “Baseline” Disposition Plans
- Tunnel 1 Remediation
    - Grouting Option
    - Conceptual Design

Tunnel 2 Current State and Options Analysis

- Tunnel 2 Current State and Baseline
    - Tunnel 2 Inventory
    - “Baseline” Disposition Plans
- Tunnel 2 Remediation Options
    - Options Evaluated
    - Basis
    - Previous DOE Experience

Options Analysis Process

- Review Process

- Decision-Making Criteria Identification

Summary and Next Steps (Including Next Meeting)

Web Conference 3 - Panel Evaluation and Discussion of Alternatives (September 8, 2017)

Options Analysis and Scoring

- Evaluation and Discussion of Alternatives
- Weighting Factors for Criteria
- Scoring Results

Summary and Next Steps (Including Next Meeting)

Web Conference 4 - Panel Evaluation and Discussion of Alternatives (September 15, 2017)

Options Analysis and Scoring

- Scoring Results

Summary and Formation of Recommendations

Report Format and Writing Assignments

Summary and Next Steps (Including Next Meeting)

Web Conference 5 - Panel Report Finalization (September 22, 2017)

Report Draft Review and Comment Incorporation

Next Steps and Follow-on Activities

- Report Review Schedule

Attachment 2
PUREX Tunnel 2 Expert Panel
Member Biographies

JOHN MARRA, PHD
John Marra is Chief Engineer for the Department of Energy, Office of Environmental Management (DOE-EM). Dr. Marra joined the Department in 2015 as a Senior Technical Advisor and was appointed Chief Engineer in 2016. Prior to joining DOE, he worked at the Savannah River Site in Aiken, South Carolina.

Dr. Marra joined the Savannah River Laboratory (now the Savannah River National Laboratory, SRNL) in 1987. He held a number of management and technical positions in both the Laboratory and Operations at the Savannah River Site. He held positions in the High-Level Waste (HLW) tank farm as was Engineering Manager at the Extended Sludge Processing (ESP) facility when the first HLW sludge was transferred to the Defense Waste Processing Facility in 1996. Dr. Marra also served as Chief Engineer in the Defense Programs Division at SR, with technical and engineering responsibility for the Tritium Mission during commissioning of the Tritium Extraction Facility.

In his later years at SR, Dr. Marra served as Associate Laboratory Director for the Environmental & Chemical Process Technology Directorate and Associate Laboratory Director of the Science & Technology Directorate. At the time of his retirement from SRNL in 2015, Dr. Marra held the dual positions on Laboratory Fellow and Chief Research Officer.

Dr. Marra received a bachelors degree in Ceramic Science and a bachelors degree in Chemistry from the New York State College of Ceramics at Alfred University, and a doctorate in Ceramic Engineering from The Ohio State University. He received the Distinguished Alumnus Award from the Department of Materials Science & Engineering at Ohio State in 2002 and delivered the McMahon Lecture at Alfred University in 2009. Dr. Marra is a Fellow and Past-President of the American Ceramic Society.

THOMAS FLETCHER
Tom Fletcher was named Deputy Manager of the DOE Richland Operations Office (RL) in December 2016. RL manages an annual budget of approximately $1 billion and oversees multiple contractors involved in cleanup of the 580-square-mile Hanford Site, a former production site for nuclear weapon materials. As Deputy Manager, Fletcher is responsible for oversight of daily operations, program planning, project execution, budgeting, compliance with the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement), and safe, environmentally acceptable and responsible management of the Hanford Site.

Prior to being named Deputy Manager, Fletcher was Assistant Manager for Waste Treatment and Immobilization Plant Start-Up, Commissioning and Integration, at the Office of River Protection, responsible for engineering, procurement, construction, nuclear safety, hazardous waste management, and operations of the Hanford tank farms.

Fletcher has more than 15 years of experience managing projects involving nuclear operations, construction, deactivation and demolition, and environmental remediation. He started at Hanford in 2006 as a project controls officer for the Groundwater and Soil Remediation project at RL. Prior to coming to Hanford, Fletcher served at the U.S. Department of Army Corps of Engineers, Walla Walla District, in Washington State. While at the Army Corps of Engineers, he was the co-lead for the Richland Operations Life Cycle Cost Baseline, which became the basis for the $3 billion Mission Support Contract and $7 billion Plateau Remediation Contract.

Fletcher holds bachelors and masters degrees in civil engineering from Washington State University. He is a registered professional engineer in Washington State and a certified project management professional through the Project Management Institute.

DAVID KOSSON, PHD
David S. Kosson is Cornelius Vanderbilt Professor of Engineering at Vanderbilt University, where he has appointments as Professor of Civil and Environmental Engineering, Chemical Engineering, and Earth and Environmental Sciences. Professor Kosson also is the Principal Investigator for the multi-university Consortium for Risk Evaluation with Stakeholder Participation (www.CRESP.org), supported by the DOE to improve the risk-informed basis for remediation and management of nuclear waste from former defense materials production and nuclear energy. Professor Kosson's research focuses on management of nuclear, energy production and industrial wastes, and water resources protection through leaching assessment including process development and contaminant mass transfer applied to groundwater, soil, sediment, waste and cementitious materials systems.

Dr. Kosson has served on many review and advisory capacities for the DOE, including for the Hanford Waste Treatment Plant, Hanford Low-Activity Waste Pretreatment System, Savannah River plutonium processing, and the Idaho Integrated Waste Treatment Unit, and tank waste processing at both Savannah River Site and Hanford. Dr. Kosson co-led the Cementitious Barriers Partnership (www.CementBarriers.org) a multi-institution initiative focused on developing advanced tools for predicting the long-term performance of cementitious materials in nuclear applications. Dr. Kosson served as a member of DOE Secretary Chu's team to address design challenges associated with the Hanford Waste Treatment Plant. Dr. Kosson also serve on the Secretary of Energy Advisory Board panel on research and development needs for the Office of Environmental Management.

Dr. Kosson, in collaboration with Dr. Hans van der Sloot, other Vanderbilt researchers, the U.S. EPA and the Energy Research Centre of The Netherlands, has led the development of the Leaching Environmental Assessment Framework (www.vanderbilt.edu/Leaching) for understanding the release of contaminants from wastes and construction materials under a wide range of use and disposal scenarios. Professor Kosson is the Vanderbilt University lead for the Sterling Ranch (Colorado) – Vanderbilt partnership for development of a smart, sustainable and connected city. Professor Kosson has provided expertise and leadership for the National Academies, and as advisory to the Department of Defense, for two decades on demilitarization of chemical weapons in the United States and abroad. Professor Kosson has authored more than 100 peer-reviewed professional journal articles, book, book chapters and other archival publications. He received his doctorate in Chemical and Biochemical Engineering from Rutgers University, where he subsequently was Professor of Chemical and Biochemical Engineering. Prof. Kosson served as the Department Chairman for Civil and Environmental Engineering at Vanderbilt University from 2000 through 2012.

CRAIG BENSON, PHD, PE, NAE

Craig H. Benson is Dean of the School of Engineering and the Janet and James Hamilton Endowed Chair in Civil & Environmental Engineering at the University of Virginia (UVA). Prior to his appointment at UVA, Benson was Wisconsin Distinguished Professor of Civil & Environmental Engineering and Geological Engineering at the University of Wisconsin-Madison (UW-Madison). At UW-Madison, Benson held several leadership roles with an environmental engineering emphasis, including Director of Sustainability Research and Education for the university, Chair of the Department of Civil and Environmental Engineering, Chair of the Department of Geological Engineering, and Director of the Recycled Materials Resource Center. Dr. Benson has a bachelors degree from Lehigh University and masters and doctorate degrees from the University of Texas at Austin, all in Civil Engineering, with an emphasis in geoenvironmental engineering and waste containment systems. Dr. Benson is a member of the US National Academy of Engineering.

Dr. Benson has been conducting research related to protection of the environment for three decades, with primary focus on environmental containment of solid, hazardous, radioactive, and mining wastes; beneficial use of industrial byproducts; and sustainable infrastructure. He is recognized as the foremost international authority on engineered barriers for waste containment and is widely sought after for his expertise in design and performance assessment, especially for disposal facilities containing low-level waste (LLW), mixed waste (MW), and/or uranium mill tailings. Dr. Benson leads the Landfill Partnership for DOE's Consortium for Risk Evaluation with Stakeholder Participation, which provides research and technical support on issues related to performance assessments for LLW and MW disposal facilities, as well as evaluation of the performance of existing and historic disposal facilities owned and/or operated by DOE.

Dr. Benson's recent projects have involved design, review, and/or assessment of containment systems at the following facilities for containment of LLW, MW, and mill tailings: Energy Fuels White Mesa (Utah), Energy Solutions Clive Disposal Facility (Utah), DOE Monticello Uranium Mill Tailings Disposal Facility (Utah), Energy Solutions Barnwell Disposal Facility (South Carolina), Waste Control Specialists Andrews Disposal Facility (Texas), DOE Portsmouth On-Site Disposal Facility (OSDF) (Ohio), DOE Paducah OSDF (Kentucky), DOE Fernald OSDF (Ohio), DOE Hanford Environmental Restoration Disposal Facility (Washington), and DOE West Valley Disposal Facility (New York). These projects have involved review, design, evaluation, testing, and/or assessment of the waste containment system. The projects related to mill tailings have also included assessment of radon fluxes and long-term erosion modeling. Dr. Benson is the primary author of U.S. Nuclear Regulatory Commission NUREG/CR-7028, *Engineered Covers for Waste Containment*, which is often used as guidance for cover design and performance assessment for LLW and MW disposal facilities.

Dr. Benson's research experience involves laboratory studies, large-scale field experiments, and computer modeling. He has published more than 300 refereed articles based on his research and has received numerous research awards, including the Ralph Peck Award, the Huber Research Prize, the Alfred Noble Prize, and the Croes Medal (twice), Middlebrooks Award (twice), Collingwood Prize, and Casagrande Award from the American Society of Civil Engineers and the Award of Merit, Ivan Johnson Award for Outstanding Achievement, and the Best Practical Paper Award (twice) from ASTM International. Dr. Benson is former Editor-in-Chief of the *Journal of Geotechnical and Geoenvironmental Engineering*, past President of the ASCE Geo-Institute (GI), past Chair of the GI Geoenvironmental Committee, past Vice Chair of the Executive Committee of

ASTM Committee D18 on Soil and Rock, and past Chair of ASTM Committee D18.04 on Hydraulic Properties and Barriers.

KATHRYN HIGLEY, PHD

Kathryn A. Higley is a Professor and Head of the School of Nuclear Science and Engineering in the College of Engineering at Oregon State University. Dr. Higley received both her doctorate and masters degrees in Radiological Health Sciences from Colorado State University, and her bachelors degree in Chemistry from Reed College. She has held both Reactor Operator and Senior Reactor Operator's licenses, and is a former Reactor Supervisor for the Reed College TRIGA reactor. Dr. Higley started her career as a Radioecologist for Portland General Electric. She later worked for Pacific Northwest National Laboratory for ten years as a Senior Research Scientist in the area of environmental health physics. Dr. Higley has been at Oregon State University since 1994 teaching undergraduate and graduate classes on radioecology, dosimetry, radiation protection, radiochemistry, and radiation biology.

Her fields of interest include environmental transport and fate of radionuclides; radioecology; radiochemistry; radiation dose assessment; neutron activation analysis; nuclear emergency response; and environmental regulations. She is current Vice Chair of Committee 4 of (Implementation of the Commission's Recommendations) of the International Commission on Radiological Protection and past Chair of Committee 5 (Protection of the Environment). She is also a councilmember of the National Council on Radiation Protection and Measurements and serves on Council Committee 1 (radiation protection recommendations of the NCRP) and Committee 2 (where are the radiation professionals). She is a fellow of the Health Physics Society and a Certified Health Physicist. Dr. Higley and her students have done research in radiologically contaminated environments around the globe.

CHRISTINE LEE, PHD

Christine Lee is the Vice President of Environmental, Safety, Health, Quality and Security (ESHQ) at the West Valley Demonstration Project in Western New York. The ESHQ organization is responsible for the development and oversight of the compliance envelope required to deactivate and demolish highly contaminated fuel reprocessing facilities in a safe and compliant manner.

Dr. Lee has more than 25 years of experience in waste management, environmental regulatory closure, and ESHQ compliance in the nuclear demolition industry. Dr. Lee's nuclear decommissioning, decontamination, and demolition experience includes senior management positions at the Miamisburg Closure Project, the Rocky Flats Closure Project, Eastern Tennessee Technology Project, Dounreay, and the West Valley Demonstration Project.

Her broad experience in the nuclear industry includes development and negotiation of closure strategies; development of nuclear safety compliance programs; management of radiological waste; and large-scale remediation projects. She earned her doctorate in Mathematics at Warnborough College, Canterbury, UK.

KURT KEHLER

Kurt Kehler is the Vice President of Decommissioning & Waste Management for Canadian Nuclear Laboratories (CNL). CNL's Decommissioning & Waste Management organization is responsible for the development and implementation of all decommissioning, waste management, and environmental remediation activities required to reduce Canada's nuclear legacy.

Kehler has more than 35 years of experience in engineering, construction, and demolition projects, including 25 years experience in managing the decommissioning, decontamination, and demolition of nuclear facilities. Kehler's nuclear decommissioning, decontamination, and demolition experience includes senior management positions at the Hanford Nuclear Reservation, Miamisburg Closure Project, and the Rocky Flats Closure Project.

His broad experience in the nuclear industry includes reactor decommissioning; spent nuclear fuel management; decontamination and demolition of hundreds of contaminated facilities; construction, startup, and operation of nuclear facilities; and large-scale remediation projects. Kehler earned his Bachelor of Science in Construction Management at Boise State University.

JOHN BALLANTYNE

John Ballantyne is a Chartered Civil Engineer and is currently Chief Engineer, Nuclear Structures for CH2M-UK. Ballantyne has over 35 years of experience and has a specialization in the design of nuclear facilities, hydroelectric structures, and tunnels. He has over 30 years continuous experience of the structural design of nuclear related facilities to United Kingdom (UK) nuclear regulatory standards. Additionally, Ballantyne is an expert in seismic analysis and design of structures, including seismic soil structure interaction analysis and the use of performance-based seismic design retrofit methods. He is also experienced in the design of concrete and steel nuclear structures to a variety of international standards.

Ballantyne has been with CH2M-UK for 37 years and has held a series of positions of increasing responsibility since joining as a Design Engineer in 1976. He has worked a variety of projects in the UK, as well as large design projects in Norway and Sri Lanka. He earned a BSc (Hons) in Civil Engineering from the University of Strathclyde, UK, and an MSc in Civil/Structural Engineering from the University of Glasgow, UK. Ballantyne is a Chartered Engineer and a member of the Institution of Civil Engineers.

Attachment 3
Graphical Depiction of Panel Stabilization Options Scoring

Assessment Criteria →	Safety			**Implementation**			**Future Options**		**Score**	
Remediation Option ↓	Worker Safety	Implemented	Long-Term	**Experience**	**Schedule**	**Cost**	**In-Situ**	**Removal**	**Raw**	**Weighted**
No Further Action	↑	↓	↓	↑	↑	↑	↘	↗	→	↘
High-Density Polyethylene Cover	↗	→	↓	↑	↑	↑	↘	↗	↗	→
Soft-Surface Tent Cover	→	→	↘	↑	↑	↑	↘	↗	→	→
Hard-Surface Tent Cover	→	→	↘	↑	↗	↗	↘	↗	→	→
Pre-Engineered Building Cover	→	→	→	↑	↗	↗	↘	↗	→	→
Injection of Poly Foam Void Filler	↘	→	↘	→	↗	→	↓	↘	↓	↓
Controlled Collapse in Place	↓	↗	↘	↘	→	→	↘	↓	↓	↓
Sand or Clay Void Fill	↘	↗	→	→	↗	↗	→	↓	↘	↘
Grout Void Fill	→	↑	↑	↑	↑	→	↑	→	↑	↑
Stored Waste Retrieval	↓	↗	↑	→	↓	↓	↘	↑	↓	↘
Weight?	3	3	3	2	1	1	2	2		