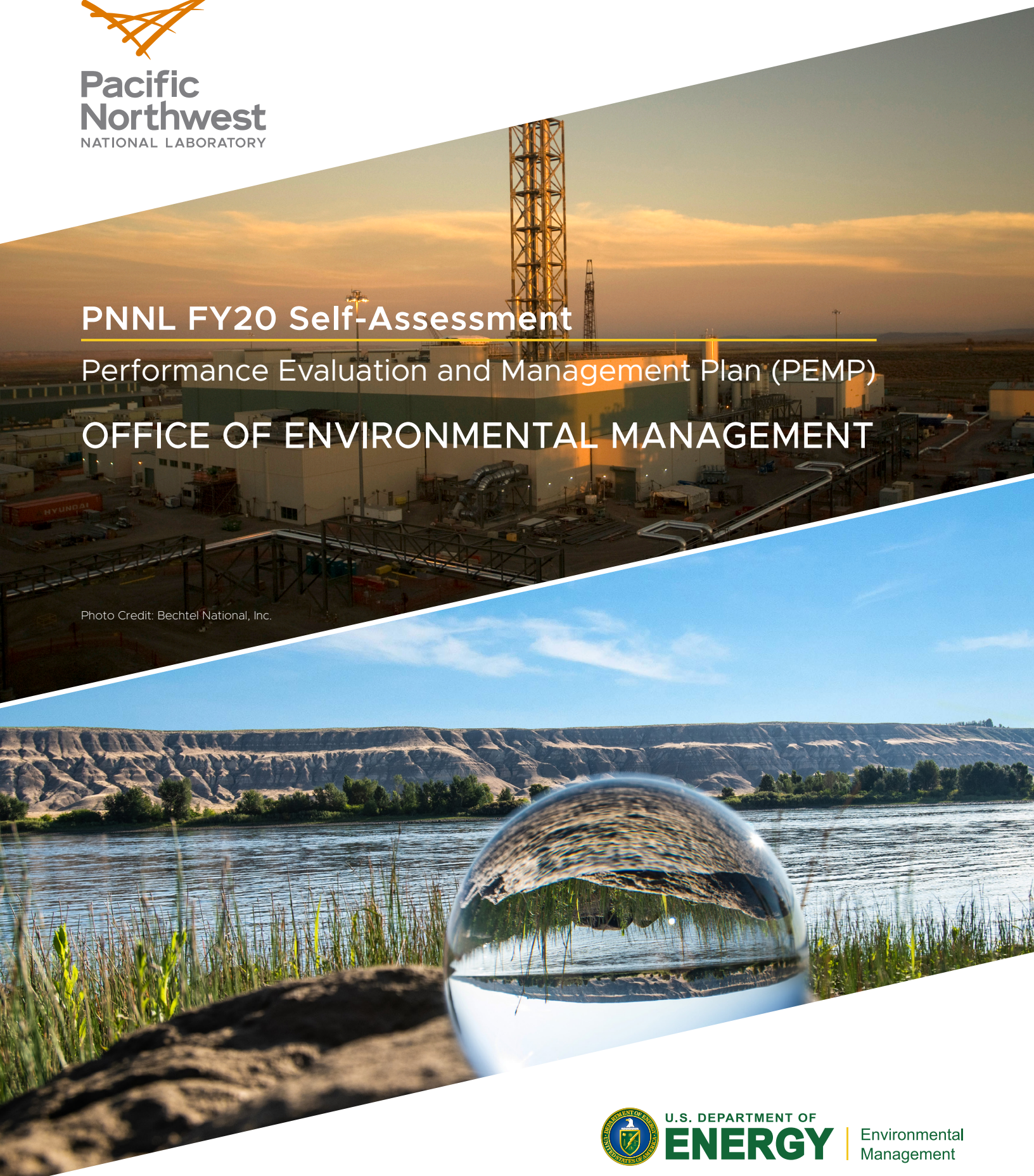
Pacific Northwest
NATIONAL LABORATORY

PNNL FY20 Self-Assessment

Performance Evaluation and Management Plan (PEMP)

OFFICE OF ENVIRONMENTAL MANAGEMENT



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Pacific Northwest National Laboratory FY20 Performance Evaluation and Management Plan (PEMP) Self-Assessment

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Executive Summary

The U.S. Department of Energy (DOE) and its contractors rely on Pacific Northwest National Laboratory (PNNL) to provide impactful scientific and technical results to safely complete cleanup of the environmental legacy from nuclear weapons development and government-sponsored nuclear energy research. To meet this need, PNNL is:

- Providing analyses of integrated systems and constraints therein to identify and address technical gaps and operational/environmental risks
- Providing scientific and technological solutions to enable the baseline and opportunities for improvement in process efficiency
- Providing independent technical bases for near- and long-term decisions and missions needs
- Providing engineering solutions for remediation of complex sites (co-mingled contaminant plumes and deep vadose zone environments) and adaptive management approaches to achieve end states and site closure

PNNL directly supports the DOE Office of Environmental Management (EM) mission in three primary research and technology areas:

1. EM Headquarters-led assessments and development of next generation and innovative solutions to reduce cost and risk across the complex
2. Site-office-led research and analysis to understand the challenges and define remediation/operational baselines
3. Site-contractor-led technology analysis and maturation to address technical gaps and unanticipated challenges to the baselines

To meet EM's mission needs, PNNL's EM research and development portfolio stewards an exceedingly capable and diverse set of staff and capabilities. Over 175 scientists, engineers, and professional staff across the laboratory provide answers for nuclear waste management and environmental remediation challenges. Technical experts, many of whom are internationally recognized leaders in their respective fields, have earned a reputation for excellence, resulting in leadership roles for PNNL on several EM-led partnerships. These staff underpin PNNL's core competencies in waste processing (tank waste chemistry, waste forms, fluid dynamics and scaling, and safety basis) and environmental remediation (nature and extent, remediation science, remediation systems, and end states), which integrate and build on the fundamental disciplines and core competencies recognized by the DOE Office of Science.

PNNL leverages research and knowledge from other programs to enable critical cleanup decisions. Additionally, working with our partners, PNNL has made significant Laboratory Directed Research and Development (LDRD) investments to deliver scientifically defensible solutions to the market. We do this in service to DOE in collaboration with other government sponsors (DOE Offices of Science, Nuclear Energy, and Fossil Energy, and the U.S. Department of Defense), industry customers, universities, and our fellow national laboratories. Rooted in a broad understanding of complex systems, our innovations provide crucial science-based and risk-informed solutions to larger challenges. Our strategically focused research, analyses, and technological contributions are saving the nation billions of dollars (in cost avoidance) and reducing the risks and time frames for cleanup of legacy waste. PNNL is committed to restoring the environment for a cleaner future.

In fiscal year (FY) 2020, PNNL successfully managed and supported over 130 EM projects across 13 sponsors with a business volume totaling over $37.6M. PNNL supported Hanford Site contractor's performance-based incentives and four special emphasis area milestones or deliverables to the DOE Office of River Protection (ORP). In addition, PNNL successfully executed scope directly supporting ORP to increase Direct Feed Low-Activity Waste (DFLAW) operational flexibility; resolve the long-term, potentially high-impact challenges associated with increasing the waste loading of glass waste forms; and provide glass standards to support analysis during waste qualification activities at the Hanford Waste Treatment and Immobilization Plant.

For the DOE Richland Operations Office (RL) and its contractors, PNNL successfully executed milestone-driven scope in support of RL and CH2M Hill Plateau Remediation Company to resolve the long-term, potentially high-impact challenges associated with soil and groundwater remediation, supporting nine Tri-Party Agreement milestones and four performance-based incentives. For RL, PNNL reduced the uncertainty associated with effective monitoring of vadose zone contaminants using the vadose monitoring test bed, evaluated delivery options to ensure that in situ remedy approaches can be effectively deployed at field scale, and identified cost-effective long-term monitoring approaches using geophysical methods. PNNL provided critical technical support to the Hanford Site contractor on their environmental remediation projects to develop effective characterization plans for appropriate remedy selection and optimization and to demonstrate more effective vadose zone characterization and remedy performance monitoring.

In addition to major technical accomplishments impacting EM mission needs, PNNL also:

- Provided national leadership in the development, maturation, and deployment of advanced technologies to solve complex issues of contaminated subsurface environment through the Center for Remediation of Complex Sites.
- Provided leadership and served in key roles in the Basic Energy Sciences Energy Frontier Research Centers focused on the EM mission.
- Completed the final year of a 5-year Nuclear Process Science Initiative focused on interfacial chemistry in radiation environments as it applies to tank waste processing and other PNNL mission areas.
- Supported DOE at several forums with independent experts, regulators, and stakeholders to discuss the results of the multi-laboratory, federally funded research and development center study on supplemental low-activity waste treatment alternatives.
- Co-chaired the EM National Laboratory Network, which focuses on information exchange, consensus building, and coordination to facilitate EM's ability to access and leverage capabilities across the complex.
- Continued to steward key facilities and capabilities critical to the EM mission; in FY20 investing over $4.5M in the Radiochemical Processing Laboratory alone.
- Published one book, six book chapters, and over 380 abstracts, conference papers, presentations, technical reports, and peer-reviewed journal articles documenting support to and transformation of the cleanup mission. Led the national laboratory complex in high-impact publications associated with glass waste form development and nuclear glass corrosion efforts.
- Developed a glass corrosion procedure that is transitioning toward an international standard to be used by national and international colleagues.
- Dedicated key technical staff to critical EM assignments to provide technical and programmatic integration, planning, and management support.

- Continued to mentor the next generation of scientist and engineers through the Minority Serving Institutions Partnership Program and cooperative agreements with EM for workforce development with a focus on environmental remediation and treatment of tanks waste streams.

It is our aspiration to continue to provide outstanding science and technology and to grow our role in EM's vital national missions.

Acronyms and Abbreviations

ANL	Argonne National Laboratory
AR	augmented reality
ASCEM	Advanced Simulation Capability for Environmental Management
ASNF	aluminum-clad spent nuclear fuel
BES	Basic Energy Sciences
BNI	Bechtel National, Inc.
CFD	computational fluid dynamics
CHPRC	CH2M Hill Plateau Remediation Company
CLIN	contract line number
CTO	Chief Technology Office
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science, Inc.
DAV	Data Access and Visualization
DFHLW	Direct Feed High-Level Waste
DFLAW	Direct Feed Low-Activity Waste
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DSA	documented safety analysis
DST	double-shell tank
EFRC	Energy Frontier Research Center
EM	Office of Environmental Management
EMAT	electromagnetic acoustic transducer
EMF	Effluent Management Facility
EMNLN	EM National Laboratory Network
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERT	electrical resistivity tomography
ETF	Effluent Treatment Facility
FFRDC	federally funded research and development center
FIU	Florida International University
FY	fiscal year
GIS	geographic information system
HEPA	high-efficiency particulate air
HLW	high-level waste
HQ	Headquarters
HWEE	Hanford Waste End Effector
IAEA	International Atomic Energy Agency

ICTP	International Centre for Theoretical Physics
IDAV	Internal Data Access and Visualization
IDF	Integrated Disposal Facility
IF	impact factor
ILAW	immobilized low-activity waste
IRID	International Research Institute for Nuclear Decommissioning
ISG	International Simple Glass
ITRC	Interstate Technology and Regulatory Council
LAW	low-activity waste
LAWPS	Low-Activity Waste Pretreatment System
LDRD	Laboratory Directed Research and Development
LERF	Liquid Effluent Retention Facility
LLNL	Lawrence Livermore National Laboratory
LM	Office of Legacy Management
MSA	Mission Support Alliance
NAS	National Academy of Sciences
NCRP	U.S. National Council on Radiation Protection and Measurements
NDAA	National Defense Authorization Act
NDE	nondestructive evaluation
NE	Office of Nuclear Energy
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFFS	nuclear fuel fragment specimens
NIST	National Institute of Standards and Technology
NMSU	New Mexico State University
NPSI	Nuclear Process Science Initiative
NQA	Nuclear Quality Assurance
NVLAP	National Voluntary Laboratory Accreditation Program
ORP	Office of River Protection
P&T	pump and treat
PA	performance assessment
PAC	Program Advisory Committee
PBI	Performance Based Incentive
PEMP	Performance Evaluation and Management Plan
PFAS	per- and polyfluoroalkyl substances
PFP	Plutonium Finishing Plant
PHB	Prototype Hanford Barrier
PHOENIX	PNNL-Hanford Online Environmental Information Exchange
PNNL	Pacific Northwest National Laboratory

POC	point of contact
QTP	qualified technical professional
R&D	research and development
RAVIS	Robotic Air-Slot Volumetric Inspection System
RemPlex	Center for Remediation of Complex Sites
RL	Richland Operations Office
RPL	Radiochemical Processing Laboratory
RPP	River Protection Project
RREVIS	EMAT Volumetric Inspection System
S&T	science and technology
SC	Office of Science
SCRA	stirred coupon reactor analysis
SEA	Special Emphasis Area
SIP	spectral induced polarization
SLAW	supplemental low-activity waste
SOCRATES	Suite of Comprehensive Rapid Analysis Tools for Environmental Sites
SPFT	single-pass flow-through
SRNL	Savannah River National Laboratory
SSSA	Soil Science Society of America
SST	single-shell tank
STEM	science, technology, engineering, and math
SVE	soil vapor extraction
TEPCO	Tokyo Electric Power Company
TOC	Tank Operations Contractor
TOS	Thermal Oxidization System
TRAC	Tracking Restoration and Closure
TRT	Technical Review Team
TSCR	Tank Side Cesium Removal
TSR	technical safety requirement
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VE	virtual environment
VR	virtual reality
WCS	Waste Control Specialists
WMA	Waste Management Area
WRPS	Washington River Protection Solutions
WSU	Washington State University
WTP	Waste Treatment and Immobilization Plant

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1.0 PEMP Goals and Grading Metric Overview

The Performance Evaluation and Measurement Plan (PEMP) provides a standard by which the U.S. Department of Energy (DOE) determines whether the national laboratories are being managed and operated to meet DOE mission requirement and performance expectations. The purpose is to identify areas where the national laboratory is excelling, opportunities for improvement, and other trends that may indicate a change in our sponsors' perception regarding our performance. With respect to PEMP goals, the DOE Office of Science (SC) appraisal process uses a five-point (0 to 4.3) scoring system with corresponding grades for the performance goals and objectives. The following table shows the scale SC uses for assigning scores and letter grades.

Key:	A+	A	A-	B+	B	B-	C+ or Below
	4.3-4.1	4.0-3.8	3.7-3.5	3.4-3.1	3.0-2.8	2.7-2.5	2.4-0

To establish corresponding grades, SC also supplies a series of metrics from which the Laboratory's performance can be gauged. More specifically, SC defines overarching performance goals with more granular objectives and elements/factors within each objective upon which performance measures should be based. SC solicits input from other organizations that support work at PNNL, including the DOE Office of Environmental Management (EM), focusing on two specific performance goals: 1.0 Mission Accomplishment and 3.0 Science and Technology Project/Program Management. Five objectives specifically aligned with performance goals 1.0 and 3.0 are outlined below with example elements/factors:

Objective 1.1: Science and Technology Results Provide Meaningful Impact on the Field

- Impact of science and technology (S&T) results on DOE or other customer mission(s)
- Impact of S&T results and publications on the field, as measured by peer review
- Deliver on proposed S&T plans
- Invited talks, citations, providing high-quality data to the scientific community
- Development of tools and techniques that become standards or are widely used in the scientific community

Objective 1.2: Provide Quality Leadership in S&T that Advanced Community Goals and DOE Mission Goals

- Willingness to pursue novel approaches and/or demonstration of innovative solutions to problems
- Willingness to take on high-risk/high-payoff/long-term research problems,
- The uniqueness and challenge of science pursued, recognition for doing the best work in the field
- Extent and quality of collaborative efforts
- Significant awards
- Staff members visible in leadership positions in the scientific community, involvement in professional organizations, National Academies panels, and workshops

Objective 3.1: Provide Effective and Efficient Strategic Planning and Stewardship of Scientific Capabilities and Program Vision

- Development and maintenance of core competencies
- Ability to attract and retain highly qualified staff
- Efficiency and effectiveness of joint planning (e.g., workshops) with outside community
- Creativity and robustness of ideas for new facilities and research programs

Objective 3.2: Provide Effective and Efficient S&T Project/Program/Facilities Management

- The use of Laboratory Directed Research and Development (LDRD) and other Laboratory investments and overhead funds to improve the competitiveness of the Laboratory
- The Laboratory's management of research and development (R&D) programs and facilities according to proposed plans
- Effectiveness in leveraging across multiple areas of research and between research and facility capabilities

Objective 3.3: Provide Efficient and Effective Communications and Responsiveness to Headquarters Needs

- The quality, accuracy, and timeliness of the Laboratory's response to customer requests for information
- The extent to which the Laboratory provides point-of-contact resources and maintains effective internal communications hierarchies to facilitate efficient determination of the appropriate point-of-contact (POC) for a given issue or program element
- The effectiveness of the Laboratory's communications and depth of responsiveness under extraordinary or critical circumstances
- The effectiveness of Laboratory management in accentuating the importance of communication and responsiveness

Given that the overarching goals capture one or more objectives, this self-assessment document is structured such that the five objectives define the major sections. Each major section defines the overarching goal, the specific objective, and a complete list of specific elements and factors that SC identifies to support this assessment. Following the list of SC goals, objectives, and elements/factors, PNNL describes discrete accomplishments that align with the metrics used by SC to measure PNNL's performance. The information provided by PNNL should be considered in measuring and evaluating the Laboratory's performance by the organizations that funded work at PNNL in fiscal year (FY) 2020 to support the EM legacy waste cleanup mission.

2.0 Objective 1.1: Science and Technology Results Provide Meaningful Impact on the Field

Goal 1: Produce high-quality, original, and creative results that advance science and technology (S&T); demonstrate sustained scientific progress and impact; receive appropriate external recognition of accomplishments; and contribute to overall research and development (R&D) goals of the DOE and its customers

Objective 1.1: Science and Technology Results Provide Meaningful Impact on the Field

Description: By which we mean demonstrated sustained technological and scientific progress and state-of-the-art advancements as measured by progress reports, program and project reviews and external reviews; the number of articles and citations in well-respected journals; and demonstrated progress compared to the technical objectives.

In assessing the performance of the Laboratory against this objective, the following assessment elements should be considered:

- Performance of the Laboratory with respect to proposed research plans, community impact and peer review, and DOE mission needs

The following is a sampling of factors to be considered in determining the level of performance for the Laboratory against this objective. The evaluator(s) may consider the following as measured through progress reports, peer reviews, field work proposals (FWPs), program office reviews/oversight, etc.:

- Impact of S&T results and publications on the field, as measured by peer review
- Impact of S&T results on DOE or other customer missions(s) and/or outside the field indicating broader impact
- Successful stewardship of mission-relevant research areas
- Deliver on proposed S&T plans
- Invited talks, citations, providing high-quality data to the scientific community
- Development of tools and techniques that become standards or are widely used in the scientific community

2.1 Impact of S&T Results on DOE and Other Client Missions

PNNL's science, technology, and leadership are enabling critical cleanup decisions across the DOE complex, reducing technical uncertainty, and helping to protect human health and the environment. PNNL provided the technical foundations to enable critical cleanup decisions as well as technology development, maturation, and deployment. Our contributions are aligned with EM's mission in waste processing, nuclear fuels and materials management, and environmental remediation, and are often delivered directly in support of EM's contractor community to support the baseline. The next three subsections highlight PNNL's major technical accomplishments supporting the EM mission in three key areas: waste processing (Section 2.1.1), nuclear fuel and material management (Section 2.1.2), and environmental remediation (Section 2.1.3).

2.1.1 Waste Processing

2.1.1.1 Washington River Protection Solutions (WRPS)

Where noted, the following PNNL performance areas supported WRPS in their completion of Performance-Based Incentives (PBIs) and Special Emphasis Areas (SEAs) by providing technical expertise, laboratory studies and testing, documentation, and/or embedded staff as detailed further in each technical summary. The associated PBIs or SEAs supported with this work are identified for each entry.

- **In support of WRPS SEA-3 and SEA-8, PNNL is developing the fundamental knowledge needed to advance low-temperature and low-cost waste forms and improve processing of Hanford's low-activity and secondary wastes**. PNNL is applying its expertise in material science, waste form fabrication, mineralogy, and geochemistry, and its extensive performance testing capabilities, to support the Tank Operations Contractor (TOC) in evaluating low-temperature waste forms for (1) Hanford Waste Treatment and Immobilization Plant (WTP) liquid secondary wastes [including processes at the Hanford Site Effluent Treatment Facility (ETF) and the Effluent Management Facility (EMF)]; (2) solid secondary wastes [including non-debris and debris wastes produced from Direct Feed Low-Activity Waste (DFLAW) and full WTP operations]; and (3) potential supplemental low-activity waste (SLAW) immobilization. The data generated and analyses are critical to qualifying these waste forms for disposal in the Hanford Integrated Disposal Facility (IDF) or offsite facilities and will help provide the defense in depth for IDF performance assessment (PA) maintenance activities. Additionally, PNNL has provided significant input to WRPS and the DOE Office of River Protection (ORP) on the Grout/Cementitious Waste Form Technology Development and Integration Plan and has presented on grout technologies to many stakeholder groups, including the Hanford Advisory Board, Washington State Department of Ecology, Oregon Department of Ecology, and DOE. *POC: WRPS, Jason Vitali*
- **PNNL is directly supporting the WRPS Chief Technology Office (CTO) with respect to the Low-Activity Waste (LAW) IDF PA Program (WRPS SEA-3 and SEA-8).** PNNL provides direct support to the CTO with substantial input to the WRPS CTO IDF PA program plan, which identifies critical data needs, identifies the testing program required to obtain the data to fill those gaps, integrates scope among the various technology providers, and prioritizes the overall program relative to programmatic objectives. The program plan discusses the testing programs for various waste forms, how the data generated will be integrated into the PA, and the critical decision points to support facility operations and final waste form disposition. *POC: WRPS, Jason Vitali*
- **PNNL continues to serve as the immobilized low-activity waste (ILAW) lead laboratory for WRPS, integrating across the complex to provide the technical basis for the glass waste form strategy, including defining data needs and testing protocols, to support the IDF PA (WRPS SEA-3 and SEA-8)**. PNNL is delivering critical PA input data (rate model parameters) for the enhanced glass compositional envelope through standardized and high-throughput test methods. The outcomes of this work when integrated with the ORP Vitrification Support Program provide a link between the IDF and facility operations with respect to long-term glass performance, enable flexibility for facility operations (larger compositional region of acceptability), and allow for higher waste loadings to be targeted for facility operational efficiency and, in turn, reduce mission life. Additionally, PNNL is using alternative testing techniques to increase data collection, actively reducing risk and uncertainty in long-term glass disposal and providing a means to represent the enhanced glass composition envelope in PA modeling using composition parameter correlation modeling methods developed at PNNL. Field lysimeter testing is underway to validate PA release model parameter estimations and reduce uncertainty in waste form degradation prediction in the IDF. *POC: WRPS, Jason Vitali*

- **PNNL continues to operate the Hanford Radioactive Test Platform in the Radiochemical Processing Laboratory (RPL) (WRPS SEA-3 and SEA-8).** The Radioactive Test Platform is being used to (1) optimize the baseline DFLAW flowsheet with respect to integrated unit operations, (2) provide process data (such as Tc speciation) to inform critical decisions on disposal options, and (3) evaluate a wide variety of proposed changes to the baseline flowsheet (before facility implementation, reducing risks) with actual waste samples from the Hanford tank farms. Design and operational options evaluated included assessing changes to the DFLAW flowsheet, including dead-end filtration planned for the Low-Activity Waste Pretreatment System (LAWPS) and crystalline silicotitanate media for Tank Side Cesium Removal (TSCR) and LAWPS. FY20 work focused on evaluating the second batch of feed for TSCR, with filtration and ion exchange tests of AP-105. In addition, PNNL completed vitrification of a radioactive tank waste sample from AP-107 with recycled condensate. Samples generated from the Radioactive Test Platform also support work on the speciation of Hg and I in the process flowsheet. Use of this test platform capability to process actual waste slated to be processed through DFLAW provides valuable data and insight on the performance of the WTP in upcoming planned operations. *POC: WRPS, Jason Vitali*
- **PNNL leveraged its expertise in nondestructive evaluation (NDE) technology engineering and reliability testing to define, organize, and provide technical oversight during design reviews and site acceptance testing of the Robotic Air-Slot Volumetric Inspection System (RAVIS) and remote robotic EMAT (Electromagnetic Acoustic Transducer) Volumetric Inspection System (RREVIS) under the Non-visual (Volumetric) Nondestructive Examination Technology Engineering Program [WRPS SEA-3 and PBI 62.0, contract line number (CLIN) 2, Milestone 62.0.25].** The RAVIS and RREVIS are complementary robotic ultrasonic guided wave inspection systems that are being engineered by commercial vendors to inspect access-limited/physically inaccessible Hanford primary tank bottoms that are at high risk for corrosion, comprise ~90% of a tank bottom area, and have not been thoroughly inspected since tank construction.

  PNNL worked with RAVIS sensor and robotic technology vendors to complete several test campaigns to evaluate (1) the radiation tolerance of the air-slot sensor and radiation-vulnerable robotic components at radiation and temperature conditions that are conservatively representative of those in the tank farm; (2) the reproducibility of flaw detection performance of the air-slot sensor under blind test conditions that represent tank farm conditions; and (3) the positioning performance of the robotic system in representative tank farm air-slots. The test results will be used as a basis for declaring the air-slot sensor ready for continuation of flaw detection qualification and declaring whether the robotic system is safe/suitable for pilot testing in a double-shell tank (DST) system in the 2020-2021 timeframe. PNNL worked with the RREVIS sensor/robotic vendor to complete a thorough review of their sensor and robotic designs via direct evaluations, calculations, or finite element analysis to provide input on how to address design aspects that did not meet requirements prior to the vendor advancing to system fabrication.

  Under a parallel effort, PNNL is leveraging its data science/machine learning capability to develop data processing and data reduction strategies that will be used to convert NDE inspection results to flaw location and size information needed to inform operational decisions on remaining tank service life or repair for tank life extension. Input to TOC technology maturation plans and implementation plans continued to be provided to specify the verification and qualification process of NDE sensors and robotic systems, and the qualification process for RAVIS and RREVIS to provide a technical basis for endorsing them for primary tank bottom inspections. *POC: WRPS, Jason Vitali*

- **PNNL continues to provide independent ultrasonic testing data review and statistical analysis of DST data (WRPS SEA-3).** WRPS has a program to perform periodic ultrasonic inspections of DST walls plus part of the accessible outer liner floor. PNNL receives the data, reviews the data for completeness and consistency, then performs an extreme value statistical analysis plus a temporal trend analysis to estimate the maximum corrosion-based wall thinning, pitting, and cracking that would be expected over the entire system based on a limited ultrasonic test sample. This analysis is released to WRPS as a fully reviewed PNNL report. In 2020, three tank data sets were reviewed: AW-101, AW-102, and AW-106. The results of these reports either (a) support continued operation of the tanks with confidence that corrosion is being safely managed or (b) provide the basis for a change to the tank corrosion management program (e.g., more frequent inspection, adjusting effluent chemistry, adjusting the liquid level to move the air/fluid interface, or adjusting the annulus ventilation). *POC: WRPS, Jason Vitali*
- **PNNL is leveraging an emerging Lab investment in solid phase processing to demonstrate the feasibility of repairing a pitted carbon steel plate with cold spray – a candidate method for in-service repair of high-level waste (HLW) tanks on the Hanford Site (WRPS PBI 62.0, CLIN 2, Milestone 62.0.34).** PNNL conducted feasibility tests to evaluate the powder preparation requirements and investigate the cold-spray operating parameters necessary to build up uniform, high-density deposits of mild steel on 1/2-inch-thick mild-steel plate and over simulated small-diameter flaws. Test results provide a basis for developing a full set of cold-spray process parameters for carbon steel primary tanks and secondary liners that would result in long-term, metallurgically sound repairs. The process parameters developed at PNNL for carbon steel repair would be used with commercial cold-spray technology by the TOC to restore the leak integrity of primary tanks and secondary liners, and thereby extend tank service life. Application of in situ cold-spray repair to the DOE complex has the potential to reduce cost and schedule impacts associated with component failures and the need to procure and construct replacement infrastructure. Although not formally included in the WRPS PBI, PNNL's analysis process, technology testing, and documentation of the down-select process used to identify potential methods for repairing and extending the service life of infrastructure provided input and support to the WRPS PBI. *POC: WRPS, Jason Vitali*
- **PNNL is providing the technical underpinning for the TSCR system deployment (WRPS SEA-3, SEA-5, SEA-8, PBI 61.0, CLIN 3, and Milestone 61.0.8).** PNNL initiated additional technical support activities, employing expertise in simulant development, waste filtration, ion exchange, and safety analysis, to strengthen the technical underpinnings and safety basis of the TSCR system. TSCR performance at higher solids concentration arose as a potential uncertainty for future operation. PNNL proposed a pilot-scale test system to address the performance uncertainty using prototypic operations. The system, in conjunction with an appropriately designed simulant, would be used to establish the limits of performance of the filtration and ion exchange systems at high solids loading. PNNL also coordinated a collaborative study with Los Alamos National Laboratory to perform critical testing of the ion exchange column breather filter. The testing addressed a safety basis concern regarding the filter's ability to withstand a flammable gas deflagration/explosion. PNNL continues to support WRPS and its design agent in maturing technologies in the areas of ion exchange performance, gas generation, simulant development, filtration, and the TSCR safety basis. *POC: WRPS, Jason Vitali*

- **PNNL is analyzing and integrating performance results from respirator cartridge testing data on Hanford tank vapors to provide a technical basis for cartridge service life estimation by industrial hygiene professionals. PNNL is supporting WRPS and ORP in providing independent analysis and reporting on cartridge performance to support the tank farms respiratory protection program (WRPS SEA-7).** Between 2016 and 2018, 38 air purifying and powered-air purifying respirator cartridge tests on Hanford tank headspace or exhauster vapors were completed. PNNL applied expertise in materials, chemistry, toxicology, and chemical engineering to independently analyze test data, integrate results from all testing, and document results in a series of individual draft reports and two integrated summary reports. These drafts were subsequently peer reviewed by an external expert panel, and a subset of the reports was also reviewed by a qualified technical professional (QTP) as required by the Vapors Settlement Agreement. PNNL addressed all expert panel and QTP comments and issued publicly available, final versions of sixteen reports in FY20. The results provide a technical basis for industrial hygiene professionals to select respirator cartridges for tank farm applications, and define the change schedule for cartridge replacement. Based on the results of 3 years of cartridge testing on a wide range of tank vapor sources, lessons learned are being incorporated into planning for a future test capability that can address any residual cartridge performance uncertainties and new cartridge performance evaluation under the unique mixture conditions that exist in tank farms. *POC: WRPS, Jason Vitali*
- **PNNL is generating the technical strategy to advance the NUCON Thermal Oxidization System (TOS) toward deployment in the Hanford tank farms (WRPS SEA-3).** PNNL is partnering with WRPS to formulate test objectives, define analysis methods, and specify sampling techniques for a tank farm (full-scale) NUCON TOS demonstration unit to be installed on single-shell tank (SST) BY-108. The BY-108 tank farm TOS design, installation, and testing are based on recently completed PNNL-led testing, i.e., Phase 2. PNNL serves as the technical steward of the test approach for future BY-108 (Phase 3) testing operations. This testing is a key component of the Vapor Consent Decree with the State of Washington. The Phase 3 testing of the NUCON TOS on BY-108 will provide a set of field data on destruction of chemicals of potential concern that advises the TOC on whether the technology can be used to treat other SSTs. The data will also provide critical information that guides future installations across SSTs in tank farms. *POC: WRPS, Jason Vitali*
- **PNNL is developing and deploying data analysis tools to support WRPS industrial hygiene functions, including exposure assessments (WRPS SEA-7).** PNNL developed the public-facing Tank Vapors Data Access and Visualization (DAV) application in FY18 to support transparency in communication of available tank vapor data, and in FY19 initiated development and deployment of a set of analysis and visualization tools (IDAV) to assist industrial hygiene analysts in performing routine exposure assessments for tank farms, facilities, and job-specific work activities. In FY20, the IDAV web application was completed and deployed with industrial hygiene customers to support tank-farm-specific exposure assessments and pre-job assessments. A chemical mixtures methodology was also implemented within IDAV to allow future exposure assessments to evaluate the potential impact of mixtures of chemical vapors. Additional tools were deployed to support quality and consistency reviews of vapor data, analysis of acute exposures in tank farms, and analysis and reporting of bulk/surface and other industrial hygiene data sets. *POC: WRPS, Jason Vitali*
- **PNNL is establishing the technical defensibility to the proposed DFLAW feed delivery flushing strategy (WRPS SEA-8).** PNNL is using its expertise in waste chemistry and physical properties and corrosion to establish the technical defensibility for an innovative flush strategy that backflushes the DFLAW feed line with WTP liquid effluent. The technical evaluation informs decisions on whether a flush is required, at what frequency and volume, and with what flush fluid properties. This alternative flushing strategy offers a potential savings of 400,000 gallons of flush fluid each year. *POC: WRPS, Jason Vitali*

- **PNNL is performing a structural integrity analysis of record to qualify the AN and AW DSTs for increased storage volume (WRPS SEA-3).** Since 2003, PNNL has performed the structural integrity analyses of record for the DSTs and SSTs at Hanford. These analyses dictate the maximum waste level allowed in the DSTs. In 2008, PNNL completed a structural analysis that demonstrated that the AP tanks could safely store an additional 38 inches of waste, representing 720,000 gallons of additional storage volume in the eight AP tanks. In 2017, WRPS requested that PNNL perform a similar analysis to qualify the AN and AW tanks for increased waste height. In 2019, the seismic spectra were updated to the 2014 probabilistic seismic hazard analysis, and the analysis will be completed in 2020. Conclusions similar to those of the AP analysis are expected, which could increase the storage capacity of the 13 AN and AW tanks by 1,170,000 gallons. PNNL has also used its verified tank structural models to assess the addition of new tank dome risers for increased access during waste retrieval. *POC: WRPS, Jason Vitali*
- **PNNL completed the AX-102 structural integrity analysis (WRPS SEA-3).** Concrete spalling was found on the inside wall of the AX-102 SST during in-tank inspection in June 2019. The spalling occurred where a metal flashing is embedded in the wall at a 45° angle just above the top of the primary liner. PNNL completed a structural analysis in early August 2019, showing that the AX-102 tank continued to meet the American Concrete Institute structural code in the spalled condition. This timely analysis allowed WRPS to restart waste retrieval in AX-102 and meet their PBI. The analysis was later reviewed and accepted by an expert structural engineer and the final report was issued in April 2020. This demonstrates the value of PNNL's long experience in analyzing the Hanford tanks and in maintaining the detailed finite element models that can be used to evaluate specific tank conditions such as the AX-102 spalling. *POC: WRPS, Jason Vitali*
- **PNNL continued to provide technical support to Waste Management Area (WMA) C and A-A-X PAs (PBI-59, CLIN 2, Milestones 59.0.18 and 59.0.19) by strengthening the technical basis for the WMA C conceptual model and the impact of geologic heterogeneities on both past leak and closure scenarios.** PNNL has also provided technical support for the modeling approach developed in the WMA C PA, and its adaptation to the initial WMA A-AZ PA through technical reviews of PA documents and presentations. *POC: WRPS, Jason Vitali*
- **PNNL is providing technical support to develop the test methods/protocols that will support waste feed qualification efforts for DFLAW operations (WRPS SEA-8).** PNNL provided technical procedures and glass-forming chemicals, and performed demonstrations on how to effectively and efficiently convert melter feed (waste plus glass-forming chemicals) to a glass product to WRPS personnel at the 222-S Laboratory. The information was used by staff at 222-S to convert a simulant melter feed to glass using newly installed equipment at 222-S, completing a major milestone for the contractor. *POC: WRPS, Jason Vitali*
- **PNNL is providing technical support for producing the TSCR documented safety analysis (DSA) and technical safety requirements (TSRs) (WRPS PBI 61.0, CLIN 3, Milestone 61.0.8, and SEA-5).** PNNL is producing DSA and TSR sections for credited safety controls that prevent or mitigate analyzed hazards of the TSCR process. Producing the credited safety control sections supports the contractor's milestone of submitting the DSA and TSR for DOE approval. *POC: WRPS, Jason Vitali*
- **PNNL is providing technical support in a collaborative effort with the Vitreous State Laboratory and Savannah River National Laboratory (SRNL) to evaluate technologies that could be implemented to improve performance and operations of a SLAW grout flowsheet (WRPS SEA-3).** PNNL has supported this effort with literature evaluations, document drafting and reviews, and engagement with collaborators. The end deliverable of the evaluation will be a memo summarizing the findings and providing a roadmap for near-term development needs. *POC: WRPS, Jason Vitali*

- **PNNL provided a technical review report of biodegradation pathways for acetonitrile present at the Liquid Effluent Retention Facility (LERF) and destined for ETF (WRPS SEA-3).** The review highlighted the potential for biodegradation pathways to reduce acetonitrile concentrations in the LERF basins, which would substantially reduce risk associated with disposal of effluent wastes from ETF. Due to the small, yet promising, volume of literature on the topic and lack of data on conditions simulating the LERF basins, PNNL provided a targeted test plan to measure degradation rates of acetonitrile at LERF under existing conditions to enable projections of the improvement to ETF operations without added process steps. *POC: WRPS, Jason Vitali*
- **PNNL provided experimental evaluations of media capable of sequestering iodine from waste streams directed from LERF to ETF (WRPS SEA-3 and SEA-8).** Recent projections from WRPS have highlighted the risk associated with iodine at ETF exceeding acceptability limits for immobilized wastes directed to the IDF and exceeding radiological hazard category limits. Removal of iodine from this stream would alleviate this risk. The initial testing effort will down-select candidate media for lab-scale column testing. The data from the column testing will be used to design scaled column testing in support of a near-term deployment of an iodine removal system at ETF during DFLAW operations. *POC: WRPS, Jason Vitali*
- **PNNL is providing a conservative correlation for the aerosol release fraction of sprays from postulated pipe accidents to support the hazard categorization determination of the LERF (WRPS SEA-5).** PNNL previously developed a conservative correlation for the cumulative generation rate (volume per time) of aerosol droplets less than or equal to specific sizes from spray releases as a function of the spray pressure, orifice area, and droplet diameter. To support the hazard categorization determination of LERF, this correlation needed to be recast into a release fraction using a model for the flow rate of the spray. In addition, release fraction estimates were needed for pressures below the lowest pressure tested in developing the previous generation rate correlation. PNNL developed a new release fraction correlation and demonstrated that it is conservative for all previous test data and extrapolation of previous test data to the lower spray pressure. This correlation was then used to determine the conservative release fraction of a series of LERF pipe breaches, which directly supported the LERF final hazard categorization. *POC: WRPS, Jason Vitali*
- **PNNL continues to support performance testing and design evaluations of the exhaust stack environmental monitoring instrumentation and sample collection systems for the WTP.** PNNL performed stack verification testing observations at the WTP LAB facility and has provided an analysis of the stack qualification for this facility. In addition, PNNL will provide oversight for the verification testing activities for the LAW and EMF stacks, and has provided guiding documents for WTP use. Federal regulations mandate the sampling and monitoring of releases from airborne radioactive substances from exhaust stacks. Sample collection systems must be designed to extract samples that are representative of the airborne effluent stream. Hence, exhaust stack monitoring, and specifically the planned verification testing, is on the critical path for the DFLAW WTP startup and safe operations. *POC: WRPS, Jason Vitali*
- **PNNL is providing technical support to WRPS with the characterization of plutonium-bearing particles that are held in small waste samples that originate from the Hanford tank farms to address nuclear criticality concerns.** The Pu particles of concern have been described as having forms such as PuO_2, Pu oxyhydroxides, Pu-bismuth (Bi), and Pu-Bi-phosphate. The objectives of the study are to characterize these particles and inventories more definitively, especially for composition, size, and density, to inform the criticality safety evaluations to allow handling and processing of these Pu-bearing wastes. More information is needed on the chemical compositions and densities of the Pu particles to establish potentials for particle segregation under special hydrodynamic conditions. Nuclear criticality safety concerns arise because a small fraction of Pu inventory in the Hanford tank waste is in the form of large, dense particles that might be segregated from other waste solids by hydrodynamic conditions during waste handling. Initial characterizations have estimated that about

4% of all Pu in the tank farms is in the particulate form that presents the criticality safety concerns. PNNL has used a combination of scanning transmission electron microscopy and atom probe tomography to examine the nature of these Pu solids. The phases appeared to consist of mainly 10- to 30-nm particles of PuO_2, with nano-particle impurities, and voids that may have undergone orientated attachment processes to form 10- to 40-micron-sized particles. The results indicated that the particles formed from the rapid precipitation of Pu, Bi, phosphate, and other trace metals, are much less dense than pure PuO_2. No evidence of metallic forms or pure Pu-Bi phosphate phases was found. *POC: WRPS, Jason Vitali*

- **PNNL is isolating and quantifying inorganic iodine species in Hanford tank waste and during waste processing (WRPS SEA-8)**. PNNL has separated and quantified inorganic iodine species for multiple Hanford waste tanks (i.e., AP-107, AP-105, and AN-102) and from representative lab-scale waste processing unit operations (i.e., filtration, cesium ion exchange, and vitrification) by leveraging radioactive effluents from PNNL's Radioactive Test Platform. Innovative separation methods and iodine-sensitive analytical equipment enable these accurate measures of key iodine species that are important to establishing iodine inventory, understanding and predicting iodine behavior during waste processing, and compliance with waste disposition assumptions. The iodine inventory in the Hanford tank farms is currently uncertain and the speciation of that iodine inventory is only assumed. Iodine mass movements throughout the flowsheet are highly variable and pose significant risk to air permit authorizations at multiple facilities and to secondary waste disposition assumptions. The new iodine speciation capability and flowsheet measures validate and update iodine feed inventory and flowsheet assumptions for the entire waste processing mission. *POC: WRPS, Jason Vitali*
- **PNNL is identifying, developing, and establishing underlying technical bases for the River Protection Project (RPP) Integrated Flowsheet (WRPS SEA-8).** PNNL is using its expertise in waste chemistry and physical properties, fluid dynamics and scaling, waste processing technology development, waste form development and testing, and applied engineering solutions to identify and innovatively resolve technical gaps and improvement opportunities for the RPP Integrated Flowsheet. The technical work generated by this project closes flowsheet and operations gaps and realizes opportunities by providing technically defensible bases and tools used in establishing flowsheet strategies and modeling parameters to predict and plan the successful execution of the RPP waste cleanup mission. *POC: WRPS, Jason Vitali*
- **PNNL has developed and implemented a methodology to isolate and determine mercury speciation in Hanford tank waste with part per billion detection capability (WRPS SEA-3 and SEA-8).** PNNL has developed and implemented a methodology to isolate and determine mercury species in Hanford waste streams based on the low-level mercury methods used to isolate and quantify mercury in the environment. The work has speciated mercury in raw tank waste samples from AP-107, AP-105, and AN-102 to establish a defensible feed inventory basis for two of the first feed inventories to be processed during DFLAW. In addition, the work leveraged effluent samples from PNNL's Radioactive Test Platform to speciate mercury after filtration, cesium ion exchange, and vitrification using prototypic lab-scale unit operations. Currently, there is very little information on mercury in Hanford tank wastes, with assumptions and speculation on mercury speciation throughout the flowsheet. Mercury inventory and flowsheet assumptions have both been validated and updated with this new mercury information. This work validates mercury feed inventories, which will ensure compliance with mercury-to-sodium waste acceptance criterion; it demonstrates mercury behavior and mass movements to anticipate secondary waste land disposal restrictions and air permit abatement assumptions during the DFLAW mission and beyond. *POC: WRPS, Jason Vitali*

- **PNNL is evaluating and summarizing fluoride-salt dissolution kinetics to predict and optimize required sludge washing durations and dilution volumes during Direct Feed High-Level Waste (DFHLW) operations (WRPS SEA-8).** PNNL is evaluating data on fluoride-bearing sludge washing to minimize dilution volumes and the duration of sludge washing operations at Hanford. Fluoride can be detrimental to waste vitrification and is therefore limited through sludge washing with water. Fluoride salts, however, are sparingly soluble. Significant wash water volumes requiring evaporation and treatment are predicted to result. Process parameters that may significantly influence the washing time – like temperature, wash fluid, and particle size – are assessed, as is the relative importance of various parameters to dissolution trends. This work establishes the current technical bases for predicting the rate and extent of fluoride-salt dissolution, identifies key knowledge gaps, and recommends solutions. *POC: WRPS, Jason Vitali*
- **PNNL is evaluating existing sludge solids settling behavior data at Hanford and within the DOE complex to predict the success of DFHLW settle-decant operations for WRPS.** PNNL is compiling and summarizing all sludge settling rate data (in situ and laboratory) to provide insight into potential time periods for settle-decant operations. This work also establishes settled solids strength knowledge to inform Hanford mobilization, mixing, and feed transfers after settle-decant operations. Tracking suspended and insoluble solids across the flowsheet is essential for treatment throughput and to predict slurry compositions for processing, mitigate potential safety issues (e.g., transfer line plugging and flammable gas release), and anticipate infrastructure/capability needs (e.g., filtration) and operations protocols (e.g., settle and decant timing or transfer pump inlet height). *POC: WRPS, Jason Vitali*

2.1.1.2 Office of River Protection

- **In support of ORP, as mandated by congress in National Defense Authorization Act (NDAA) Section 3134 (2017), PNNL completed key technical and regulatory analysis and provided leadership to assess the acceptability of SLAW forms.** PNNL applied subsurface science, modeling, waste form, and regulatory expertise to the multi-laboratory NDAA project team to evaluate the potential disposal of a LAW grout as well as other alternative waste forms in both onsite (IDF) and offsite commercial mixed low-level waste disposal sites. Specifically, PNNL conducted a waste form performance simulation in FY19 to predict long-term performance of waste forms in the IDF. This study evaluated the future groundwater impacts of glass, grout, and steam-reforming waste forms and their secondary wastes on a common basis for side-by-side comparison. A range of parameters from the most current research was used along with benchmarking to the current IDF PA for glass and secondary waste forms. The study concluded that the grout waste form would meet DOE performance requirements as well as Washington State groundwater protection expectations if best-performing grout formulations from recent studies could be consistently produced. Results were documented in a final federally funded research and development center (FFRDC) report released in early FY20 and presented publicly by PNNL to the companion National Academy of Sciences (NAS) study committee, DOE, and the State of Washington. PNNL also organized with EM and ORP a 2020 Waste Management Symposia panel session on supplemental LAW treatment with representatives from the Government Accountability Office, NAS, and FFRDC (SRNL and PNNL) to discuss the findings. *POC: ORP, Kaylin Burnett*

- **Alongside ORP and its contractor, PNNL is directly contributing to the HLW analysis of alternatives, the first task in re-invigorating the HLW treatment mission at Hanford.** ORP is re-evaluating the HLW treatment mission at Hanford as a basis for future Consent Decree and Tri-Party Agreement negotiations and restarting the HLW treatment mission. Working alongside ORP and its contractors, PNNL used its expertise and experience in radiochemical flowsheets to establish technically viable HLW treatment flowsheets covering a range of complexity. Additionally, PNNL used its expertise and experience in tank waste treatment project management to accurately identify and quantify the threats and opportunities associated with these flowsheets. *POC: ORP, Kaylin Burnett*
- **To facilitate transition to DFLAW operations, PNNL recommended and implemented the programmatic and cultural elements important for sustained waste treatment operations for ORP.** ORP recognizes that the RPP mission needs to transition from a posture commensurate with design and construction to one optimal for commissioning and sustaining operations. PNNL used its expertise and experience with first-of-a-kind radiochemical facility operations to identify and recommend the programmatic and cultural elements important to commissioning and sustaining waste treatment operations. Working alongside ORP and its contractors, PNNL used the same experience to ensure that resolution of current issues and opportunities for improvement is consistent with a sustainable operations culture. Consistent with its recommendations, PNNL is further using its risk and decision science expertise to contribute to establishing an integrated and contractually impartial risk management program for the DFLAW program encompassing the risks to ORP and its contractors. The risk management program drives risk-based decision-making across the DFLAW program. *POC: ORP, Kaylin Burnett*
- **PNNL created a tool that summarizes the risks and benefits associated with retrieving waste from selected SSTs, enabling ORP decision-making for alternative tank waste disposition pathways.** Advice from multiple sources using multiple, sometimes conflicting, technical bases introduces uncertainty into ORP's decision-making on SST waste retrieval strategies. PNNL is using its expertise and experience in the risk and decision sciences and radiochemical flowsheets to create a tool that captures the critical and impartial attributes associated with retrieving the waste from each Hanford SST. Taking input from across the Hanford tank farm community, the tool is based on broadly accepted technical information. The tool is designed to be used directly by ORP staff to underpin their future discussions internally and with stakeholders on alternate disposition pathways. *POC: ORP, Kaylin Burnett*
- **Important for robust DFLAW operations, PNNL is leading definition of a DFLAW integrated operational process control strategy for ORP.** With the current mission focus almost wholly on DFLAW startup, PNNL is facilitating the transition to operations by identifying process control parameters and their operating ranges to predict operational performance and establish the flexibility of the DFLAW process system. Using its expertise across the entire DFLAW flowsheet and working with the Hanford contractors, in Phase I, PNNL identified the functions and requirements for each unit operation with their technical bases and the process parameters used to control or monitor the unit operations consistent with their functions and requirements. *POC: ORP, Kaylin Burnett*
- **PNNL is enabling Raman spectroscopy for real-time, in situ chemical analysis of nuclear waste during Hanford tank farm and WTP waste processing operations.** PNNL is developing and demonstrating real-time sampling technology for chemical analysis of Hanford waste in tanks and pipes. This on-line and real-time analysis uses small footprint probes inserted into process lines or tanks connected by fiber optics to instrumentation that can be located remotely. This allows safe distancing of sensitive items (instrumentation and personnel) while only the robust probes are exposed to radiation, where probes have demonstrated no significant loss in signal reliability up to 10^8 rad. Systems are being configured to provide real-time output of information that can be directly

understood by plant operators and used to enable real-time process control. Laboratory demonstrations include using an on-line configured Raman spectroscopy system to detect and quantify Raman-active analytes within real waste samples from multiple stages of AP-105 processing (filtration and ion exchange as well as evaporation). The results demonstrated that the on-line configured system was capable of detecting and quantifying Raman-active analytes in the sample with a typical accuracy of 5% to 10% within results obtained by traditional off-line analytical laboratory methods. Commercially available Raman spectroscopy equipment was used to support data acquisition, and PNNL's chemometric analysis algorithm/software was used to perform automated data analysis to generate real-time analyte concentration values. With additional verification, an on-line Raman spectroscopy system and other complementary on-line instruments could be qualified and configured for field deployment (tank farms and/or WTP) to reduce demands for traditional sampling and off-line analysis and to provide real-time chemical identification and quantification, which are ultimately necessary to support tank farm and WTP waste management and processing operations. *POC: ORP, Kaylin Burnett*

- **PNNL is providing waste vitrification strategies to ensure safe, efficient, and successful commissioning and operations of the WTP HLW and LAW facilities within the DFLAW concept.** PNNL has applied expertise in waste form development, melter processing, and waste form performance to increase waste loading, address troublesome component solubility limits, increase melting rate and waste throughput, and decrease total glass volume. In addition to the mission benefits, these efforts enable greater operational flexibility and efficiency, both in the various stages of startup and through operational upsets and challenges. These efforts facilitate execution of operational concepts such as the DFLAW flowsheet by ensuring an understanding of any downstream impacts of early operations. PNNL participates in strategies to reduce known risks and stewards testing capabilities to efficiently address issues that emerge. Recent work in this area includes (1) evaluating glass-forming chemicals needed for vitrification as the raw materials market changes, (2) addressing the behavior of troublesome components in the melter offgas such as iodine, and (3) maintaining the capability to evaluate melter feeds from simple benchtop tests up to dynamic melter testing with actual tank waste. Development and implementation of enhanced glass property models and glass formulations will decrease the cost of Hanford tank waste management by reducing the schedule for tank waste treatment and reducing the amount of HLW and LAW glass for storage, transportation, and disposal. Enhanced glass formulations may also result in more cost-effective direct vitrification of the HLW fraction without significant pretreatment. The advances in Al_2O_3 and Cr_2O_3 solubility in borosilicate glasses should reduce or eliminate the need for caustic or oxidative leaching in pretreatment. The ability to target higher Na_2O concentrations will translate into higher waste loadings and ultimately reduce container counts for the LAW Integrated Flowsheet. The integration of increased waste loading, reduced leaching/washing requirements, and improved melting rates provides a system-wide approach to improve the effectiveness of the WTP process. *POC: ORP, Albert Kruger*
- **PNNL is enabling Tc management strategies for LAW vitrification.** PNNL is developing technologies to achieve high Tc retention in LAW glass, leveraging its technical expertise in vitrification and a fundamental understanding of Tc volatilization mechanisms. Another primary focus has been on increasing the waste loading of glass by incorporating Tc into various minerals from the off-gas solution, which could eliminate recycling of the off-gas solution to the melter. Understanding these mechanisms and compiling a database of what does and does not work for Tc capture will support a timely response if Tc management issues arise during WTP commissioning and operations. *POC: ORP, Albert Kruger*

2.1.1.3 Bechtel National Inc. (BNI)

- **PNNL is supporting BNI/WTP in implementation of the Glass Formulation Algorithm to allow DFLAW operations.** As various equipment uncertainties and operating procedures are updated, the impacts of those changes on design and qualification of glass are being assessed and support is given to the project process engineering staff.
- **PNNL is developing key analytical glass standards for BNI/WTP to support DFLAW operations.** Critical to successful operations of the DFLAW flowsheet is the ability to obtain key compositional information that forms the basis for decisions regarding the additions of glass-forming chemicals to the incoming LAW feed vector as well as decisions associated with the acceptability of the melter feed to meet all process and product performance specifications. The current baseline technology for obtaining this compositional information is laser ablation coupled with inductively coupled plasma mass spectrometry or inductively coupled plasma optical emission spectrometry. To support analytical laboratory activities, PNNL has developed a matrix-matched set of glass standards that will be used to calibrate the analytical equipment within the compositional region of interest for LAW vitrification. PNNL is providing scientific leadership to advance or mature WTP analytical capabilities to ensure all critical analytical data can be obtained within the appropriate confidence limits required.

2.1.2 Nuclear Fuel and Material Management

- **PNNL is leading actual waste testing to enable retrieval, storage, and treatment of Hanford Site K-Basin sludges**. PNNL maintains the inventory of well-characterized K-Basin sludge samples to enable testing of future treatment options. Testing over the course of this project has included sludge shear strength as a function of time to better understand how sludge stored in the large engineered containers may develop strength or otherwise change during interim storage. PNNL also conducted essential characterization activities of the K-Basin water sand filter to enable for proper waste designation and disposal. PNNL has additionally supported alternatives analysis, engineering evaluations, and process development and process/unit operation validation tests, and will continue these functions as the overall project progresses toward final sludge treatment and disposition. FY20 efforts included monitoring long-term sludge settling characteristics and maintaining sample inventory integrity. *POC: CH2M Hill Plateau Remediation Company (CHPRC), Mark Byrnes*
- **PNNL continues to conduct safety assessment measurement for spent nuclear fuel stored in the Hanford Canister Storage Building.** PNNL is measuring the helium-to-xenon ratio in gas samples originating from the atmosphere surrounding multi-canister overpacks to identify the presence of moisture and atmospheric oxygen, indicating whether hydrides are being formed and the generation rates of hydrogen. This work supports the continued safe storage of spent nuclear fuel and the long-term transfer from the Canister Storage Building to an off-site permanent repository. *POC: CHPRC, Mark Byrnes*
- **PNNL is providing source term estimates and atmospheric dispersion modeling in support of demolition of the Plutonium Finishing Plant (PFP) at Hanford.** Since the contamination event at PFP in December 2017, PNNL staff have participated in numerous meetings with staff from DOE, the Washington State Department of Health, the Washington State Department of Ecology, and EPA to help plan the restart of demolition. Updated emission and dispersion modeling using the PFP facility current status, plans for cleanup technologies and timing, and multiple years of meteorology have been used to estimate potential concentrations of contaminants in air and on nearby surfaces. Demolition of the 234-5Z building has been completed, and cleanup of the 236Z rubble is underway, incorporating the key model parameters to minimize the likelihood of future mishaps. *POC: CHPRC, Mark Byrnes*

- **PNNL is providing radiological characterization to Hanford Site contractors using NDE assay methods and techniques**. PNNL is applying NDE methods and techniques to support radiological characterization for Hanford contractors. PNNL used gamma spectroscopy and neutron counting techniques to conduct radiological characterization of waste containers and facility components (HEPA filters, pipes, glove boxes, ductwork, etc.) to support environmental remediation activities with waste classification/disposal, transportation, environmental reporting, safeguards and security, work planning, and facility safety basis development. *POC: Mission Support Alliance (MSA), Panfilo Gonzalez*
- **PNNL is providing high-range gamma and neutron radiological instrument calibrations to Hanford Site contractors.** PNNL is using its unique gamma and neutron irradiators to calibrate radiation detection and survey instruments that cannot otherwise be calibrated. In addition to instrument calibration, PNNL also troubleshoots and repairs radiological instruments and high-purity germanium detectors for the Hanford Site. Hanford contractors rely on these instruments and detectors to safely accomplish site remediation activities. PNNL calibrates and repairs roughly 350 instruments a year for the Hanford Site. *POC: MSA, Lindsay Nelson*
- **PNNL is providing NIST/NVLAP (National Institute of Standards and Technology / National Voluntary Laboratory Accreditation Program) accredited radiological exposures for Hanford's dosimetry program**. This includes performing blind testing of dosimetry and preparing quality control dosimetry services. PNNL provides approximately 3,500 dosimetry irradiations for the Hanford Site annually. *POC: MSA, Lindsay Nelson*
- **PNNL is performing radiological effects testing on a unique type of cement for CHPRC.** CHPRC is determining whether a certain type of cement will work to immobilize the 324 Building soil contamination plume. This concrete will be subjected to extremely high radiation. Using two different gamma irradiators, PNNL is subjecting samples of the concrete during the cure time to various levels of radiation to help CHPRC determine if the product will provide the long-term characteristics desired. *POC: CHPRC*, *Mark Byrnes*

2.1.3 Environmental Remediation

- **In support of Hanford milestones M-015-110B, M-015-84, M-015-91B, and M-015-92B:**
  - **PNNL is reducing the uncertainty associated with effective monitoring of vadose zone contaminant sites through a vadose monitoring test bed.** PNNL is defining approaches for monitoring vadose zone fluxes to groundwater so that compliance can be demonstrated for residual contamination at the Hanford Site BC Cribs and Trenches. Although remedies at Hanford and other EM and DOE Office of Legacy Management (LM) sites may result in contaminants being left in place, approaches have not yet been adapted for monitoring contaminants in the deep vadose zone. Traditional sampling approaches are costly, labor-intensive, and are difficult to extrapolate over large regions. The cost-effective, short- and long-term monitoring approaches being tested and configured at this test bed site are relevant for vadose zone sites with both active and leave-in-place remedies, monitored natural attenuation, surface barriers, and SC programs. The vadose zone within the Hanford Central Plateau contains large quantities of mobile contaminants that have not yet reached the groundwater. In situ remedies for vadose zone sites, monitored natural attenuation, or other passive approaches will need to identify monitoring appropriate to the remedy. Platforms include adapting traditional high-resolution geophysical approaches used for monitoring groundwater to unsaturated conditions, integrating geophysics, use of autonomous data collection and robust sensors, and advancing gas and pore-water sampling approaches. *POC: RL, Mike Cline*

- **PNNL is identifying innovative approaches for using geophysical methods to identify key stratigraphic features that create preferential flow paths impacting contaminant transport and remedy applications.** PNNL is determining how geophysical methods can be used for fast, cost-effective, and large-scale characterization, and the utility of integrating various geophysical methods with other hydrogeological data and the data collection and interpretation needed to characterize stratigraphic features important for contaminant transport. Electrical resistivity tomography (ERT) is a candidate method showing promise for characterization of the deep subsurface, using numerical models to assess feasibility prior to conducting field testing. *POC: RL, Mike Cline*
- **PNNL is providing technical input to support a characterization plan for the perched water unit in the Hanford 200-DV-1 operable unit.** PNNL is helping to define the characterization needed to increase extraction rates from the perched water unit in the 200-DV-1 operable unit. The perched water zone contains elevated levels of uranium, technetium-99, nitrate, and other contaminants of concern and is a potential continuing source for the unconfined aquifer in the 200-BP-5 operable unit. A removal action is designed to recover as much perched water as practical in accordance with DOE/RL-2014-37, *Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*, while awaiting issuance of the 200-DV-1 OU Record of Decision. This characterization sampling and analysis plan is being prepared in support of this non-time-critical removal action. *POC: CHPRC, Mark Byrnes*
- **PNNL is supporting the evaluation of technologies for addressing contaminants in the vadose and perched water zones**. PNNL is leading the maturation of coupled treatment strategies to address the remediation of the complex biogeochemistry of contaminant mixtures in both the vadose zone and the perched water zone. PNNL is leading the identification of combined technologies, amendment delivery mechanisms, and combined technology and monitoring approaches to provide key indicators for remedy transitions. This information will be used to identify potential treatability tests for the 200-DV-1 operable unit. *POC: RL, Mike Cline*
- **PNNL is demonstrating ERT as a method for providing large-scale 3D depictions of waste fluid migration pathways to guide placement of characterization boreholes.** PNNL pioneered an innovative method that integrates time lapsed ERT images with complementary characterization methods to identify characterization borehole locations. This approach also identified waste fluid migration pathways at the Hanford U5/U6 cribs, using temporal data to quantify contaminant movement. This approach demonstrates the continued use of cost-effective ERT for vadose zone characterization throughout the Hanford Site. *POC: CHPRC, Mark Byrnes*
- **PNNL is supporting the evaluation of delivery options to ensure that in situ remedy approaches are effectively deployed at the field scale.** PNNL is leading the systematic evaluation of amendment delivery options for combinations of solid, liquid, and gaseous reactants to measure the effectiveness of amendment delivery technologies for reactant performance, contaminant immobilization, sequestration, and stabilization across a range of Hanford-specific waste site conditions. As potential remediation technologies are identified for hot-spot vadose zone treatments and in the perched water zones, an assessment of delivery medium effectiveness is needed to evaluate the feasibility of in situ remediation approaches. Select reactants for delivery and reactivity are being evaluated for stability and efficacy relative to Hanford Site conditions. *POC: RL, Mike Cline*
- **PNNL is supporting the evaluation of the use of spectral induced polarization (SIP) to monitor subsurface phase changes associated with remedy applications.** PNNL is leading the evaluation of SIP as a method for nonintrusive monitoring for in situ remedy applications. Whereas direct current measurements with ERT can be used to monitor the injection extent of subsurface amendments, alternating current measured with SIP can capture changes resulting from reactivity

associated with biogeochemical reactions. Several different aqueous and gas phase amendments are being considered for subsurface remediation in the vadose zone and perched water zone at Hanford. Laboratory experiments are being used to identify geochemical or microbial evidence amendment reactivity so that this information can be applied at the field scale. *POC: RL, Mike Cline*

- **PNNL completed the 20+ year Prototype Hanford Barrier (PHB) PA and is transitioning this barrier test site into long-term monitoring with lower costs with the use of geophysical surveys.** PNNL is identifying cost-effective methods for long-term barrier monitoring following Nuclear Quality Assurance (NQA)-1 requirements for instrumentation and data collection. DOE has identified long-term surface barriers as a candidate remedy for contamination in the deep vadose zone to reduce contaminant flux into the groundwater. Because surface barriers are an important component of waste site management, surface-deployed, low-cost, and low-intensity geophysical monitoring techniques are being tested at the PHB, a satellite site of the Deep Vadose Zone Test Bed. This effort is evaluating barrier performance with alternative approaches with 20+ years of monitoring data collected at the PHB. The PHB over the 216-B-57 crib was completed in 1994, but past monitoring accounts for only about 2% of the design life. Hence, it is important to monitor barrier structural stability and transition the long-term monitoring to cost-effective methods that monitor moisture content, rather than costly measures of drainage, to indicate barrier performance. *POC: RL, Mike Cline*
- **PNNL is leading an integrated, site-wide data management plan that will support site closure and transfer to LM.** PNNL is leading the development of a data management program plan to support remedy management and site closure. The program plan establishes DOE authority and vision, while establishing a process to support centralized data management and the steps needed to achieve this vision. The program plan includes input and contributions from contractors as well as detailed evaluations of relevant data and information systems that will provide the site data file needed for site closure and transfer to LM. *POC: RL, Mike Cline*

- **In support of the Hanford 200-PW-1, 200-PW-3, and 200-PW-6 operable units, PNNL is identifying mechanisms responsible for plutonium and americium mobility to support remediation decisions.** PNNL is leveraging plutonium characterization and mobility work sponsored by the SC Biological and Environmental Research Program at Lawrence Livermore National Laboratory (LLNL) by identifying mechanisms responsible for lateral plutonium and americium migration. Whereas LLNL is focusing on reconstructing waste history releases and plutonium interactions with clean sediments, PNNL is identifying relevant mineralogical transformations caused by the waste releases and determining how these transformations affect the solubility and adsorption of plutonium and americium. This provides the technical basis to address the nature of plutonium and americium contamination and to provide defensibility for the associated remedy decision. *POC: RL, Mike Cline*
- **In support of Hanford milestone M-016-119-T01:**
  - **In support of 200-UP-1 and 200-PO-1 regulatory decisions, PNNL is collaborating with Argonne National Laboratory (ANL) to provide a technical basis for risk-informed standards for low beta emitters.** PNNL is partnering with ANL to provide a defensible technical basis for science-based protectiveness criteria that can be used in evaluating risk management strategies. Standards in the United States for low-energy beta radioisotopes in drinking water are based on health parameters developed 4 to 5 decades ago that are now shown to be conservative with respect to health impacts. Updated information on dosimetry, effective dose, and biokinetics can be implemented to develop a risk-based approach for evaluating protectiveness, assessing technical impracticability waivers and land use end states, and informing remedial decision-making for environmental management of low-energy beta radioisotopes in groundwater. *POC: RL, Mike Cline*

- **In support of 200-UP-1 and 200-PO-1 regulatory decisions, PNNL is providing an approach for measuring radioiodine speciation using ion chromatography inductively coupled plasma-mass spectrometry.** PNNL is leading the development of a new analytical capability to determine *speciated* $^{127}I/^{129}I$ in the vadose zone and groundwater with detection limits below the federal drinking water standard of 1 pCi/L (~ 5.6 ng/L). Established analytical methods only measure total iodine concentrations, but since iodine speciation controls the rate of iodine transport and plume behavior, speciation information is needed to support radioiodine plume remedy evaluations and technical impracticability waiver efforts. Spatial distributions of iodine speciation are being mapped in support of these remedy assessment activities. *POC: RL, Mike Cline*
- **PNNL is preparing a sampling and analysis plan for performing groundwater tracer tests in the Hanford Central Plateau.** In some areas of the Central Plateau, the observed groundwater gradient is nearly flat due to highly transmissive sediments, and flow direction and velocity are difficult to define. In other areas, operation of groundwater extraction and injection wells creates variable local flow gradients that are not consistent with regional conditions under natural gradient. PNNL's plan will define the requirements for tracer injections, sampling activities, field and analytical measurements, and quality assurance processes for tests to be conducted at two locations: the 200-BP-5 operable unit in the vicinity of the B Tank Farm complex and the 200-UP-1 operable unit near U Plant. These tests will be designed to provide empirical flow direction and velocity data that can be used to assess the representativeness of groundwater flow simulations. *POC: CHPRC, Mark Byrnes*
- **PNNL is providing technical input to support updating the remedial design/remedial action work plan, performance monitoring plan, and operations and maintenance plans for the 200-ZP-1 operable unit.** PNNL is supporting updates to the 200-ZP-1 remedial design/remedial action work plan, performance monitoring plan, and operations and maintenance plan to incorporate elements consistent with managing the active portion of the remedy and the transition to the passive component of the remedy in the future. Drawing from its leadership in national guidance documents, PNNL is providing input to apply appropriate technical defensibility in these documents and use of relevant exit strategy and adaptive management approaches. *POC: CHPRC, Mark Byrnes*
- **PNNL is providing technical input to support a characterization plan for the 200-ZP-1 operable unit deep portion of the aquifer**. PNNL is helping to define the characterization needed to support remedy optimization for the deep portion of the aquifer in the 200-ZP-1 operable unit (Ringold A aquifer unit). PNNL is providing technical input to develop a sampling and analysis plan that supports both active remedy optimization and the transition to the passive component of the remedy. PNNL is also developing a field hydraulic testing plan to further characterize the aquifer properties. This characterization is needed because of the evolving understanding of the carbon tetrachloride plume in the deep aquifer and recognition that contamination in this deep zone may require a different approach and timeframe than the shallower contamination that is the primary focus of current remedy actions. *POC: CHPRC, Mark Byrnes*
- **PNNL is identifying the potential short- and long-term system performance effects of the 200W pump-and-treat (P&T) effluent injection impacts to the Hanford 200W aquifer.** PNNL is leading the development of quantitative conceptual models to determine the impacts of the P&T system on the aquifer and provide performance evaluations of operational changes and aquifer-system injection limits. The 200W P&T system was designed to support 200-ZP-1 remedial action objectives, but other current and potential sources vary the geochemical signatures of the influent waste stream. PNNL is addressing combined operational and influent changes to support remedy optimization efforts and short- and long-term remedy decisions related to multiple operable units within the Hanford Central Plateau. *POC: RL, Mike Cline.*

  - **PNNL is supporting performance assessment of enhanced remediation being implemented for a uranium source zone in the 300-FF-5 operable unit.** PNNL provided real-time monitoring of amendment injection using ERT to assess distribution of phosphate in the targeted portion of the periodically rewetted zone of the Hanford 300-FF-5 operable unit aquifer. This information supported operational decisions during implementation and provided data used as part of remedy PA. PNNL conducted the laboratory assessment of sediment samples to quantify the uranium mobility change induced by the phosphate treatment. This information is a key aspect of the performance assessment and role of the enhanced attenuation portion within the overall passive attenuation approach for the plume. *POC: CHPRC, Mark Byrnes*

- **PNNL is performing analyses to identify secondary chromium sources in the Hanford 100 K Area (Milestone M-016-116-T02)**. PNNL is performing analyses and integrating characterization data to identify a suspected chromium source area for a plume in the 100 K Area of the Hanford Site. This analysis will help quantify the geochemical nature of the continuing chromium source and support performance assessment of soil flushing being applied as a treatability test of potential source treatment. This source characterization and treatment are the remaining elements to be addressed prior to termination of active P&T remediation for this portion of the 100 K Area. *POC: CHPRC, Mark Byrnes*
- **PNNL is supporting CHPRC soil flushing experiments at the 100-KR-4 operable unit by identifying mechanisms that control chromium leachability (Milestone M-016-110-T02).** PNNL is performing analyses to identify mechanisms controlling chromium retention in natural sediments and remedial conditions. Stable Cr-52 and Cr-53 isotopes are being used to identify controlling processes, in chromium that is present from waste (with one isotopic ratio) and chromium that is naturally present (with a different isotopic ratio). *POC: CHPRC, Mark Byrnes*
- **PNNL is collaborating with Sandia National Laboratories to identify in situ materials that can be used as subsurface remedial technologies for co-located contaminants (Milestones M-015-110B, M-015-84, M-015-91B, M-015-92B, and M-016-119-T01).** PNNL is leading the identification of advanced materials that can sequester co-located contaminants in situ, including Tc-99, I-129, and uranium. The overall remediation strategy for the Hanford Central Plateau requires remedial alternatives that consider the complex biogeochemistry of contaminant mixtures, the impact of both chemical and physical subsurface properties on the performance of remedies, and adaptive remediation approaches for implementation. Materials that show great promise for treatment of multiple contaminants are being tested for long-term performance and optimization. These efforts are critical to identifying viable treatment options for challenging, waste-specific species of contaminant mixtures in the deep vadose zone and perched water zone at the Hanford Site, for which existing commercial methods are ineffective. *POC: RL, Mike Cline*
- **PNNL is providing the environmental science and risk and decision expertise to finalize the remedial investigation and initiate the feasibility study for the Pre-Hanford Orchards Lands operable unit, enabling DOE to decide if pre-Hanford pesticides must be remediated (Milestone M-015-96)**. PNNL is leading the completion of the site characterization and remedial investigation report and the draft feasibility study report for orchard lands. Farmstead communities existed adjacent to the Columbia River from 1880 to 1943 and lead arsenate was used to control pests in orchards during this time. *POC: RL, Mike Cline*
- **PNNL is demonstrating a characterization approach for identifying chromium transport between the upper and lower aquifers in support of Hanford 100-HR-3 Area plume assessments and remedy closure.** PNNL is identifying a characterization approach that identifies the hydraulic connection between the upper, unconfined aquifer and the lower Ringold Upper Mud because it influences the selection of an optimal P&T strategy and an appropriate closure strategy for the 100-HR-3 remedy. Traditional well-based approaches available for contractor implementation are

expensive and provide limited data. Thus, an advanced method based on integrated use of multiple data types is needed. This includes the use of data from existing wells, tracer tests, and geophysics to enable more cost-effective P&T operations. The innovative approach supports remedy design and closure at 100-HR-3 and other sites within the River Corridor. *POC: RL, Mike Cline*

- **PNNL is providing the technical basis for selecting representative compliance points for chromium at the Columbia River in support of Hanford 100-HR-3 Area site closure.** PNNL is providing a technical evaluation of spatial and temporal chromium concentrations within 100-HR-3 to identify relationships between the inland groundwater plume and surface-water discharges at the Columbia River. A multi-component approach is being used to evaluate the processes responsible for dilution as the plume migrates toward the Columbia River. This information is being used to support the selection of representative compliance points for meeting cleanup levels that are protective of ecological receptors in the Columbia River. *POC: RL, Mike Cline*
- **PNNL is providing technical support for WMA A and AX tank farm vadose zone characterization (PBIs 52.0.2 and 52.0.5, CLIN 2).** PNNL is providing technical guidance, laboratory experiments, and analyses to assess contaminant mobility and attenuation in the vadose zone for the Hanford WMA A and AX tank farms. This effort leverages PNNL's previous work for the 200-DV-1 operable unit in providing advanced geochemical and hydraulic characterization that enables improved assessment of contaminant flux in the vadose zone and potential impacts to groundwater. This information is needed to provide technical defensibility for tank farm closure activities. *POC: WRPS, Jason Vitali*
- **PNNL maintains the soil moisture monitoring system for the T, TY, and SX tank farm interim surface barrier vadose zone, retrieves monitoring data from the monitoring system, and evaluates the data (Milestone M-045-59 and WRPS PBIs 52.0.1 and 52.0.6, CLIN 2)**. PNNL maintains the monitoring system, collects monitoring data regularly, and provides technical consultation in the analysis of the monitoring data. The precipitation that ends as recharge is the primary force that drives the vadose zone contaminant migrating downward. The T tank farm interim surface barrier was constructed in FY08, the TY tank farm interim surface barrier was constructed in FY10, and the SX farm interim surface barrier was constructed in FY18. These interim surface barriers are used to intercept precipitation so that rainwater does not infiltrate into the soil. With a surface barrier at ground surface, the peak concentration at the groundwater is expected to be substantially reduced and its arrival time is delayed. *POC: WRPS, Jason Vitali.*
- **PNNL leads the national, multi-institutional Deep Vadose Zone - Applied Field Research Initiative to provide the scientific underpinnings and develop and demonstrate transformational remedial strategies**. PNNL continues to lead the development and implementation of integrated technical, regulatory, and policy frameworks to enable remediation of vadose zone environments. This approach integrates efforts from SC and DOD to enhance our understanding of vadose zone challenges and infuses investments from EM to develop cost-effective characterization and monitoring methods, remedial strategies, and design. The results provide a systems-based understanding of water, gas, and chemical exchange within this complex deep vadose zone, to drive improved characterization and long-term monitoring approaches of contaminant behavior and remedial approaches that reduce contaminant fluxes to groundwater, reducing risks to human health and the environment. The initiative is critical for providing the scientific and technical basis to identify, demonstrate, and predict the near- and far-term impact of remedial strategies that prevent contamination from reaching groundwater. *POCs: EM Headquarters (HQ), Kurt Gerdes; RL, Mike Cline*

- **PNNL is leveraging research on contaminant fate and transport while making vital scientific contributions to the ASCEM (Advanced Simulation Capability for Environmental Management) initiative.** PNNL leads the maturation of Akuna software for the multi-DOE national laboratory team by leveraging past investments by SC, the DOE Office of Fossil Energy, and the DOE Office of Nuclear Energy (NE). ASCEM is being demonstrated at the Nevada National Security Site to evaluate the impact of past nuclear testing and prioritize elements of the NQA-1 qualification. ASCEM is also supporting analyses at the Waste Isolation Pilot Plant site through Florida International University (FIU). ASCEM improves the ability to predict the fate and movement of underground contaminants and the degradation of engineered materials that contribute to contaminant release, to enable remedial decisions with less conservatism and greater technical defensibility. *POC: EM HQ, Kurt Gerdes*
- **PNNL continues improvement of the PHOENIX web application, which provides universal access to decades of Hanford Site data.** PHOENIX (PNNL-Hanford Online Environmental Information Exchange) continues to provide easy access to a suite of public-facing web-GIS applications that inform decision-making. PHOENIX continues to support monthly updates to the Remediation Dashboard to visually represent the remediation progress of Hanford's groundwater treatment systems. This tool provides open and transparent access to and visualization of data to facilitate evaluation and communication, furthering public trust and engaging the regulatory and stakeholder communities. PHOENIX enables DOE to communicate cleanup progress and risk reduction as a direct result of cleanup activities. *POC: RL, Mike Cline*
- **PNNL is creating online decision-support tools (SOCRATES) to meet DOE needs for groundwater assessments, real-time remedy support, and P&T exit strategies.** PNNL is providing online NQA-1 qualified tools that enable users to analyze water-level or contaminant data and provide the technical basis for shutting down P&T systems needed to reach site closure. The tools provide rapid online access to data and data analytics relevant to contaminant transport and remedy decisions, enabling identification of transition points from active to passive remediation. An additional tool within the Suite of Comprehensive Rapid Analysis Tools for Environmental Sites (SOCRATES) enables access to real-time geophysical imaging of in situ subsurface amendment delivery, providing critical feedback to field operators to optimize remedy performance. *POC: RL, Mike Cline*
- **PNNL is creating web-based analysis tools within the SOCRATES suite using remotely sensed data to predict potential changes resulting from extreme events.** PNNL is creating new tools that enable users to visualize remotely sensed data and identify elevation changes relevant to waste site management and early response to potential structural collapses. This is accomplished through an automated data acquisition process that provides satellite data at regular frequencies and analytical tools that provide decision support through an automated email alert system. In addition, remotely sensed data provides seasonal estimates of groundwater base flow to the Columbia River, which can improve predictive simulations that are used to make decisions on waste site remedies, site closure, and long-term protectiveness of human health and the environment. Use of remote sensing data is cost-effective and eliminates the need for manual flux measurements at the groundwater-surface water interface. *POC: RL, Mike Cline*
- **PNNL is creating web-based reporting tools within the SOCRATES suite to streamline graphics needed for annual reporting requirements.** PNNL is creating a report generation tool that enables users to generate publication-quality graphics for all the analysis tools within SOCRATES, including contaminant concentrations, water-levels, flow directions, and analysis of pumping tests. This tool enables consistent formatting and documentation and integrates with the annual groundwater monitoring report. Integration of content and profile management systems allows for user authentication and different access privileges, as well as the persistence of multiple user sessions and preferences even after the web browser is closed. *POC: RL, Mike Cline*

- **PNNL is creating web-based access to the Hanford Site geologic framework model within SOCRATES**. PNNL is creating a web-based 3D geologic viewer of the Hanford Site. Geology informs many aspects of research at the Hanford Site related to groundwater flow, fate and contaminant transport, and cleanup progress, providing guidance on critical decision-making and regulatory action. The online 3D viewer provides ready access to site geology that was previously only accessible through proprietary software. The 3D viewer also integrates additional information, such as well and contaminant concentration data, to support DOE decision-making and facilitate stakeholder and regulatory communication. *POC: RL, Mike Cline*
- **PNNL is creating web-based access to P&T data within SOCRATES**. PNNL is creating web-based access and visualization of sensor and chemistry data for relevant P&T data. There is a large amount of temporal operational data collected for the P&T systems, which could potentially provide insight to P&T system operations and issues, such as well injection capacity decline. The SCADA system is on an isolated network and access to it (and the logged data) is limited. PNNL is providing access to a comprehensive set of P&T data and automated tools for analyzing this information to assess and optimize P&T performance. *POC: RL, Mike Cline*
- **PNNL continues to conduct experiments focused on the ability of a concrete encasement structure to retard radionuclide migration into the surrounding soil.** Concrete encasement is used to contain and isolate waste packages from hydrologic environments and acts as an intrusion barrier. It is necessary to assess the performance of the concrete encasement structure to retard radionuclide migration into the surrounding soil. The results provide insight into modeling assumptions for radionuclide partition coefficients. *POC: CHPRC, Mark Byrnes*

2.2 Impact of S&T Results and Publications on the Field

As PNNL focuses on developing and deploying innovative solutions for complex DOE challenges, documentation and communication of results become critical components or attributes of S&T delivery. As an Office of Science Laboratory, PNNL continually focuses on publishing its technical results in high-impact, peer-reviewed journals or through peer-reviewed technical reports and presentations to its clients. Our S&T results are also presented to technical peers in both national and international forums. In this section, PNNL's FY20 EM-related publication portfolio is discussed, books and key journal covers related to EM S&T activities and their impact to the national and/or international community are presented, and examples of how PNNL ranks relative to other national laboratories in specific technical areas are discussed.

- **PNNL has delivered on schedule more than 380 abstracts, conference papers, presentations, technical reports, and peer-reviewed journal publications to support and transform the cleanup mission thus far this fiscal year.** In FY20, PNNL supported over 130 unique projects directly from EM and indirectly from its contractors. Appendix A provides a complete bibliography of FY20 publications, to date and planned by the end of the FY, in support of the EM mission. In addition, PNNL staff had six key journal covers in both waste processing and environmental remediation research areas (see Appendix B). PNNL has provided high-quality research and development results through the publication of journal articles and reports.
- **PNNL publishes in high-impact journals and leads the other national laboratories in high impact publications in glass waste form development and nuclear waste glass corrosion.** PNNL produces high-quality, original, and creative results that advance S&T, demonstrate sustained scientific progress and impact, receive appropriate external recognition of accomplishments, and contribute to the overall research and development goals of DOE and its sponsors. To provide insight into the impact of PNNL's publications to the technical community and toward DOE's mission goals, and to assess how PNNL ranks relative to other national laboratories, a parameterized literature

search was conducted in two technical areas: (1) waste form development and (2) nuclear waste glass corrosion. See Appendix C for details on the search parameters and national laboratories included in each search.

Impact factors (IFs) are used to measure the importance of a journal by calculating the number of times selected articles have been cited within the last few years. The higher the IF, the more highly ranked the journal. High-impact publications are defined based on the number of citations in a specific scientific area as measured by Clarivate, the creator of Web of Science. Quartile rankings were then derived for each journal in each of its subject categories according to which quartile of the IF distribution the journal occupies for that subject category. Q1 denotes the top 25% of the IF distribution, Q2 the middle-high position (between top 50% and top 25%), Q3 the middle-low position (top 75% to top 50%), and Q4 the lowest position (bottom 25% of the IF distribution). The results of these searches are summarized below.

Glass Waste Form Development

- The majority of PNNL publications are in high-impact journals (93 Q1 and Q2 publications out of 118 total). Note: 17 were not rated of which 14 were conference papers.
- PNNL continues to lead the national laboratories in high-impact publications in glass waste form development.
- PNNL leads the national laboratories in the number of high-impact Q1 publications, with over 70% of the all Q1 publications (see Figure 1).
- PNNL also leads the national laboratories in the top 10% publication citations with over 61%. ANL and ORNL have the second highest top 10% publication citations with 15% each (see Figure 2).
- PNNL has four of the top five most cited journal articles and review papers.

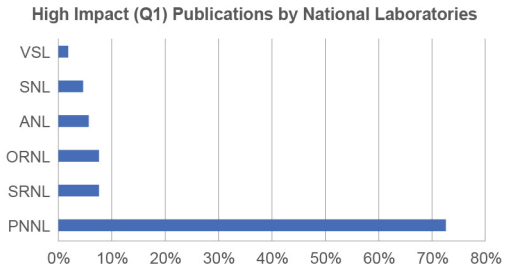


Figure 1. Percentage of high impact glass waste form development Q1 publications by national laboratory.

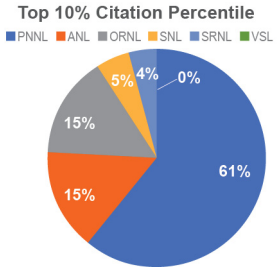


Figure 2. Top 10% glass waste form development publication citations by national laboratory.

Nuclear Waste Glass Corrosion

- The majority of PNNL publications are in high-impact journals (36 Q1 and Q2 publications out of 48 total). Note: 11 were conference papers and were not rated.
- PNNL continues to lead the national laboratories in high-impact publications in nuclear waste glass corrosion.
- PNNL leads the national laboratories in the number of high-impact Q1 publications, with over 65% of the all Q1 publications (see Figure 3).
- PNNL also leads the national laboratories in the top 10% publication citations with 57%. ANL and SRNL have the second and third highest top 10% publication citations with 15% and 14%, respectively (see Figure 4).
- There were two Top Cited Papers and PNNL is an author on both.

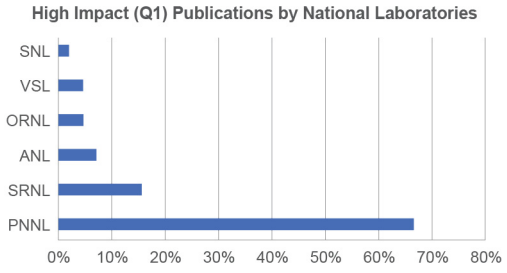


Figure 3. Percentage of high impact nuclear waste glass corrosion Q1 publications by national laboratory.

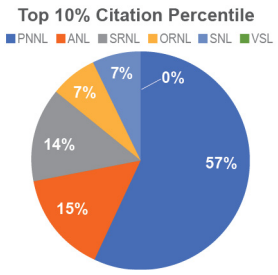
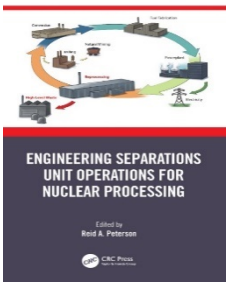


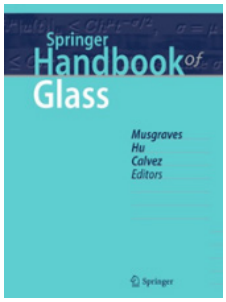
Figure 4. Top 10% nuclear waste glass corrosion publication citations by national laboratory.

PNNL staff published the following books/chapters in FY20. In addition to publishing in high IF journals and delivering numerous peer-reviewed conference papers, presentations, and technical reports, PNNL staff also published books, book chapters, and key journal covers related to the development and deployment of innovative solutions for complex DOE challenges.

– **Engineering Separations**. PNNL staff published the book *Engineering Separations Unit Operations for Nuclear Processing,* which focuses on processes that separate materials from nuclear reactor products or waste streams. This book provides a historical perspective on these separations processes and brings greater understanding of how these separation processes impact the treatment processes that are currently underway at both the Hanford Site and Savannah River Site. In particular, the book provides chapters on filtration, ion exchange, and solvent extraction, all of which are key unit operations in the current HLW processing schemes at those two sites. The book will provide a central reference to those working in the area of nuclear waste processing.

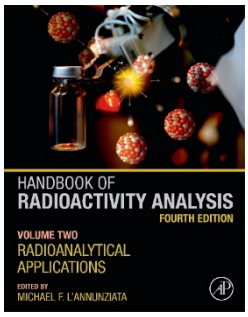


– **Chemical Durability of Glasses.** PNNL's Jim Neeway published a chapter titled "Chemical Durability of Glasses" in the *Springer Handbook of Glass*. The book includes chapters on several different applications of glass. The chapter was co-authored with Profs. Bernd Grambow and Abdesselam Abdelouas of the University of Nantes. The chapter covers aqueous corrosion processes of glass of interest in industry and for nuclear purposes. The chapter's emphasis is the long-term durability of glasses used for nuclear waste disposal, which is interest to EM as they manage radioactive waste at several sites around the U.S.



– **Handbook of Materials Modeling, Nuclear Materials.** The *Handbook of Materials Modeling*, 2nd edition, is a six-volume major reference serving a steadily growing community at the intersection of two mainstreams of global research: computational science and materials science and technology. The Handbook was authored by an international group of experts. PNNL's Ram Devanathan edited a 250-page section on modeling nuclear materials along with UCLA's Prof. Jaime Marian, wrote 1 of the 11 chapters in this section and co-authored the introduction to the section. This extensively expanded new edition reflects the significant developments in all aspects of computational materials research over the past decade, featuring progress in simulations at multiple scales and increasingly more realistic materials models. Thematically separated into two mutually dependent sets – Methods: Theory and Modeling (MTM) and Applications: Current and Emerging Materials (ACE) – the handbook runs the entire gamut from theory and methods to simulations and applications.

– **"Go-To" radioactivity handbook features chapter by O'Hara and Grate.** PNNL research scientists Jay Grate and Matthew O'Hara co-authored a chapter in the 4th edition of the *Handbook of Radioactivity Analysis*, along with Oleg Egorov, a former PNNL scientist. They contributed their expertise in the fields of automated radiochemical separation, analysis, and sensing. The handbook is widely used by students and researchers in nuclear chemistry, nuclear medicine, nuclear physics, radioecology, and beyond. The book is the go-to resource on the current status of radioactivity technology and analysis. It has been so successful that it has expanded to two volumes and over 2,000 pages since the first edition was published in 1998.



- **Waste Management Symposia.** PNNL staff also co-chaired over 11 sessions, delivered 24 presentations, 5 posters, and participated in 4 panel discussions. PNNL staff were awarded Superior Paper and Paper of Note recognition in FY20 for their Waste Management Symposia conference papers for distinguished contributions to the advancement of radioactive waste and radioactive material management. A superior level rating is based on the Symposia judging criteria of demonstrating superb knowledge and understanding and laying the foundation for future waste management endeavors.
  - Waste Management 2020 Superior Paper Award Winners
    - "Refining the Approach to Process Flowsheet Development and Maturation at Hanford" – 20049. Authors: Laura Cree, Todd Wagnon, Stuart Arm.
    - "Technology Assessment for Radioiodine at the Hanford Site" – 20230. Authors: Vicky Freedman, Michael Truex, James Szecsody, Carolyn Pearce, Nikolla Qafoku, Guohui Wang, Hilary Emerson.
    - "Advances in PFAS Monitoring and Remediation Using a Functionalized Material Approach" – 20080. Authors: Chatterjee Sayandev, Radha Kishan Motkuri, Michael Truex, Dushyant Barpaga, Vaithiyalingam Shutthandadan, Kee Sung Han, Carl Enderlin, Beric Wells, Sagnik Basuray, Michael Reed, Robert Allen Wilson.
    - "Field Test Bed for Vadose-Zone Monitoring Approaches" – 20404. Authors: Christopher Strickland, Hunter Knox, Timothy Johnson, Benjamin Roberts, Vincent Vermeul, Michael Truex, Vicky Freedman.
- Dr. Jud Virden, Associate Laboratory Director for PNNL's Energy and Environment Directorate, was an invited panelist at the Waste Management Symposium "Ensuring Strong Return on Investment for DOE EM Technology Development." The panel represented the views of DOE national laboratories and contractors, with a focus on approaching DOE technology development projects to maximize return on investment, including examples of successful projects. Virden spoke about PNNL's role to provide technical solutions to the EM mission's operational problems and improvement initiatives. This includes offering seamless development and maturation of science-based solutions through the technology readiness levels, especially where S&T advancements can reduce operational risk, mission life, and costs. Using examples of PNNL's waste form development – specifically advanced glass formulation – plus on-line monitoring and characterization techniques for tank waste, Virden talked about how the return on investment leads to the resolution of critical technical challenges.

2.3 Deliver on Proposed S&T Plans

Based on institutional leadership and 50 years of EM support, PNNL has a long history of developing strategic S&T plans or technology roadmaps not only for internal use but also for clients. In general, these plans or roadmaps define functions and requirements, process limitations or expectations, technology development strategies to define baseline flowsheets or operable units, or techniques and approaches to increase operational efficiency or reduce risks.

- **PNNL assisted in ensuring continuity of Hanford support through revision of a technology transition package for WRPS/ORP that captured the breadth of continuing technical support to the ORP cleanup mission.** The updated transition package provides a comprehensive program that will deliver necessary technical outcomes for FY21 through FY23. The proposed work scopes span the entire integrated flowsheet from safe storage, management, and retrieval of waste to pretreatment technologies and flowsheet unit operations, and ultimately strategies for waste form development and disposal and closure. The scopes leverage PNNL core competencies and are focused on (1) supporting development and implementation of the baseline flowsheet, (2) reducing risks

associated with operating facilities or strategic planning, and (3) providing alternative approaches to increase operational efficiency. The data package will be instrumental in supporting or providing continuity to potential tank farm contractor turnover.

- **PNNL continues to lead and contribute to efforts to integrate ORP/WRPS vitrification support for Hanford.** Staff have helped organize and focus recent efforts to align multiple ORP subcontractors to address the risks to ORP during this transition from vitrification plant construction to operations, and have taken actions to fill in several gaps in addressing risks. The vitrification support program plan outlines key program elements that are needed to provide critical data to support maturation of the baseline flowsheet, providing opportunities for improvement, including providing increased operational flexibility for plant operations, and ensuring emerging processing issues during operations can be effectively and efficiently addressed to minimize facility downtime. Current and future work scopes were classified or grouped into the four primary program elements: (1) Enhanced Waste Glass Compositions; (2) Melter/Off-gas Pilot Capabilities, Cold Cap and Melt Chemistry Dynamics; (3) Troubleshooting, Problem Solving, and Potential Modifications; and (4) Glass Corrosion Testing/Modeling. These elements complement one another to form a well-rounded mitigation strategy and support capability. Advancement of work in these four key technical elements is aligned with ORP's near-term schedules, goals, and objectives, and maintains the knowledge base, experts, and support capability needed for ORP to efficiently handle the challenges that arise as the Hanford Site transitions from construction to operations of the vitrification facilities. *POC: ORP, Albert Kruger*
- **PNNL contributed significantly to a multi-laboratory FFRDC effort to assess a range of candidate waste forms for supplemental LAW treatment.** The SRNL-led, six-laboratory team, formed to address the requirements of NDAA-17, developed a multi-year S&T plan for evaluating alternative waste forms and further processing options for SLAW. PNNL led the regulatory analysis, including implementing a waste form performance evaluation simulation effort to quantitatively evaluate the expected performance of each waste form candidate in the IDF environment. The study culminated in a report and analysis describing the expected cost, performance, barriers, and recommended actions associated with each alternative along with an independent NAS committee peer review of the FFRDC results – providing DOE with recommendations to support future actions and decision making. *POC: ORP, Kaylin Burnett.*
- **PNNL provided significant support to DOE HQ in the development of an Information Brief distributed across DOE sites with radiological operations.** The Information Brief summarized DOE site requirements for complying with the EPA regulations for radioactive material emissions to the air. This Information Brief applies to all DOE program offices. DOE NESHAPS external public website: https://www.energy.gov/ehss/downloads/national-emission-standards-hazardous-air-pollutants-neshap-compliance-monitoring.
- **PNNL summarized radiological information for DOE radiological operations for key public dose and liquid effluent measures to provide a 2015-2017 snapshot of DOE radiological impact to the communities in which they operate.** This summary of Site Environmental Report information has not been done since the early 2000s. This information is presented to highlight comparative measures for sites in each DOE program office.

2.4 Invited Talks, Citations, Providing High-Quality Data to the Scientific Community

PNNL uses its core competencies to solve problems challenging the successful execution of the baseline; resolve high-risk, high-payoff challenges; and provide the enduring site-specific knowledge to develop and implement solutions to long-term problems. These efforts can result in PNNL staff being invited to

showcase technology development efforts and their impacts on the community (local, state, and national) or the EM mission. In FY20, several PNNL staff were invited to give invited talks or plenary speeches in both waste processing and environmental remediation in local, state, national and international forums.

- Mark Triplett, "Fukushima Revitalization: Insights from the Hanford Site and Tri-Cities Communities Experience." Invited talk for Higashi Nippon International University and Shouheikou Educational Foundation, Nov. 6-7, 2019, Iwaki city and Tomioka town, Fukushima, Japan.
- Carolyn Pearce, "Mechanisms of Radionuclide Immobilization: A Hanford Case Study." Plenary invited talk at Migration 2019, Sept. 15-20, Kyoto, Japan.
- Steven Ross, "International Multi-Modal Surrogate Spent Nuclear Fuel Transportation Test: The SNF Transportation Test Triathlon." Invited talk at the Spent Fuel Storage Seminar, Mitsubishi Research Institute, Jan. 30, 2020, Tokyo, Japan.
- Carolyn Pearce, "Redox Cycling of Iron Minerals in the Environment: Probing Transformation Mechanisms with Magnetism." Invited talk at the Advanced Light Source User Meeting 2019, Oct. 1-3, Lawrence Berkeley National Laboratory, Berkeley, CA.
- Nik Qafoku. "How nanoscale processes affect soil systems on local, regional, and global levels." Keynote address, 2019 NSF National Nanotechnology Science and Engineering Grantees Conference, Dec. 9-10, Alexandria, VA.
- Carolyn Pearce, "Properties of water in far-from-equilibrium environments." Invited talk, ACS Spring 2020 National Meeting & Expo, March 2020, Philadelphia, PA (Postponed due to COVID-19).
- Carolyn Pearce, "Role of nanoscale materials in environmental pollution and remediation." Invited talk, ACS Spring 2020 National Meeting & Expo, March 2020, Philadelphia, PA (Postponed due to COVID-19).
- Carolyn Pearce, "Characterizing technetium and plutonium in subsurface sediments for contaminant remediation." Invited talk, ACS Spring 2020 National Meeting & Expo, March 2020, Philadelphia, PA (Postponed due to COVID-19).
- Josef Matyáš, "Waste Form Synthesis and Characterization." Keynote talk at the 43rd International Symposium, Oct. 21-24, 2019, Vienna, Austria.
- Carolyne Burns, "Advancing the Hanford Site Mission." Invited talk for the Department of Nuclear Engineering, Nov. 7, 2019, Penn State University, State College, Pennsylvania.
- Craig Maloney, "Risk Analysis of DOE Megaprojects in Safran." Invited talk, Safran Risk Online User Conference, May 28, 2020. https://www.safran.com/safran-risk-online-user-conference-2020.
- Jamie George, "Glass: A Common Material Solving An Uncommon Problem – How Do We Immobilize Nuclear Waste?" Invited talk for the Community Science and Technology Seminar Series, Richland, WA (Postponed due to COVID-19).
- Sarah Saslow, Carolyn Pearce, and Vicky Freedman. "Materials for Targeted ^{99}Tc Capture: From Nuclear Waste Form to Environmental Remediation" Invited talk, ACS Spring 2020 National Meeting & Expo, March 2020, Philadelphia, PA (Postponed due to COVID-19)
- Carolyn Pearce, Invited speaker at 3rd International Conference on Ionizing Processes (ICIP), July 12-17, 2020, Idaho Falls, ID (Cancelled due to COVID-19).

- Jose Marcial, Richard Pokorny, Jaroslav Klouzek, Steven Luksic, Seung Min Lee, Pavel Hrma, and Albert Kruger. “In-situ visual observations of glass melting processes.” Invited talk at the 2020 Glass & Optical Materials Division Annual Meeting, Aug. 3-5, New Orleans, LA (Cancelled due to COVID-19).

2.5 Development of Tools and Techniques That Become Standards or Are Widely Used in the Scientific Community

In addition to national leadership in nuclear waste processing and environmental remediation challenges, PNNL collaborated extensively throughout the broader federal complex and the international community to provide thought leadership, address complex international challenges, and facilitate technology transfer between the U.S. and foreign countries. As PNNL focuses on having a broader impact on the DOE complex and global research in various technical areas, internal procedures often mature, gain external exposure, and are ultimately transitioned to international standards, where they are adopted by other organizations as standards. In FY20, PNNL developed an internal glass corrosion procedure, which is transitioning toward an international standard to be used by national and international colleagues and updated an ASTM standard.

- **Stirred coupon reactor analysis (SCRA).** It is important that the portion of PA models used to describe the radionuclide release rate due to glass dissolution is accurately parametrized. In the past, glass dissolution rates have been obtained primarily using the single-pass flow-through (SPFT) test method (ASTM C1662), a relatively time-consuming technique with dozens of experiments monitored over weeks, resulting in hundreds of solution samples requiring analysis for a single glass. PNNL has developed the stirred-reactor coupon analysis (SRCA) technique as a higher throughput yet technically comparable alternative to the SPFT method. SRCA has enabled a rapid expansion of the number of glasses for which dissolution rate data can be obtained over a short time period. In doing so, larger datasets have been obtained that have facilitated in-depth evaluations of correlations between glass composition and structure and the resulting glass dissolution parameters to be used in updates to the Hanford IDF PA. The international waste glass community also sees the usefulness of this technique and has shown interest in helping PNNL execute the next necessary step: an international round-robin to evaluate the reproducibility of the technique, introduction of any modifications the community identifies, and approval as an international standard procedure.

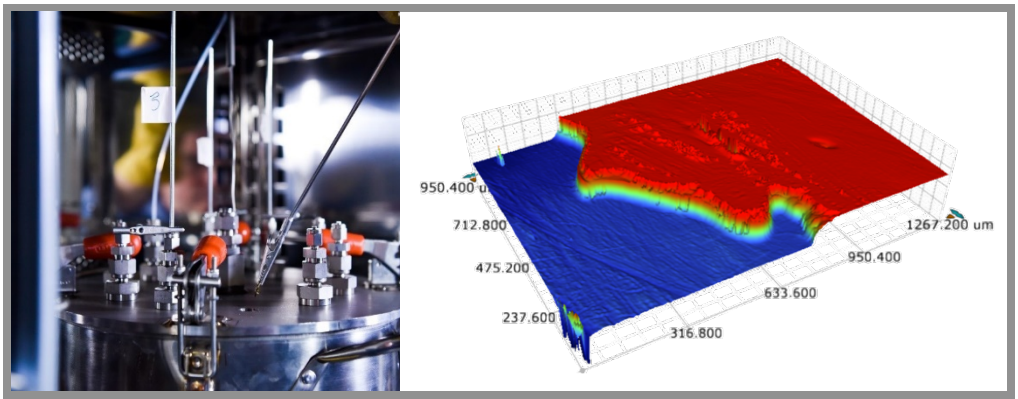
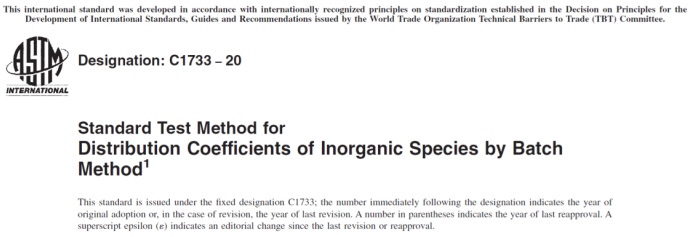


Figure 5. SCRA experimental test reactor bottom (left); Optical profilometry measurement of corroded glass surface (right)

- **ASTM Method C1733-20a.** PNNL scientist Matthew Asmussen updated ASTM Method C1733-20a (*Standard Test Method for Distribution Coefficients of Inorganic Species by Batch Method*) by incorporating a precision and bias section based on a round robin of the method executed by PNNL. The standard has been updated to account for other material testing, including waste forms, based on procedures regularly performed at PNNL. The standard is a laboratory method primarily intended to assess sorption of dissolved ionic species subject to migration through pores and interstices of site specific geomedia, or other solid material. However, it may also be applied to other materials such as manufactured adsorption media and construction materials.



This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C1733 – 20

Standard Test Method for
Distribution Coefficients of Inorganic Species by Batch Method[1]

This standard is issued under the fixed designation C1733; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

3.0 Objective 1.2: Provide Quality Leadership in S&T that Advanced Community Goals and DOE Mission Goals

Goal 1: Produce high-quality, original, and creative results that advance science and technology (S&T); demonstrate sustained scientific progress and impact; receive appropriate external recognition of accomplishments; and contribute to overall research and development (R&D) goals of the DOE and its customers

Objective 1.2 Provide Quality Leadership in S&T that Advanced Community Goals and DOE Mission Goals

Description: By which we mean effectiveness in leading and setting the priorities (of the science and technology community); receiving external recognition for doing the best work in the field; and collaborative efforts that enhance the effectiveness and productivity of the Laboratory's efforts.

In assessing the performance of the Laboratory against this objective, the following assessment elements should be considered:

- Innovativeness/novelty of research ideas put forward by the Laboratory
- Extent to which Laboratory staff members take on substantive or formal leadership roles in their community and/or in DOE and SC activities
- Extent to which Laboratory staff members contribute thoughtful and thorough peer reviews and other research assessments as requested by DOE and SC

The following is a sampling of factors to be considered in determining the level of performance for the Laboratory against this objective. The evaluator(s) may consider the following as measured through progress reports, peer reviews, FWPs, program office reviews/oversight, etc.:

- Willingness to pursue novel approaches and/or demonstration of innovative solutions to problems
- Willingness to take on high-risk/high-payoff/long-term research problems, evidence that previous risky decisions by the principal investigator/research staff have proved to be correct and are paying off
- The uniqueness and challenge of science pursued, recognition for doing the best work in the field
- Extent and quality of collaborative efforts
- Significant awards (Nobel Prizes, R&D 100, FLC)
- Staff members visible in leadership positions in the scientific community, involvement in professional organizations, National Academies panels, and workshops
- Effectiveness in driving the direction and setting the priorities of the community in a research field
- Success in competition for resources

Consistent with EM's performance expectations, during FY20, PNNL collaborated extensively with SC, DOD, other national laboratories, and contractors to take on and deliver high-risk S&T solutions that address EM's key technical challenges for ORP, RL, and the broader DOE complex. PNNL also demonstrated technical leadership in several key areas that advanced DOE mission goals. Key examples of PNNL's national and international leadership are reflected in the Energy Frontier Research Center (EFRC) IDREAM and PNNL's launch of the Center for Remediation of Complex Sites (RemPlex), and commitment to RemPlex programs supporting DOE and other national and international partners. PNNL also demonstrated thought leadership and collaboration in pursuing novel technical approaches and

demonstrating innovative solutions to address complex problems, including international efforts to use natural analogues to assess the long-term durability of vitrified waste, transferring technologies between the U.S. and Japan, and partnerships with national and international organizations in both waste processing the environmental remediation. PNNL also demonstrated leadership in community, academic, and technical organizations to support current and future DOE goals. Specific examples of PNNL's leadership follow.

3.1 Willingness To Take On and Deliver High-Risk S&T and To Pursue Novel Approaches

- **PBI- and milestone-driven scope.** PNNL uses its core competencies to solve problems challenging the successful execution of the baseline; resolve high-risk, high-payoff challenges; and provide the enduring site-specific knowledge to develop and implement solutions to long-term problems. In FY20, PNNL executed over $17.7M of scope in support of three WRPS PBIs, five associated milestones, and four SEAs, including issues such as tank vapors with outcomes directly supporting the vapors settlement agreement, and informing the design, operation, and safety basis for DFLAW/LAWPS. In addition, PNNL conducted over $6.7M of scope directly supporting ORP to increase DFLAW operational flexibility; resolve the long-term, potentially high-impact challenges associated with increasing the waste loading of glass waste forms; and provide glass standards to support analysis during WTP waste qualification activities. PNNL executed over $9.7M of milestone-driven scope in support of RL and CHPRC to resolve the long-term, potentially high-impact challenges associated with soil and groundwater remediation, supporting nine Tri-Party Agreement milestones and four PBIs.
- **PNNL dedicated key technical staff to EM assignments**. PNNL scientists and engineers serve in direct, full-time positions with EM to provide technical and programmatic integration, planning, and management support. Two PNNL staff members provide direct support to the Savannah River Operations Office with technical and quality management support to the Salt Waste Processing Facility project. Three PNNL staff members directly support ORP with management of tank waste remediation technical issues and Hanford Site-wide cleanup integration. One PNNL staff member serves in a direct, full-time position supporting the WRPS Integrated Flowsheet Team and another staff member is embedded in the WRPS CTO. The staff members support strategic planning, technical program definition, program integration, and program prioritization to achieve WRPS objectives in key programs, including the IDF PA, LAWPS, tank vapor chemical hazards resolution, and secondary waste form development and performance. One PNNL staff member is supporting the WRPS Nuclear Safety organization producing the TSCR DSA and TSRs. Four PNNL scientists directly support RL and CHPRC in planning, technical program definition, and program prioritization to achieve key program objectives in environmental remediation, including completion of the River Corridor project and remediation of environmental contamination in the Hanford Central Plateau. These dedicated assignments enabled EM to access PNNL's technical expertise to support complex-wide cleanup efforts.

- **PNNL provides leadership and key roles in the Basic Energy Sciences (BES) EFRCs focused on the EM mission.** PNNL continues to lead IDREAM, which focuses on the frontier of Interfacial Dynamics in Radioactive Environments and Materials. In FY20, IDREAM advanced its scientific mission to master fundamental interfacial chemistry in complex environments characterized by extremes in alkalinity and low-water activity and chemical phenomena driven far from equilibrium by ionizing radiation. As shown in Figure 6, new knowledge of aluminum interfacial chemistry in alkaline, concentrated electrolytes, and interfacial radiolysis is providing a foundation for innovation to markedly accelerate waste processing. Clearly, reducing the timeline to stabilize these wastes by a decade or more would have a considerable impact on the aggregate cost. By achieving its fundamental science mission, in addition to its broader impacts, IDREAM is enabling such cost reductions. See Appendix D for the FY20 IDREAM publications.

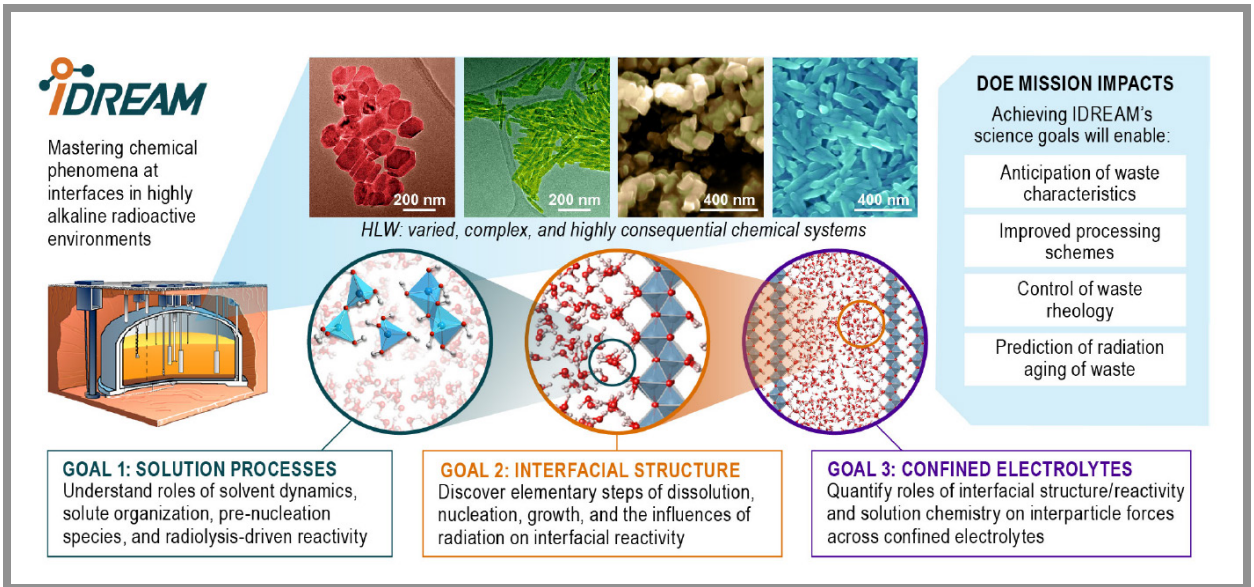


Figure 6. IDREAM aims to provide the fundamental science basis to speed up processing of the millions of gallons of highly radioactive wastes stored at DOE's Hanford and Savannah River Sites. With currently available technologies, removing these wastes from tanks and stabilizing them for disposal will take decades and will cost hundreds of billions of dollars. Building on IDREAM's research progress, our research goals advance a foundation of use-inspired knowledge, enabling accelerated waste-processing alternatives.

In FY20, IDREAM produced a transformative new understanding of the chemical and physical phenomena controlling the dynamics of aluminum under conditions that are relevant to legacy HLW. IDREAM has developed new experimental and computational tools to yield insights into aluminum chemistry under highly alkaline conditions, including the dynamics of complex electrolytes at interfaces in radioactive environments. EM is using these results to develop alternatives for waste processing, and results from IDREAM are also informing plans for design of future waste-processing schemes. Furthermore, PNNL is producing a new generation of scientists with expertise in these areas who are the future workforce needed to drive the fundamental science behind processing these legacy wastes in the coming decades. IDREAM is currently the only EFRC focused on the staggering chemical complexity of the legacy HLW materials that await processing. In IDREAM, we demonstrated that our previous understanding of the behavior of ions in concentrated electrolytes at interfaces was too simplistic to explain observed behavior. We discovered how to differentiate solution versus steady-state transformation pathways of major aluminum (oxy)hydroxides such as gibbsite (α-$Al(OH)_3$) and boehmite (γ-AlOOH) in highly alkaline solution, revealing the impact of precursor type, concentration, alkalinity, pH, and temperature. IDREAM is enabling first-ever

precision control of the properties of product phases. This body of work has resulted in a diverse and highly characterized materials library of aluminum nanomaterials that serve to unify IDREAM's collective efforts. Furthermore, these insights resolve knowledge gaps that have perplexed industrial aluminum process chemists for more than a century.

One of IDREAM's most impactful, integrated contributions to date is the advancement of the ternary phase diagram that describes the transformation of various important aluminum (oxy)hydroxide and sodium aluminate hydroxy hydrate phases in concentrated sodium hydroxide electrolytes, as shown in Figure 7. For HLW processing, this ternary diagram defines the chemical conditions under which given aluminum phases should predominate, which is foundational for the development of industrial-scale processing schemes. This foundation of knowledge around aluminum speciation and phase stability is derived from our efforts to understand (1) solution-phase processes in alkaline-concentrated electrolytes, (2) interfacial structure and reactivity, (3) particle interactions in alkaline slurries, and (4) the impact of radiation at the aqueous–solid interfaces of gibbsite and boehmite.

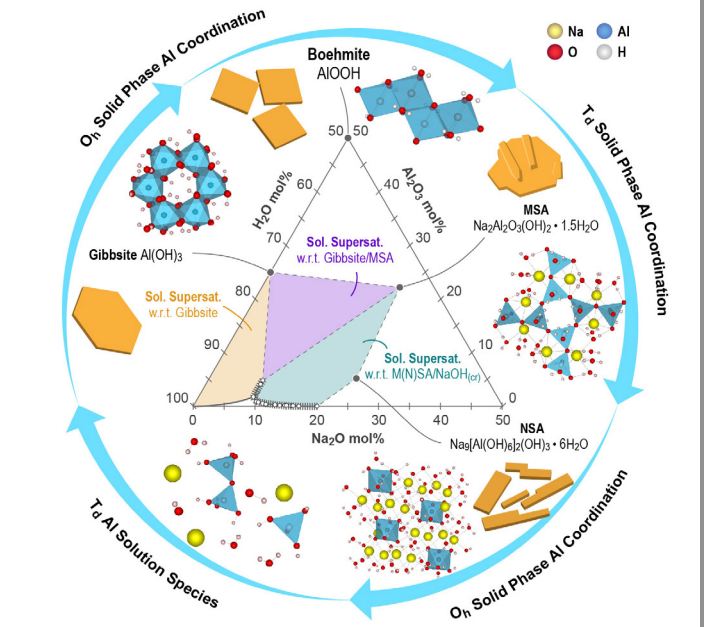


Figure 7. IDREAM is defining in molecular detail the basis for transformations between important solid phases such as aluminum (oxy)hydroxides and aluminate hydroxy hydrates in low-water, concentrated sodium hydroxide solutions relevant to HLW treatment systems. Much of the retrieval and processing centers on the dissolution and precipitation of these solids in alkaline mixtures that contain additional anions, elements, and organic constituents. IDREAM is advancing new knowledge on the mechanisms of solid-phase transformations during chemical processing, where Al ions cycle between the tetrahedrally coordinated (Td) aluminate anion ($Al(OH)_4^-$) in the solution phase to dominantly octahedral coordination (Oh) in the solid phase. The orange icons represent the complex particle morphologies that are often observed and are an important variable in the structure at particle interfaces.

- **PNNL is providing national leadership in remediation of complex sites.** The Center for the Remediation of Complex Sites (RemPlex) is a PNNL platform that couples unique core competencies and expertise with state-of-the-art facilities and physical assets to develop, mature, and deploy advanced technologies to solve complex issues of contaminated subsurface environments.

REMPLEX
CENTER FOR THE REMEDIATION OF COMPLEX SITES
@PNNL

RemPlex provides scientific and technical expertise to support environmental remediation and complex site stewardship decisions on both a national and international stage. Our expertise in basic and applied remediation science and technology continues to grow through direct support to the Hanford Site, one of the most complex contaminated sites in the world. Our integrated approach to laboratory, field, and predictive site-specific analyses; our adherence to obtaining the necessary understanding of processes for better decision-making; and our partnering with regulatory agencies to generate national and international guidance documents relevant to adaptive site management makes PNNL an ideal location for RemPlex. Our strategically focused research, analyses, and technological contributions provide crucial science-based and risk-informed solutions to global environmental remediation and stewardship challenges that save significant cleanup dollars and reduce both environmental risks and timeframes of the cleanup activities.

As a national laboratory, PNNL views its role in technology development and deployment as a partner with its client to ensure deployment of technically sound solutions to environmental remediation challenges. To that end, RemPlex leverages PNNL's internationally recognized expertise in successfully transitioning remedial technologies from conception to implementation through:

– Solution development: leverage existing capabilities spanning all technology readiness levels to successfully and economically address challenges

– Multi-institutional collaborations: facilitate solution development by fostering federal and private partnerships

– Technical leadership: proven track record of supporting deployment of advanced technologies and development of alternative strategies

In May 2020, Dr. Dawn Wellman (RemPlex Director) provided the inaugural RemPlex webinar, titled "Innovative Solutions for Environmental Challenges," which showcased how RemPlex fosters technical stewardship and advances the R&D needed to translate science and engineering innovation into practical, adaptive, operational solutions to address complex site remediation. Additional RemPlex webinars are planned for summer 2020 on topics related to co-mingled contaminants, contaminant behavior in the subsurface, transitioning from active to passive remediation, and remedy selection. More information on RemPlex can be found at https://www.pnnl.gov/projects/remplex.

- **WSU-PNNL Joint Institute continues major initiatives in mastering phenomena associated with radioactive materials**. The Washington State University (WSU) – PNNL Nuclear Science and Technology Institute is one of three WSU-PNNL institutes. The joint institutes bring together complementary expertise and resources of the partner institutions to address significant scientific and engineering challenges, and each institute has its own unique focus area. The WSU-PNNL Nuclear Science and Technology Institute aims to understand and control how materials evolve in radiation environments to prevent the use of illicit nuclear materials, resolve issues in nuclear waste management, and advance next-generation nuclear energy.

- **PNNL showcases novel S&T approaches at the Waste Management Symposia to support EM Mission goals.** PNNL hosted a booth at the 2020 Waste Management Symposia to help facilitate continued awareness of PNNL's capabilities to support disposal of nuclear waste and environmental remediation across the complex. PNNL highlighted some of its core competencies and capabilities as well as some of the novel research activities focused on EM mission needs that are defining baseline operating units or flowsheet, identifying opportunities for improvement, or defining risk reduction opportunities. Three key technology development efforts were highlighted by the following exhibits at this year's conference:
  - **Exhibit #1: Virtual Environment/Virtual Reality: Waste Tank Experience.** Throughout the DOE complex, there is a need to deploy new, unique equipment and systems for cleanup activities, waste processing, infrastructure repair, and decommissioning and demolition in radioactive and hazardous environments. The deployment of custom systems that are "turnkey" ready for first-time installation and application has its risks. Use of test platforms and mockups for cold (i.e., non-radioactive) testing is one method to mitigate that risk; however, full-scale test mockups for operations such as waste retrieval and tank inspection can be expensive and must be modified to incorporate the uniqueness of each application.

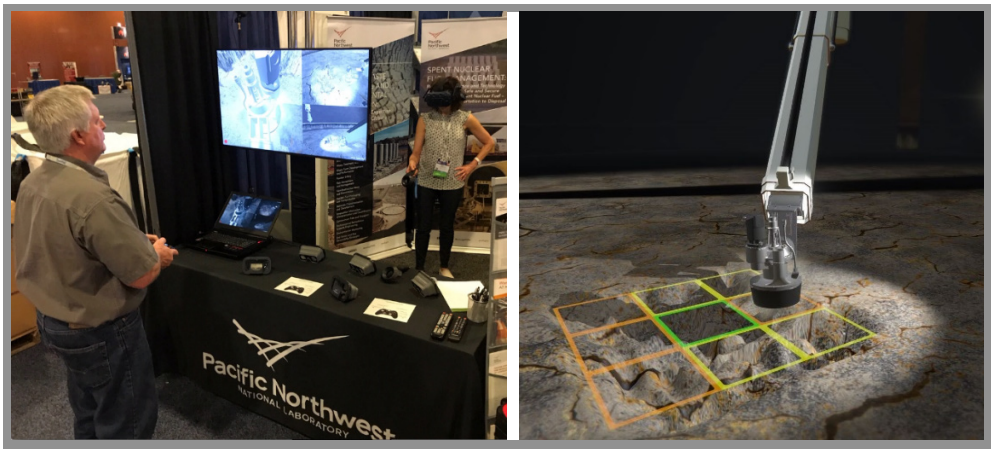


Figure 8. Attendee virtually operating the simulated waste retrieval system and another using virtual reality to explore inside of the waste tank.

An alternative to full-scale mockups is to use 3D virtual environments (VEs) and virtual reality (VR) technology to develop interactive virtual test beds (see Figure 8). These can be used throughout the down-selection, development, system integration, operational planning, operator training, and mission execution phases of a task. Virtual test beds are readily reconfigured, can be used for multiple tasks, support multiple users in parallel, and can accommodate enhancements and changes not originally planned or conceived in the initial design.

PNNL's VE/VR show-and-tell experience used commercial software and hardware to create a waste tank/riser configuration along with the interior layout of retrieval equipment and waste as an opportunity to showcase current PNNL capabilities and to aid in educating contractors in potential applications of VE, VR, and augmented reality (AR). The experience provided a hands-on tool to present how PNNL expertise and capabilities in game development, real-time art, physical sciences, and test and evaluation can be integrated. Conference attendees were able to step inside a virtual DST and try their hand, with the aid of AR, at retrieving waste using the Hanford Waste End Effector (HWEE). Virtual technologies offer significant opportunity to increase confidence in alternative waste treatments and accelerate waste processing and can benefit the EM mission by reducing the risks, costs, and uncertainties associated with design and operation of waste processing systems.

- **Exhibit #2: Enhancement of Remote Operations Interface with Live Video Streaming in VR.** Remote operators perform complex, often hazardous tasks using robotics and live video feeds. Often this is performed using a standard TV display and video camera, which is extremely challenging. For example, it is difficult to gauge distance and depth on a flat display. Adding to the complexity, supplemental data is displayed on gauges and panels elsewhere, requiring the operator to frequently shift their visual attention. To improve the remote operator's situational awareness and interaction with the remote work environment, PNNL has combined AR/VR technologies to improve operational efficiencies. PNNL combined a Vuze XR 360/180 stereoscopic camera rig, Vive motion trackers, and an HTC Vive virtual reality headset with newly developed demonstration software. The live 360° stereo video feed is streamed to a VR headset. When viewed on a VR headset, the operator has improved depth perception, as if they were seeing it with their own eyes. Using an existing motion tracker, the camera rig position can be precisely tracked in space. This allows spatial sensor data to be aligned with the video feed to put data in the operator's line of sight and to enhance their remote workspace interface PNNL presented a hands-on remote operation exhibit using a VR interface for the operator that used live video streaming from the perspective of a remotely deployed retrieval system (see Figure 9).

Figure 9. Attendees operating a remote-control vehicle via a live streamed 360° video feed to the virtual reality headset.

The operator interface was enhanced with AR overlays. PNNL's remote operations interface exhibit offered attendees the opportunity to try a remote operation using a VR interface. The operator was given the perspective of sitting on a retrieval vehicle with a 360° visual perspective from the location of the deployed camera. To see to the left or the right, an operator turned their head as opposed to visually scanning their eyes across a monitor or changing between multiple camera views. To back up, the operators simply looked behind themselves. Having the perspective of being at the remote tool using a VR interface makes the operator more efficient and less fatigued while reducing operational risk by allowing the operator to naturally look around in any direction. In addition, AR can be used to provide virtual tools displayed within the remote environment or provided as informational displays (e.g., gages, readings, procedures) within the operator's vision.

- **Exhibit #3: Under-Tank Air-Slot NDE crawler.** Legacy waste from the Hanford production mission is stored in an array of high-level SSTs and DSTs. The Hanford cleanup mission timeline is heavily dependent on safe and reliable storage of the hazardous waste in the DSTs until the waste is treated or vitrified in the WTP. Waste treatment is scheduled to begin in 2023; however, significant shortfalls are projected between DST service lives and the estimated completion dates for tank waste retrieval, waste treatment, and DST closure. Corrosion of the DSTs is one of the biggest threats to DST leak integrity, and curtailed DST service life due to diminished integrity is one of the most significant threats to the cleanup mission. The current ages of the DSTs and the nature of the waste they contain are such that evaluation of leak integrity is prudent to provide a basis for continued usage of DSTs for storage/waste feed staging, or a basis for prioritizing DSTs for future retirement/repair to simultaneously minimize the risk of negative impacts to the environment and mission timeline.

NDE is a proven method to evaluate leak integrity of infrastructure such as DSTs, and traditional NDE technology is routinely applied during remote robotic inspection of primary tank sidewalls. Traditional NDE technology is not applicable to physically inaccessible primary tank bottoms that represent a high-risk area for corrosion, comprise ~90% of a tank bottom area, and have not been thoroughly inspected since tank construction. However, new ultrasonic guided wave NDE technology is applicable. PNNL experts in NDE measurement science and qualification of NDE technology/procedure/personnel are working with WRPS and commercial companies to evaluate and qualify novel ultrasonic guided wave NDE sensor technology adapted for primary tank bottom inspections. Included are the robotic systems that will enable guided wave sensor deployment and remote operation in limited-access interstitial spaces and ventilation channels beneath the primary tanks in the presence of strong radiation fields. Clearly, this is difficult but vital work in direct support of the Hanford environmental restoration and remediation mission.

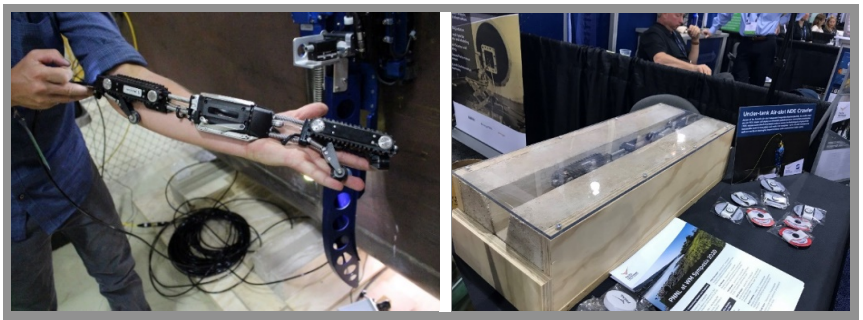


Figure 10. RAVIS air-slot inspection crawler in a mock-up ventilation channel at the 2020 Waste Management Symposia (left) and during testing at PNNL (right).

As part of the RAVIS, the under-tank air-slot NDE crawler (see Figure 10) will deploy an ultrasonic guided wave NDE sensor under Hanford primary tanks to assess the leak integrity of physically inaccessible tank bottom plates.

3.1.1 Waste Processing

- **PNNL staff supported DOE with attendance at several key forums with independent experts, regulators, and stakeholders to discuss results of the multi-laboratory FFRDC study on supplemental LAW treatment alternatives.** PNNL with SRNL provided key technical briefings on the results of the waste form performance evaluation to the NAS committee reviewing the SLAW study at a public meeting in the Tri-Cities, and in a public forum at the 2020 Waste Management Symposia in Phoenix. PNNL also supported EM and ORP in a meeting with Senate Armed Services Committee staff in Washington, DC, responsible for the SLAW study authorization in NDAA17. Finally, PNNL and SRNL representatives briefed the Hanford Advisory Board Tank Waste Committee on the SLAW study findings. PNNL supported DOE with several Hanford Advisory Board and Washington State Department of Ecology tours of the PNNL grout laboratory to discuss recent advances in waste form development that supported the SLAW study as well as ongoing support of tank waste treatment research.
- **PNNL is providing VE, VR, and AR capabilities to reduce the costs and risks of EM mission operations.** VR provides a novel platform for modeling environments of interest to enable process understanding and evaluation of real-world challenges. Integrating state-of-the-art expertise and capabilities in game development, real-time art, physical sciences, and test and evaluation, PNNL is demonstrating how virtual and augmented environments can reduce the risk and cost of EM mission operations. PNNL leveraged previously funded client projects (e.g., HWEE development and testing, Raman probe measurement applications, remote-system development, waste characterization) to provide a virtual Hanford DST environment to facilitate understanding of system component design, assessment of operational interfaces, and integration and operation of novel engineered systems in complex environments. VEs allow site contractors and operators to resolve issues earlier in the development and/or design process; view operations from various perspectives and increase their situational awareness; provide a low-cost, low-risk means to train operators; develop processes, procedures, and protocols without the need for cold test facilities and demonstrate proficiency prior to field execution; and develop recovery plans, which can be vetted with regulators and stakeholders. Application of VR and AR to EM mission needs will reduce risk, costs, schedule, and uncertainty associated with design and operation of waste processing operations.
- **PNNL is leading an international team of experts to determine the long-term durability of ancient hillfort glasses in support of the disposal of ILAW glass at the Hanford IDF.**
  - **Hillfort analogue for long-term performance:** PNNL organized, managed, and participated in an excavation of the hillfort site in Broborg, Sweden, and is leading the effort to evaluate and analyze the samples brought back from the excavation. The team has established that the hillfort glass is a defensible analogue for the ILAW glass to be produced at the WTP. Synthetic glass with the composition of hillfort glass has been produced and tested with standard short-term durability tests. The alteration layers generated by these tests are being analyzed and compared with environmentally altered hillfort glass to evaluate the effectiveness of these accelerating tests. The unique hillfort ecosystem has been used as a habitat analogue to study microbial communities associated with near-surface disposal of vitrified radioactive waste. This interdisciplinary research demonstrated that, while microbial communities associated with the vitrified niche have bio-corrosive properties that could be detrimental to waste stability, they also generate stable long-term biofilms with a homeostatic function that has the potential to limit glass alteration and stabilize vitrified radioactive waste. The implications for long-term glass alteration are of particular interest

to the nuclear waste glass community, as their vitrified products will need to withstand internment in a near-surface environment on a geological time scale. *POC: ORP, Albert Kruger*

- **Glass Leaching Assessment for Disposal (GLAD):** PNNL collaborates with Vanderbilt University and University of Sheffield to evaluate the use of EPA leaching protocols for application to ILAW glass. The project aims to evaluate use of EPA 1313 as an alternative method to provide kinetic and thermodynamic information on glass leaching, as a function of time, pH and temperature. *POC: ORP, Albert Kruger*

- **PNNL is a key contributor and technical leader within the EM-NE-international collaboration to develop a mechanistic understanding of glass corrosion, enabling next-generation performance models.** Under PNNL leadership, a team of experts from six nations, six U.S. national laboratories, and several universities worldwide are conducting coordinated glass corrosion research to develop an international standard that maximizes confidence by targeting research priorities, minimizing redundancy, and maximizing the best expertise from each institution. The results will increase public confidence in models, reduce conservatism on the durability of glass when designing repositories, and accelerate qualification of new of waste forms.

  Due to coronavirus concerns, an abbreviated and virtual International Workshop on Long-Term Corrosion was held on April 1, 2020, rather than at the Corning, Inc., facilities in Fontainebleau as scheduled. Despite this, the workshop had one of the highest attendances of the series, with 71 people from at least 27 institutions and 7 countries (USA, UK, France, Belgium, Germany, South Korea, and Japan). Despite the large differences in time zones and 4+ hour duration, the majority of participants stayed for the entire workshop. There were 10 presentations on a variety of topics, highlighted by Corning's roll-out of the new International Simple Glass (ISG). The new ISG is designed to be related but notably different from the original ISG, and the preliminary corrosion data suggests that the goals were a success. The synthesis run produced 450 very high-quality blocks of both the new ISG-2 composition and a re-run of the original ISG-1 composition for a grand total of 900 pounds of glass. These samples are now at PNNL, ready for shipment to the international community once the lab operation is restored. *POC: EM HQ, Nick Machara*

- **PNNL delivers a tutorial series on fundamentals of Hanford waste and the waste processing mission.** Transferring the historical knowledge of the Hanford Site, PNNL developed a tutorial series on fundamentals of Hanford tank waste and waste processing. The six-part series is presented in order building on the previous information, tying together the Hanford tank waste cleanup story – (1) Tank Waste Potential Threat to Groundwater, (2) History of Tank Waste Production, (3) Tank Waste 101: Chemistry and Physics of Hanford Tank Waste, (4) Hanford Mission Flowsheet, (5) Vitrification of Hanford Tank Waste, and (6) Cementitious Materials in the Hanford Mission – was delivered over a dozen times to representatives from EM HQ, ORP, and WRPS.

- **PNNL is serving DOE / National Nuclear Security Administration sites through the acceptance, maturing, and sustainment of a key legacy software used across the complex to ensure safe packaging and transportation of radioactive materials.** Sites use RadAnalysis (previously RADCALC) to determine if radioactive material packaging complies with regulatory and DOE transportation requirements. PNNL is leveraging its nuclear expertise and software quality experience to ensure that new release version(s) of RadAnalysis meet the stringent requirements of PNNL's Nuclear Quality Assurance Program. The recent release of RadAnalysis 1.0 restored usage of this important tool to a waiting user community. *POC: EM Office of Packaging and Transportation, Julia Shenk*

- **PNNL provided support to Tokyo Electric Power Company (TEPCO) related to decommissioning of the Fukushima Daiichi nuclear plants.** PNNL supported TEPCO efforts related to storage of secondary waste from contaminated water treatment and understanding the potential for dust dispersion from rubble removal at Unit 1. The slurry waste is stored in high-integrity containers and is known to generate hydrogen. PNNL experts in gas generation and retention in slurries are supporting TEPCO in designing and evaluating experiments to better understand the mechanisms causing this behavior and to assess the potential safety issues with these containers. In FY20, PNNL staff assisted TEPCO in evaluating potential dust dispersion from Fukushima decontamination and decommissioning activities.
- **PNNL is supporting Japan's International Research Institute for Nuclear Decommissioning (IRID) in their applied R&D related to decommissioning work at the Fukushima Daiichi site.** PNNL designed radiolysis experiments for IRID member company Hitachi GE Nuclear, Ltd. to improve understanding of radiolysis mechanisms from storage of fuel debris. The next phase of this work intends to carry out those experiments to improve calibration of radiolysis models needed for regulatory approvals for canister designs. Another project supports IRID member company, Central Research Institute for Electric Power Industry (CRIEPI), in the formulation and testing of waste glass formulations applicable to treatment of secondary waste products at the Daiichi site.

3.1.2 Environmental Remediation

- **PNNL is providing international leadership in defining the international approach to defining environmental remediation end states for the International Atomic Energy Agency (IAEA).** At request of IAEA, PNNL is leading the development of the international guidance on the Definition of Environmental Remediation End States, which outlines an approach that can be used to make informed and transparent decisions on the mutually agreed "end state" for a site after remediation. The document is ultimately intended to provide the basis for achieving consensus on the end state of a site so that all stakeholders involved in the decision process work from the same assumptions and the potential for misunderstanding is reduced as much as possible.
- **PNNL is collaborating with ANL to develop and pilot a new international training course for environmental remediation in support of IAEA.** In support of IAEA and in collaboration with ANL, PNNL is contributing to the management and implementation for the Constraints to Implementing Decommissioning and Environmental Remediation Phase II IAEA training program for environmental remediation across the 220 member states. PNNL supported planning and demonstration of a pilot 2-week course at ANL. A primary objective of this new training program includes providing participants with a more comprehensive understanding of basic science and engineering principles, including knowledge of (1) the nature of contamination that may be associated with different types of sites and facilities, (2) natural environmental systems and how they function, (3) physical and chemical properties of contaminants and how they behave in the environment, (4) environmental modeling methods, (5) possible engineering solutions, and (6) proven best practices for environmental remediation. In addition, the new program will train participants on project management techniques, including planning, scheduling, cost estimation, budget management, and stakeholder engagement.
- **PNNL is providing international leadership by working with the IAEA in developing the international approach to environmental remediation end states.** At request of IAEA, PNNL is leading the development of the international guidance on Determination of Environmental Remediation End States, which outlines an approach that can be used to determine an appropriate end state for a contaminated site and related remediation actions. The document is ultimately intended to provide the basis for achieving consensus on the end state of a site so that all stakeholders involved in the decision process have appropriate information from which to make site decisions.

- **PNNL is collaborating with SRNL and ANL to compile information about PFAS from current national efforts and assess potential issues at DOE EM sites**. The assessment will compile and interpret information from across the DOE complex with a goal of describing the relative magnitude of potential PFAS (per- and polyfluoroalkyl substances) issues, considering both technical and regulatory factors. The outcome will provide technical and administrative input for EM management decisions regarding PFAS. *POC: EM HQ, Kurt Gerdes*
- **PNNL is creating a web-based GIS story map of groundwater plumes throughout the DOE complex that provides summary information on progress toward cleanup and site closure.** PNNL is creating an online story map that provides online access to site plumes across the EM complex and progress toward site closure. The TRAC (Tracking Restoration and Closure) website is focused on communicating cleanup status, technical challenges, and needs for site closure. Several metrics associated with treatment technologies as well as plume and regulatory status are currently being integrated into the web application. TRAC provides relevant information on cleanup progress and closure that is consistent across all sites, enabling the user to view summary information across all sites or examine information relevant to a particular site. This information sharing is needed to maintain open communications with interested parties and to communicate efforts that ensure the long-term protection of human health and the environment. *POC: HQ, Kurt Gerdes*
- **In partnership with DOD and EPA:**
  - **PNNL is expanding the capability of ERT to monitoring of reactive processes during remediation**. PNNL is quantifying the correlation between reactive processes, changes in sediment biogeochemistry, and monitoring responses for ERT-based monitoring approaches. This DOD monitoring development project will provide for enhanced volumetric monitoring of in situ remedies to improve interpretation of amendment emplacement and verify reaction processes compared to traditional monitoring well sampling approaches.
  - **PNNL is updating the soil vapor extraction (SVE) analytical tool suite**. In conjunction with DOD, DOE, EPA, and industry, PNNL is developing additional analytical tools and field validation methodologies to expand the capabilities of the SVE tool suite. EPA, industry, DOD, and DOE are actively using these capabilities to quantify the capacity of the natural environment for passive management of residual volatile organic contaminants and to enable definition of a path for termination of active SVE operations.
  - **In partnership with the Electric Power Research Institute (EPRI), PNNL is developing and demonstrating the use of ERT for leak detection at nuclear power plants.** PNNL is adapting the ERT approach applied to environmental remediation for use in leak detection. The adaptation is enabled by PNNL's E4D code (R&D 100 Award winner), which accounts for metal infrastructure in analyzing ERT data, especially important because of the large amount of infrastructure at nuclear power plants. PNNL has been commissioned by the EPRI to demonstrate the design and use of remote subsurface electrical sensing to monitor for leaks emanating from buried piping and nuclear power plants. After a successful Phase I feasibility assessment using numerical simulation, EPRI and PNNL teamed with Duke Energy to install a detection system at the Brunswick Nuclear Power Plant in North Carolina. The system is anticipated to enable plant operators to autonomously and continuously monitor for leaks, and eventually reduce direct piping inspection intervals to significantly reduce cost and increase safety of plant operations.

- P**NNL is developing a toolbox for computational evaluations of impacts of subsurface injection operations to be used by EPA to support their planning and oversight activities.** The compilation of analytical and semi-analytical computational approaches that will be available through the toolbox will support delineation of the subsurface area impacted from brine injection operations. The advantages of this toolbox are that it allows for considerations of fluid transport, more complex and comprehensive than the currently applied methods, with a simple input structure and quick execution.

3.2 Significant Leadership / Technical Awards

PNNL scientists and researchers are recognized for their contributions in the areas of waste processing and environmental remediation through significant leadership/technical awards, leadership roles in technical workshops and seminars, serving on independent technical review panels or advisory boards, critical leadership positions in the scientific community, joint appointments/adjunct professorship, technical editorial boards, and community leadership positions.

- **Sue Clark – American Chemical Society Glenn T. Seaborg Award.** PNNL nuclear chemist Sue B. Clark received the 2020 Glenn T. Seaborg Award for Nuclear Chemistry from the American Chemical Society. This honor from the world's largest scientific society recognizes Clark's internationally known contributions to the field of nuclear chemistry, including her work in resolving our country's legacy of radioactive waste, advancing innovation in nuclear safeguards and forensics, building the pipeline of future radiochemists, and developing landmark nuclear research capabilities. Her more recent research on radionuclides in the environment and in environmentally relevant systems has focused on the chemistry needed to retrieve high-level radioactive waste from the Hanford waste tanks.

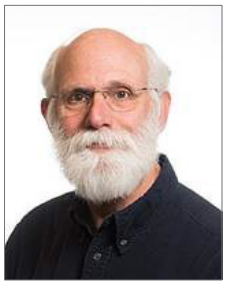
At PNNL, she is a Battelle fellow, Chief Science & Technology Officer for the Energy and Environment Directorate, and Director of the IDREAM Energy Frontier Research Center. Sponsored by DOE's Office of Basic Energy Sciences in the Office of Science, IDREAM focuses on the foundational science needed to accelerate the processing of high-level radioactive waste. Clark also is a Regents professor of chemistry at Washington State University and has held numerous national-level appointments.

The ACS award includes the Seaborg Symposium at an upcoming national conference, where Clark will give a technical address: "Radiochemistry and its applications in radioactive waste management and nuclear security."

Clark earned her Ph.D. in inorganic and radiochemistry at Florida State University and has produced more than 136 publications. Her work has been cited more than 1,600 times by other scientists building on her research.

- **Nikolla Qafoku has been elected a Fellow of the Soil Science Society of America (SSSA).** The Fellow designation is the highest recognition bestowed by the SSSA. Members of SSSA nominate worthy colleagues based on their professional achievement and meritorious service and annually only a select few are bestowed with the Fellow designation. This designation recognizes Nik's significant contributions and achievements.

- **Nikolla Qafoku was awarded the 2019 Jackson Soil Chemistry and Mineralogy Award**, Soil Science Society of America (SSSA). The award recognizes a soil scientist who has made outstanding contributions in the areas of soil chemistry and mineralogy. The award is evaluated based on significant and originality of basic and/or applied research in soil chemistry/minerology, excellence in creative reasoning and skill in obtaining pertinent data, quality of teaching soil chemistry / minerology at undergraduate and/or graduate levels, and total impact of contributions on soil science and other fields, nationally or internationally, as well as on the society at large. The award was presented during the SSSA Annual Meeting, San Antonio, TX, November 10-13, 2019.



- **Bruce Napier was elected Distinguished Emeritus Member of the U.S. National Council on Radiation Protection and Measurements (March 2020).** NCRP was chartered in 1964 by the U.S. Congress to formulate and widely disseminate information, guidance, and recommendations on radiation protection and measurements.
- **Bruce Napier is one of the eight members of the U.S. Delegation to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)**, appointed by the U.S. State Department and approved by the White House. UNSCEAR was established by the General Assembly of the United Nations in 1955. Its mandate in the United Nations system is to assess and report levels and effects of exposure to ionizing radiation. Governments and organizations throughout the world rely on the Committee's estimates as the scientific basis for evaluating radiation risk and for establishing protective measures.
- **Matt Asmussen received the ASTM Early Career Award.** This recognition is awarded out of the ASTM Emerging Professionals Program as it focuses on new members who have demonstrated he potential to be industry and committee leaders. Matt received the award for his potential leadership in the ASTM Committee C26 (Nuclear Fuel Cycle) based on his current and previous leadership with Subcommittee C26.13. Matt led a Committee/Subcommittee C26.13 Task Group that revised C1682 on characterization of spent nuclear fuel and was given a 2018 Committee C26 Nuclear Fuel Cycle Award of Appreciation for his efforts.
- **Megan Nims was honored with 2020 ACS Outreach Volunteer Award.** As chair of the Richland Local Section Women Chemist Committee, Megan organized a series of well-attended community events, in recognition of Women's History Month, focused on the local Hanford nuclear site. Nims helped to organize Expanding Your Horizons, a conference designed to expose seventh and eighth grade girls to STEM careers. The conference connected 200 students with women in a variety of disciplines ranging from chemistry to nuclear engineering.
- **Joshua Silverstein received a Strategic Initiative Award from the Microscopy Society of America for "Developing a National Network of STEM Outreach Leaders".** The Microscopy Society of America is a non-profit organization dedicated to the promotion and advancement of techniques and applications of microscopy and microanalysis in all relevant scientific disciplines. The Society provides leadership for the discovery and dissemination of information about microscopy and microanalysis, especially in relation to the following multidisciplinary areas: (1) latest developments in instrumentation, (2) emerging trends in characterization, (3) discovering the big world of micro through education and outreach, (4) uncovering the inner secrets of life and biological sciences, (5) exploring the physical and materials sciences, and (6) providing resources for nanoscience and nanotechnology.

3.3 Patents and Invention Disclosures

- Leonard Pease, Xiao-Ying Yu, Timothy Veldman, Matthew Fountain, Michael Minette, Carolyn Burns, Nathan Phillips, Jason Serkowski, filed on April 25, 2019. “Separator Assemblies and Methods.” U.S. Application No. 16/395,097.
- Leonard Pease, Shane Addleman, Carolyn Burns, Michael Minette, filed on 5/2/20. “Enabling Improved Dynamic Operation of Geothermal Plants” (IPID 31886-E).
- Leonard Pease, Shane Addleman, Carolyn Burns, Michael Minette, filed on 5/2/20. “Methods and Devices for Enhanced Industrial Flow Processing and the Recovery and Separation of Minerals” (IPID 31885-E).
- Carolyn Pearce, provisional patent filed on 12/10/2019. “Polyacrylonitrile-sorbent composites for the removal of radionuclides from groundwater” (IPID 31688).

3.4 Technical Workshops/Seminars

- **Fukushima Revitalization Symposium.** PNNL Senior Advisor, Mark Triplett, co-chaired and organized an international symposium in Iwaki, Japan, on Fukushima revitalization, January 25, 2020. The symposium was hosted by the Shouheikou Educational Foundation and the Higashi Nippon International University. The symposium was sponsored by Japanese government organizations including the Ministry of Education, Culture, Sports, Science and Technology; the Ministry of Economy, Trade and Industry; the Reconstruction Agency; and the Fukushima Prefectural government. Participants included eight representatives of Tri-Cities government, educational, and business organizations and counterparts from Fukushima organizations.
- **Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Workshop**. Xingyuan Chen, Glenn Hammond, and Vicky Freedman are partnering with the CUAHSI to conduct a week-long workshop on reactive transport modeling. This workshop focuses on identifying, implementing, and troubleshooting reaction networks in reactive transport models.
- **Interstate Technology and Regulatory Council (ITRC) Training Sessions.** Mike Truex served as a trainer for the ITRC document titled *Remediation Management of Complex Sites*. These web-based training sessions have reached several thousand attendees to facilitate understanding of complex site issues and implementation of adaptive site management strategies.
- **IAEA International Training Courses: Nuclear Waste Vitrification and Cementation.** PNNL scientists are key program contributors for the IAEA series of international training courses. In September 2019, Joe Ryan was a lecturer for the Joint ICTP (International Centre for Theoretical Physics)-IAEA International School on Nuclear Waste Vitrification. The course focused on optimal methods to use vitreous waste forms for the immobilization of dangerous radionuclides, including synthesis, characterization, and evaluation of long-term performance. Joe contributed lectures on both the background of long-term performance of glass waste forms and the optimal tests and characterization methods to use for that problem.

  Similarly, PNNL scientist Matt Asmussen will be a key program contributor for the Joint ICTP-IAEA International School on Radioactive Waste Cementation in October 2020. That workshop aims to bring together researchers from materials sciences focusing on the design of cement-based materials to enhance durability of nuclear waste immobilization for disposal. The workshop will focus on cementitious admixtures to enhance durability of nuclear waste immobilization for disposal. Information presented will help other experts from nuclear energy research, materials science, and waste management to better understand the properties of cementitious materials and potential of

cement science and technology for the long-term immobilization of radioactive waste. PNNL will be contributing three lessons to the workshop.

- **Waste Management Program Advisory Committee (PAC).** As Program Advisory Committee (PAC) members to the Waste Management Symposia, several PNNL staff served in leadership roles supporting the Symposia and EM in organizing key sessions to highlight challenges and successes in cleanup. Tom Brouns and Kent McDonald serve as track co-chairs for the HLW and spent nuclear fuel / used nuclear fuel and packaging and transportation tracks, respectively. Tom Brouns, a fellow of the Waste Management Symposia, organized tank waste panel sessions on EM tank waste challenges and supplemental LAW treatment alternatives. Vicky Freedman, an Environmental Remediation Track PAC member, organized panels on adaptive site management and reducing long-term monitoring costs as well as oral sessions on conceptual and numerical modeling in environmental remediation.
- **International Congress on Glass Short Course.** PNNL scientists were key contributors for a recent International Congress on Glass short course on glass corrosion. The course provided comprehensive knowledge about the fundamental mechanisms and kinetics of glass corrosion. PNNL experts provided the focus areas on the history and challenges of waste vitrification as well as the state of the art on advanced characterization techniques related to glass corrosion. International scientists, corporate researchers, and a computational modeler rounded out the full-day course.
- **Community Science & Technology Seminar Series.** PNNL scientist Jaime George presented "A Common Material Solving An Uncommon Problem – How do we immobilize Nuclear Waste" as part of the PNNL Community Science and Technology Seminar Series (May 2020). Attendees included community members from the Tri-Cities, Seattle region, Oregon, Gig Harbor, Port Orchard, and Berkeley, CA.
- **Bi-annual Washington State Hydrogeology Symposium.** Vicky Freedman, Catherine Yonkofski, and Mark Freshley continued to serve on the Bi-annual Washington State Hydrogeology Symposium. Catherine Yonkofski is currently the vice chair and Vicky Freedman and Mark Freshley support the symposium organization committee.
- **Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Workshop.** PNNL lead developer Tim Johnson and computational scientist Judy Robinson were selected to lead a 4-day CUAHSI workshop sponsored by the National Science Foundation. Due to COVID-19, the workshop has been postponed until May 2021. This course will provide structured, hands-on interactive training on the use of the PNNL 2017 R&D 100 Award-winning E4D software, a four-dimensional modeling and inversion code designed for subsurface imaging and monitoring using static and time-lapse 3D ERT and SIP data. This training will focus on providing users with the knowledge needed to independently execute E4D for ERT field data interpretation.

3.5 Independent Review Team / Expert Panels / Advisory Groups

- **WRPS Leak Detection Independent Panel Support; Tim Johnson.** At the request of WRPS, PNNL provided analysis and results of the sensitivity of the leak detection system currently used to detect external tank leaks during retrieval operations. Based on those results, WRPS convened a technical panel including PNNL, the current leak detection contractor, and an independent expert to review leak detection capabilities and recommend a path forward. PNNL provided technical guidance to WRPS to write a specification for a new tank leak detection system with enhanced detection sensitivity. The new system may be used for future retrievals.

- **Technical Basis for Extended Dry Storage of Al-clad Spent Fuel; Independent Technical Review; Brady Hansen.** PNNL is providing technical support to Battelle Energy Alliance, LLC / Idaho National Laboratory in review and improvement of the technical basis for extended dry storage of aluminum-clad spent nuclear fuel (ASNF). As part of the ASNF program, two tasks have been initiated: (1) oxide layer radiolytic gas generation resolution and (2) sealed and vented system episodic breathing and gas generation prediction. PNNL is providing an independent review of these tasks, which will increase the defensibility of the final technical basis for extended storage of aluminum-clad spent fuel.
- **Retrieval and Processing of Melton Valley Storage Tank Waste; Technical Review Team, Carl Enderlin and Beric Wells.** PNNL is conducting technical reviews and providing technical consultation to AVANTech for the development, design, and testing of a waste retrieval and processing systems to be employed at the Oak Ridge Site for retrieval of the Melton Valley storage vessels. Specific tasks include (1) reviews of test plan, conceptual vessel/mixer design, and strategy for development and verification of preliminary multi-phase computational fluid dynamics (CFD) model; (2) assessment of test results for mixing system; (3) review of CFD models results for verification; and (4) review/consultation for application of CFD model results to full-scale system design and processing.
- **UK Government Research Council Advisory Group; Carolyn Pearce.** PNNL representative on the International Advisory Group for TRANSCEND (TRANsformative SCience and Engineering for Nuclear Decommissioning), https://transcendconsortium.org/, large consortium grant in the UK funded by the UK government research council.
- **New Mexico State University (UMSU) Subsurface Contaminant Mixtures Relevant to the Hanford Site; Technical Advisor, Lirong Zhong.** The UMSU-lead project objective is to develop quantitative approaches for contaminant attenuation prediction, and support development of enhanced attenuation strategies to improve the effectiveness of in situ remediation and long-term management strategies for Hanford deep vadose zone contamination mixtures. The work performed by UMSU included flow-through column experiments and moment analysis, measurement of mass recovery and sorption coefficients for single and multiple contaminant systems, and HydroGeoChem modeling to measure the competitive sorption due to surface complexation for contaminants at different pH values.
- **Senior Technical Leadership to the Waste Control Specialists Technical Review Team (WCS TRT); Michael Minette.** Environmental Management Los Alamos reactivated the five national laboratory team that responded to the February 2014 Waste Isolation Pilot Plant event to evaluate 113 waste drums currently stored at Waste Control Specialists in Texas. The governor of Texas had requested the removal of the drums from the WCS site by December 2020, so this effort had high national importance. The team of national waste and chemical interaction experts provided a key evaluation (WCS TRT report) of the waste drum conditions. The team's scope has been expanded by Environmental Management Los Alamos to include technical support for the waste sampling, transportation, repackaging, and long-term disposal efforts for the 113 drums.

3.6 Leadership Positions in the Scientific Community

PNNL staff provided leadership and expertise in the areas of waste management and environmental remediation through membership in technical societies:

- **Waste Processing**
  - Stuart Arm, Member of the Public Affairs and Information Committee of the American Institute of Chemical Engineers.
  - Stuart Arm, Senior member of the American Institute of Chemical Engineers' Nuclear Engineering Division.
  - Matt Asmussen, Symposium Chair, Crosscutting Issues in Corrosion of Materials: Control, Monitoring, Mitigation and Material Selection, MS&T 2019 (September 29 – October 3, 2019)
  - Judith Bamberger, Fellow, American Society of Mechanical Engineers, Vice Chair of the Fluids Engineering Division 7/2019-6/2020.
  - Judith Bamberger, Fellow, American Society of Mechanical Engineers, Chair of the ASME Fluids Engineering Division Summer Meeting FEDSM2020 July 12-16, 2020 Rosen Shingle Creek, Orlando, Florida.
  - Judith Bamberger, Fellow, American Society of Mechanical Engineers, Secretary of the Nominating Committee
  - Judith Bamberger, Fellow, American Society of Mechanical Engineers, Chair of the Fluids Engineering Division
  - Judith Bamberger, Fellow, American Society of Mechanical Engineers, Advisor to the Nominating Committee
  - Sandy Fiskum, Chair of the Richland Section of the American Chemical Society
  - Sebastien Kerisit, Treasure of the ACS Geochemistry Division
  - Sebastien Kerisit, Alternate Counselor of the ACS Geochemistry Division
  - Charmayne Lonergan, International Commission on Glass, Vice-chair, Waste Vitrification Technical Committee TC05)
  - Charmayne Lonergan, American Ceramic Society Education and Professional Development Council member
  - Charmayne Lonergan, American Ceramic Society, Co-Chair Young Professionals Network Steering Committee
  - Charmayne Lonergan, American Ceramic Society, Kreigel Fundraising Committee
  - Josef Matyas, chair-elect for upcoming 44th International Symposium "Scientific Basis for Nuclear Waste Management" MRS Fall meeting to be held in Boston, MA, from November 29 to December 4, 2020.
  - Josef Matyas, MRS Symposium (EN08) Organizer, Scientific Basis for Nuclear Waste Management, 2020 MRS Fall Meeting and Exhibit, to be held in Boston, MA, from November 29 to December 4, 2020.
  - Leonard Pease, Senior member of AICHE
  - Reid Peterson, AIChE Nuclear Engineering Division (NED) Leadership Team

- Joe Ryan, National Nuclear Laboratory, Corrosion Scientific Advisory Panel
- Joe Ryan, Charmayne Lonergan, and John Vienna co-organized a nuclear waste vitrification symposium at the Glass and Optical Materials Conference in New Orleans in May 2020. (cancelled due to Covid-19)
- Sarah Saslow, Session Co-organizer, "Advances in understanding clay-based barrier system for Deep Geological Repositories", to be held at the 57th Annual International Meeting of the Clay Minerals Society, held at PNNL Discover Hall, June 15-19, 2020. (postponed to October 202 due to Covid-19)
- Phil Schonewill, Vice Chair of the Nuclear Engineering Division of AICHE
- Phil Schonewill, member of the NED Planning and Organizing Committee for the 2020 Annual Meeting of AIChE
- Joshua Silverstein, Education Committee at Microscopy Society of America (MSA).
- Gary Smith, Chair of ASTM International Subcommittee C26.13 on Nuclear Waste (Low, Mixed, & HLW (glass and SNF)); organized and oversaw two technical meetings February 2020 in Atlanta, GA and June 2020 in Boston, MA (due to COVID-19 held virtual meeting).
- John Vienna was the U.S. participant in the conference organizing committee (an international committee of 8 experts from around the world), Scientific Basis for Nuclear Waste Management Conference in Vienna Austria October 2019.

- **Environmental Remediation**
  - JM Barnett, ANSI/HPS standard N13.61 Working Group member developing a U.S. technical standard for ambient air monitoring for particulates.
  - Matthew Feldman, ASME Vessel and Piping (PVP Division Leadership Team
  - Matthew Feldman, ASME PVP Programs Chair (2017-2020)
  - Matthew Feldman, ASME PVP Conference Technical Program Chair
  - Matthew Feldman, ANSI N14 Accreditation Standards Committee Chair
  - Matthew Feldman, Institute of Nuclear Materials Management Executive Committee Member
  - Jim Neeway, co-organizer for symposium at Goldschmidt, Geochemical Processes in Disposal Systems for Radioactive Waste, its Barriers and Environment and Understanding Coupled Biogeochemical Corrosion Processes for Long-Term Prediction of Materials Degradation, virtual meeting (2020)
  - Carolyn Pearce, Organizing Committee member for Clay Mineral Society Meeting 2020, PNNL Discover Hall, June 15-19, 2020.
  - Nikolla Qafoku, General Chair of the 57th Annual International Meeting of the Clay Minerals Society, held at PNNL Discover Hall, June 15-19, 2020. Six sessions of this meeting are focused on waste affected environments with session organizers and presenters from leading national and international institutions.
  - Judith Robinson, Environmental and Engineering Geophysical Society (EEGS), Board member at large, Communications Chair 2019-present.
  - Sandra Snyder, ANSI/HPS standard N13.61 Working Group Lead developing a U.S. technical standard for ambient air monitoring for particulates.

– Sandra Snyder, member of ISO/TC 085/SC 2/ Working Group 17 “Radioactivity Measurements,” providing input and review for international standards. (TC 085= Nuclear Energy, Nuclear).

3.7 Joint/Dual Appointments or Adjunct Professors

– James Amonette, Joint Appointment with Washington State University, Center for Sustaining Agriculture and Natural Resources (CSANR)

– Nick Barilo, Joint Appointment with the American Institute of Chemical Engineers, Director of the Center for Hydrogen Safety

– Sue Clark, Joint Appointment with Washington State University, Chemistry Department

– John McCloy, Joint Appointment with Washington State University, School of Mechanical and Materials Engineering

– Inci Demirkanli, Adjunct Faculty, Clemson University, Environmental Engineering and Earth Sciences Department

– Michael Hochella, University Distinguished Professor (Emeritus), Virginia Tech, Department of Geosciences

– Carolyn Pearce, Visiting Academic, University of Manchester, School of Earth and Environmental Sciences

– Carolyn Pearce, Adjunct Professor, Washington State University, Department of Crop and Soil Sciences

– David Peeler, Adjunct Professor, Clemson University, Materials Science and Engineering Department

– Brian Riley, Joint Appointment with Washington State University, Materials Science and Engineering Department

– Nikolla Qafoku, Affiliate Professor and Joint Appointment with the University of Washington, Department of Civil and Environmental Engineering

– Nathalie Voisin, Joint/Dual Appointment, University of Washington, Civil and Environmental Engineering Department

– Samuel Bryan, Adjunct Faculty, Department of Chemistry, Washington State University

– Samuel A. Bryan, Affiliate Appointment, Chemistry Department - Colorado School of Mines

– Courtney Bottenus, Joint Appointment at Washington State University Voiland College of Engineering and Architecture

3.8 Technical Editorial Boards

PNNL staff supported several national/international journal editorial boards. In general, editorial board members, who are experts in their respective fields, work with the Editorial Advisory Panel to ensure that submitted research manuscripts are technically sound, scientifically valid, and ultimately suitable for publication.

– Dr. Ram Devanathan, Member of the Committee on Publications for the International Journal of Applied Glass Science (IJAGS)

– Dr. Michael Hochella, Lab Fellow, Special Issue Editor for the Journal Minerals, Multidisciplinary Digital Publishing Institute, MDPI Open Access journals, Subject of Nanomineralogy

- Dr. Nikolla Qafoku, Chief Scientist and Team Lead, Editorial Board Member, Frontiers in Environmental Sciences
- Dr. Satish Nune, Senior Research Scientist, Editorial Board Member for Nature Scientific Reports published by Springer
- Dr. John Vienna, Lab Fellow, Editorial Board Member, Associate Editor for the International Journal of Applied Glass Science (IJAGS)

4.0 Objective 3.1: Provide Effective and Efficient Strategic Planning and Stewardship of Scientific Capabilities and Program Vision

Goal 3.0: Provide effective program vision and leadership; strategic planning and development of initiatives; recruit and retain a quality scientific workforce; and provide outstanding research processes, which improve research productivity

Objective 3.1 Provide Effective and Efficient Strategic Planning and Stewardship of Scientific Capabilities and Program Vision

Description: By which we mean a scientific and technical vision that enhances DOE program efforts; successful joint planning with partners, collaborators and stakeholders, and the outside community; and ability to attract and retain highly qualified staff.

In assessing the performance of the Laboratory against this objective, the following assessment elements should be considered:

- The quality of the Laboratory's strategic plan
- The extent to which the Laboratory shows strategic vision for research
- The extent to which programs of research take advantage of Laboratory capabilities—research programs are more than the sum of their individual project parts
- The extent to which the Laboratory undertakes research for which it is uniquely qualified
- The extent to which Laboratory plans are aligned with DOE mission goals
- The extent to which the Laboratory programs are balanced between high- and low-risk research for a sustainable program
- The extent to which the Laboratory is able to retain and recruit staff for a sustainable program

The following is a sampling of factors to be considered in determining the level of performance for the Laboratory against this objective. The evaluator(s) may consider the following as measured through progress reports, peer reviews, FWPs, program office reviews/oversight, etc.:

- Articulation of scientific vision
- Development and maintenance of core competencies
- Ability to attract and retain highly qualified staff
- Efficiency and effectiveness of joint planning (e.g., workshops) with outside community
- Creativity and robustness of ideas for new facilities and research programs
- Willingness to take on high-risk/high payoff/long-term research problems, evidence that the Laboratory "guessed right" in that previous risky decisions proved to be correct and are paying off
- The depth and breadth of Laboratory research portfolio and its potential for growth

PNNL is committed to delivering scientific understanding and technological advancements to reduce the risks, time, and cost of resolving critical EM challenges to enable the baseline and to enable closure of environmental remediation challenges to support long-term stewardship.

As an SC laboratory, PNNL is uniquely positioned to deliver the scientific and engineering knowledge – from basic science and feasibility research to large-scale demonstrations – that supports maturation and deployment of advanced technologies to achieve EM mission goals (Figure 11). PNNL is committed to stewarding the necessary capabilities and delivering on an integrated and leveraged R&D portfolio, sponsored collectively through investments from SC, EM HQ, EM site offices, EM site contractors, and PNNL LDRD, that enables resolution of critical technical challenges within the EM mission.

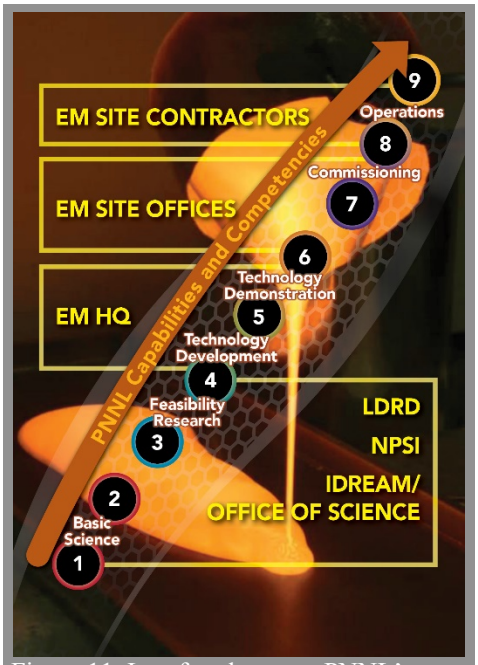


Figure 11. Interface between PNNL's integrated R&D programs and EM mission support spanning basic science through support to operations and core capabilities recognized by SC

- **PNNL's stewardship of core competencies critical to the EM mission.** As DOE's premier chemistry, earth science, and data analytics laboratory, PNNL has 19 core capabilities, as recognized by SC, each of which is composed of a powerful combination of world-class staff, state-of-the-art equipment, and mission-ready facilities (Figure 12). From this foundation, PNNL stewards four core competencies in waste processing – tank waste chemistry, waste forms, fluid dynamics and scaling, and safety basis (Figure 13) – and four core competencies in environmental remediation – nature and extent, remediation science, remediation systems, and end states (Figure 14) – that integrate and build on the fundamental disciplines

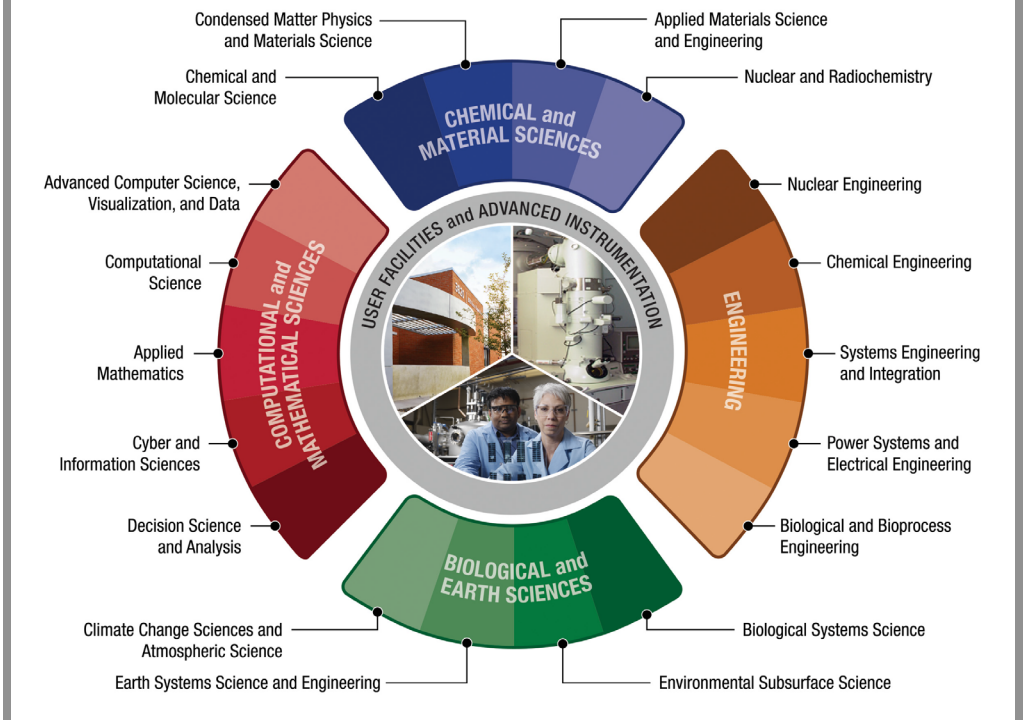


Figure 12. 19 PNNL core capabilities, as recognized by SC.

Figure 13. In support of EM, PNNL stewards four core competencies in waste processing – tank waste chemistry, waste forms, fluid dynamics and scaling, and safety basis – that integrate and build on the fundamental disciplines and core capabilities recognized by the Office of Science.

Figure 14. In support of EM, PNNL stewards four core competencies in environmental remediation – nature and extent, remediation science, remediation systems, and end states – that integrate and build on the fundamental disciplines and core capabilities recognized by the Office of Science.

- **PNNL stewards key facilities critical to the EM mission**. PNNL continues to invest in and expand core facilities and capabilities. State-of-the-art facilities provide an environment that encourages multi-disciplinary teams and enables leveraging across mission and program spaces. PNNL stewards core facilities in waste processing (Figure 15) and environmental remediation (Figure 16) that enable integrated, cross-disciplinary understanding and development from the atomistic level through bench and pilot scale. This ability and suite of capabilities are unique within the national laboratory complex and allow for the continued development of innovative solutions from fundamental R&D and feasibility research to large-scale demonstrations that support deployment to achieve EM mission goals. At the heart of our EM mission support is PNNL's RPL, which is a unique Category II nuclear facility. Its mission is to enable research with microgram-to-kilogram quantities of fissionable materials and high-curie activities of radionuclides for the development of technical solutions for nuclear waste, energy, nonproliferation, homeland security, and isotope production. Recent key capabilities installed in RPL supporting the EM mission include (but are not limited to) the Radioactive Test Platform and state-of-the-art analytical techniques.

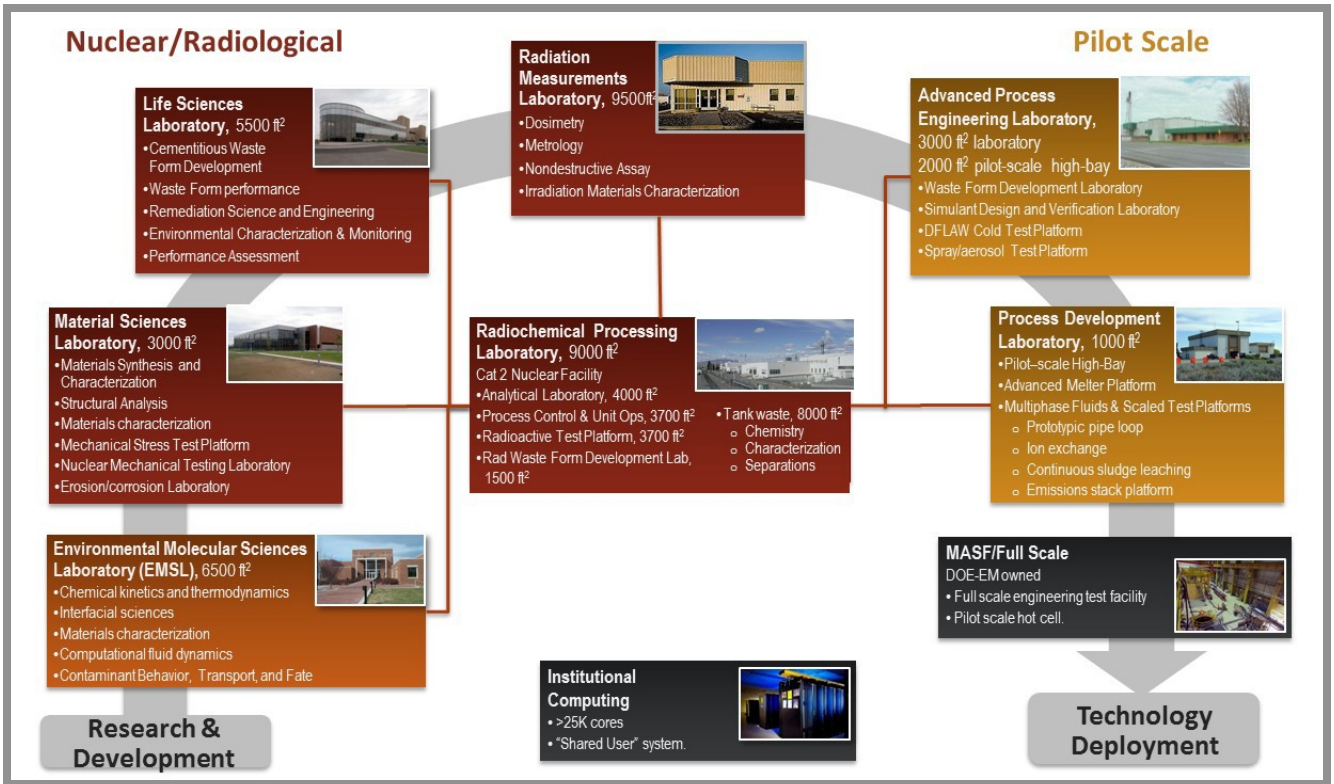


Figure 15. In support of EM, PNNL stewards core facilities that enable research from atomic- through pilot-scale in support of waste processing.

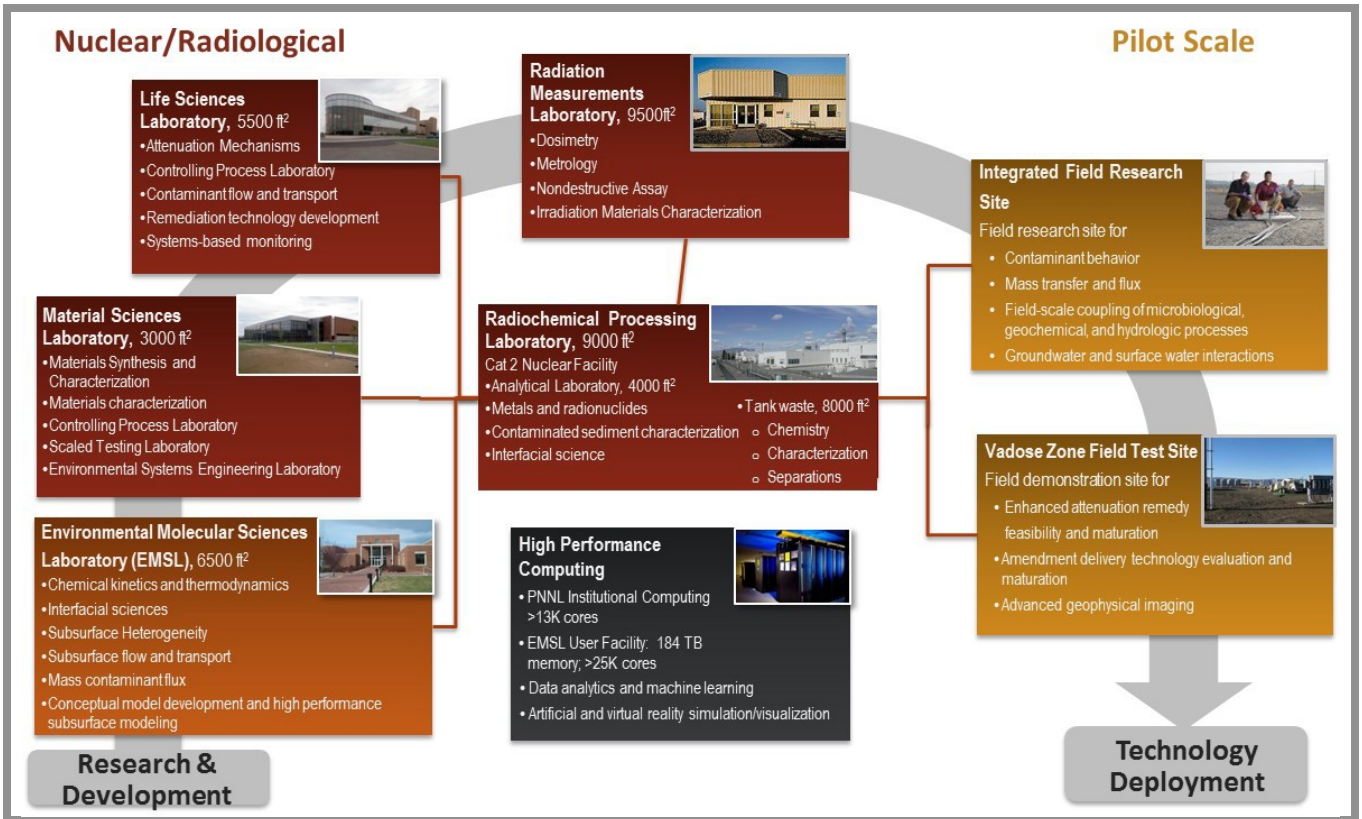


Figure 16. In support of EM, PNNL stewards core facilities that enable research from atomic- through field-scale in support of environmental remediation.

The Radioactive Test Platform is an S&T platform that is supporting the development of the DFLAW baseline flowsheet (filtration, ion exchange, and melter operations) and reducing risk for future radioactive operations. The platform builds on PNNL's historical experience as the primary developer of the unit operations for treating Hanford tank waste. In FY20, PNNL has used the Radioactive Test Platform to demonstrate cross-flow/deadend filtration and cesium removal from samples of actual Hanford LAW tank waste representing the early feed to DFLAW. In addition, the decontaminated salt solutions were converting into a stable glass product using the glass formlation algorithms developed by PNNL. PNNL also recently installed a scanning transmission electron microscope, which allows PNNL scientists to analyze tank waste samples at very high resolution, for instance those containing sub-micrometer-sized Pu-particles providing information on the chemistry, structure, and form of these phases. The scanning transmission electron microscope is complemented by a scanning electron microscope and a focused ion beam scanning electron microscope that enable representative bulk analysis of fully radioactive tank waste and subsampling of specimens for other techniques, respectively. All of these tools are equipped with an array of analytical capabilities that enable detailed chemical analysis of materials. Furthermore, with the various in situ liquid cell, electrochemical, and cryo capabilities, we can investigate specific chemical treatment processes, such as dissolution or precipitation reactions relevant to EM.

Over the past decade, PNNL has invested more than $70M in infrastructure and facility upgrades, and more than $15M in state-of-the-art microscopic and spectroscopy instrumentation to support these missions.

- **PNNL installs equipment and infrastructure at the vadose zone test bed and executes baseline measurement conditions to demonstrate advanced vadose zone monitoring approaches that meet the needs for long-term management of the Hanford Central Plateau**. PNNL is partnering with the site contractor to use the former field treatability test infrastructure of the soil desiccation site located as part of the 200-BC-1 operable unit. Baseline conditions were established so that perturbances can be measured with low-maintenance, cost-effective monitoring approaches as part of an overall Central Plateau monitoring strategy and integration of adaptive site management. Meeting this need requires monitoring to verify predictions of contaminant flux at the waste site identified as risk drivers to provide feedback on targeting of source treatment actions, performance assessment of source treatment, and/or verification that passive approaches will meet risk-based objectives.
- **PNNL continues to invest in an LDRD initiative to address fundamental science associated with EM waste processing**. PNNL has completed the final year of a 5-year Nuclear Process Science Initiative (NPSI) to provide fundamental insight into the nature of interfacial chemistry in radiation environments as it applies to tank waste processing and other PNNL mission areas. During the arc of NPSI, several LDRD projects were completed that focused on phenomena such as dissolution of tank waste materials, agglomeration of particulates in the waste stream, the impact of these processes on waste rheology and filtration, and new formulations of grout to better incorporate Tc. These projects have broad implications for waste processing activities, providing insight into the effect of radiolysis on tank waste components and the complex interactions that occur during filtration and dissolution of critical tank waste materials. This work provides a basis for EM-funded efforts to expand waste processing operational windows, and possibly accelerate overall waste processing timelines.

  As an example, PNNL researchers developed a flow visualization “micro cuf” to enable real-time visualization of filter fouling. Using radioactive waste simulant for AP-105, the system enabled staff to determine how particles in the flow field interact with the stainless-steel substrate and identify that filter fouling transitions through multiple fouling phases. These results were used in developing the approach for filtration of the actual waste AP-105 in the hot cell (Figure 17). The results of the simulant and actual waste work enable optimization of the filtration processed that are part of the TSCR for DFLAW, Tank Closure Cesium Removal at Savannah River Remediation, Salt Waste Processing Facility at Savannah River Remediation, and the WTP.

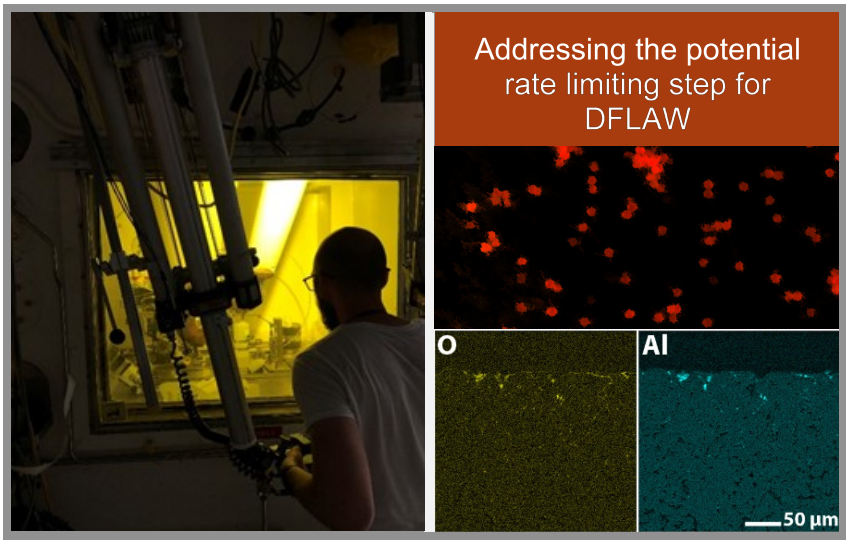


Figure 17. Filtering radioactive waste from AP-105 in RPL hot cell (left); flow visualization showing heterogenous fouling of stainless-steel filters (right).

Equally, if perhaps not more importantly, the NPSI initiative afforded the opportunity for substantial hiring, training, and development of the next generation of scientists and engineers knowledgeable in Hanford tank waste chemistry and physics. More than 20 junior scientists and engineers are participating in and benefitting from the initiative (Figure 18).

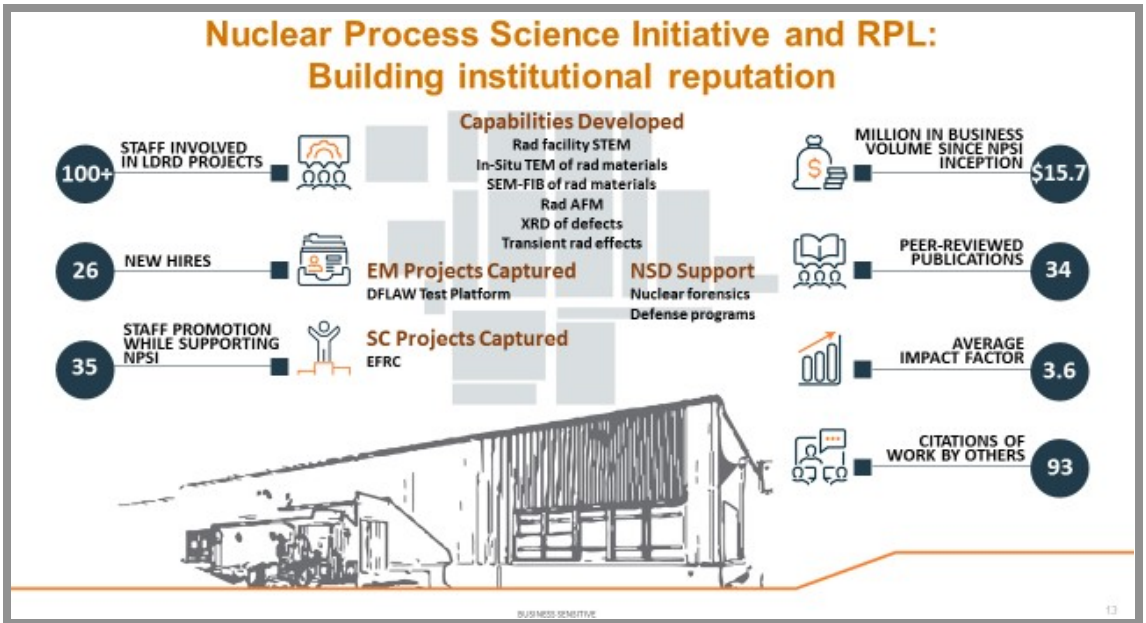


Figure 18. Development of next-generation nuclear process scientists and engineers and capabilities through PNNL's NPSI LDRD

- **PNNL is contributing to cross-cutting research to address environmental cleanup challenges for EM and helping to mentor the next generation of scientists and engineers through collaboration with Florida International University.** In FY20, this collaboration supported EM's cleanup mission through the Minority Serving Institutions Partnership Program and FIU's cooperative agreement with EM for workforce development with a focus on environmental remediation and treatment of tanks waste streams. These research projects supported both postdocs and undergraduates (three students graduated with their BS in fall 2019). The PNNL-FIU team also widely disseminates this research to the scientific community with five peer-reviewed publications and more than 20 presentations at national and international conferences and meetings in 2019-2020. *POC: Genia McKinley, EM HQ*
- **PNNL is preserving historical knowledge and cultivating future leaders in nuclear science**. PNNL is actively working to retain historical knowledge and expertise critical for continued understanding and support of the Hanford mission in environmental remediation and waste processing. An effort is currently underway to create a workshop on the topic of "Environmental Remediation of Hanford Soil and Water" that serves as a catalyst for mentoring and knowledge transfer. PNNL is using a multifaceted approach, including (1) **intergenerational teaming** - emerging leaders (early- and mid-career staff) pair with senior leaders to foster collaboration, training, and education around specific technical topics within the workshop; (2) **workshops** – emerging leaders are mentored by senior leaders to develop and deliver interactive training sessions on strategically chosen topics to cultivate technical and historical expertise; and, (3) **culture of expert development** – organizational priority is focused on developing the next generation of leaders for EM. This mentoring and workshop development effort follows a similar one from FY18 on the topic of waste processing. Both workshops can be leveraged for internal and external audiences, such as the Clay Minerals Society meeting to be held at PNNL in October 2020. A current focus is on developing in-person and on-line offerings.

5.0 Objective 3.2: Provide Effective and Efficient S&T Project/Program/Facilities Management

Goal 3.0: Provide effective program vision and leadership; strategic planning and development of initiatives; recruit and retain a quality scientific workforce; and provide outstanding research processes, which improve research productivity

Objective 3.2 Provide Effective and Efficient S&T Project/Program/Facilities Management

Description: By which we mean quality research development and demonstration plans (for example, AOPs); full consideration of technical risks; success in identifying and resolving/avoiding technical problems; and leveraging and interacting (synergy) with other areas of research, development and demonstration.

In assessing the performance of the Laboratory against this objective, the following assessment elements should be considered:

- The Laboratory's management of R&D programs and facilities according to proposed plans
- The extent to which the Laboratory's management of projects/programs/facilities supports the Laboratory strategic plan
- Adequacy of the Laboratory's consideration of technical risks
- The extent to which the Laboratory is successful in identifying/avoiding technical problems
- Effectiveness in leveraging across multiple areas of research and between research and facility capabilities
- The extent to which the Laboratory demonstrates a willingness to make tough decisions (cut programs with sub-critical mass of expertise, divert resources to more promising areas, etc.)
- The use of LDRD and other Laboratory investments and overhead funds to improve the competitiveness of the Laboratory

The following is a sampling of factors to be considered in determining the level of performance for the Laboratory against this objective. The evaluator(s) may consider the following as measured through progress reports, peer reviews, FWPs, program office reviews/oversight, etc.:

1. Laboratory plans that are reviewed by experts outside of lab management and/or include broadly- based input from within the Laboratory

During FY20, PNNL provided quality solutions to technical challenges facing EM while carefully considering technical, programmatic, and operational risks. PNNL identified and avoided numerous technical problems and provided effective project and program management for DOE's most pressing concerns, including leading the strategy for providing the technical basis for grout waste forms and closure of Hanford tanks, leading strategy development and implementation for addressing tank vapors, and enabling the safe design and operation of DFLAW-LAWPS/TSCR. PNNL demonstrated the willingness to make tough decisions, including pulling key technical experts out of roles in other mission spaces and bringing them into EM space to address critical challenges. Finally, PNNL continues to effectively manage facilities and capabilities through DOE and other mission spaces to maximize leveraging and resolve EM challenges.

- **PNNL is recognized as a leader in project management across the DOE portfolio**. In FY20, 60 project managers within the EM sector were responsible for managing **136 projects**, across **13 sponsors**, with an FY20 business volume totaling over **$37.6M**. PNNL has developed tools that enable project managers to identify risks and mitigation strategies, develop time-phased cost estimates, develop a graded approach to quality requirements, and plan the schedule so that resource constraints and key deliverables can be identified, to ensure delivery on time and within budget. Within the portfolio of WRPS projects, PNNL has successfully implemented more strict project management tools by using an earned value management system to provide weekly progress reports to WRPS, and monthly critical path analysis and variance reporting. The additional project management rigor has facilitated communication between both organizations to reduce the risk of missing key deadlines or cost overruns.
- **The PNNL Environmental Management Sector minimizes the impact of COVID-19 on EM-related projects.** As early as January 2020, PNNL senior management provided frequent communications to update PNNL staff on the evolving coronavirus pandemic, the actions of PNNL's Worker Safety and Health program, and to provide guidance to staff based on U.S. Centers for Disease Control and Prevention, the World Health Organization, and the Washington State Department of Health recommendations. PNNL's response to the COVID-19 virus was taken very seriously by Lab leadership and staff and the actions were based on the PNNL Pandemic Influenza Action Plan. In addition, PNNL established a COVID-19 Response Center to keep staff updated and to answer questions from and provide additional guidance for staff. The health and safety of PNNL employees was and continues to be the primary focal point for the Laboratory Leadership Team as demonstrated by their response, continued and active monitoring of the evolving situation, and effective communication to staff.

  Although health and safety of staff commanded much of the Laboratory Leadership Team's attention, the laboratory remained focused on delivering on our commitments to our many sponsors. Working with DOE, PNNL's return-to-campus planning transitioned from essential operations to limited operations, which was aligned with both the Governor's "Stay Home, Stay Healthy" orders and the President's reopening strategy. As part of that process, the PNNL Environmental Management Sector worked closely with the Project Management Office Director and PNNL Environmental Management Sector division directors to mitigate the potential impacts to PNNL EM-related projects. The PNNL Environmental Management Sector identified projects with the greatest risk if not promptly restarted, worked with EM clients to verify priorities and obtain support statement, and obtained approval from PNSO for numerous projects to start or resume laboratory activities while meeting all COVID-19 health and safety requirements. The PNNL Environmental Management Sector continued to work on prioritizing the restart of projects and activities to minimize impacts to our EM sponsors.

6.0 Objective 3.3: Provide Efficient and Effective Communications and Responsiveness to Headquarters Needs

Goal 3.0: Provide effective program vision and leadership; strategic planning and development of initiatives; recruit and retain a quality scientific workforce; and provide outstanding research processes, which improve research productivity

Objective 3.3 Provide Efficient and Effective Communications and Responsiveness to Headquarters Needs

Description: By which we mean the quality, accuracy and timeliness of responses to requests for information from Headquarters (HQ); the extent to which the Laboratory keeps HQ staff informed of both positive and negative events at the Laboratory so that DOE can deal effectively with both internal and external constituencies; and the ease of DOE determining who is responsible for what.

In assessing the performance of the Laboratory against this objective, the following assessment elements should be considered:

- The quality, accuracy, and timeliness of the Laboratory's response to customer requests for information
- The extent to which the Laboratory provides point-of-contact resources and maintains effective internal communications hierarchies to facilitate efficient determination of the appropriate point- of-contact for a given issue or program element
- The effectiveness of the Laboratory's communications and depth of responsiveness under extraordinary or critical circumstances
- The effectiveness of Laboratory management in accentuating the importance of communication and responsiveness

During FY20, PNNL engaged in effective communication and was responsive to its customers. In step with its value of customer focus, PNNL kept EM informed of both positive and negative events at the Laboratory to avoid surprises. PNNL provided leadership in organizing and enhancing cross-organizational communication, as demonstrated through key highlights presented above.

- **EM National Laboratory Network (EMNLN) Leadership.** PNNL co-chaired the EMNLN in FY19 through mid FY20 and remains actively engaged in supporting EM and the network to provide a forum for information exchange, consensus building, and coordination to facilitate EM's ability to access and leverage the capabilities of the DOE national laboratories. The EMNLN is actively working to support DOE through activities to provide technical support, independent assessment, strategic planning, policy study, and response to congressional inquiries. In FY20, the EMNLN completed the supplemental LAW alternatives study, provided independent assessment of the hazards associated potential shipping of TRU drums stored at WCS, and initiated new projects on disposition of crystalline silicotitanate resin and on assessment of waste streams potentially subject to the updated definition of HLW. In addition, PNNL supported updates and revisions to the EMNLN Charter, revision drafted to integrate LM and EM networks under one charter, and review of the draft EM Technology Development Program Framework document that defined the way EM technology development will be prioritized and managed.

- **PNNL is contributing to the National Lab Network technical support to LM**. PNNL is collaborating with LM, the LM contractor, and other national laboratories to evaluate high-risk sites within the LM mission. This assessment includes providing environmental remediation recommendations to address continuing contaminant sources through advances in subsurface characterization, source term remediation, and the development of beneficial and alternative end states. PNNL is contributing expertise in groundwater remediation and data analysis tools, visualization, and management. *POC: LM, Debbie Barr*
- **PNNL's Customer Service Model.** As part of its core business processes, PNNL consistently maintains, implements, and operates to the PNNL Customer Service Model. Within this model, the PNNL sector manager serves as the primary interface for customers within the business area (e.g., Environmental Management). Additionally, the sector manager may designate individuals as subsector or relationship managers. This model is not intended to assume existing relationships between the customer and PNNL program managers, project managers, technical contributors, and administrative staff. Rather, it provides a consistent point-of-contact to ensure the quality, accuracy, and timeliness of the Laboratory's response to customer requests. For EM, Tom Brouns serves as the sector manager, David Peeler is the subsector manager for waste processing, and Mike Truex is the subsector manager for environmental remediation and restoration.
- **PNNL strives to ensure EM is informed of evolving programmatic issues**. PNNL Environmental Management Sector leadership values timely communication with EM clients when technical and programmatic issues arise that may positively or negatively impact the mission. This includes efforts to support EM in highlighting newsworthy S&T advances, as well as flagging research results that may pose technical or political risks to EM activities. In FY20, PNNL notified EM HQ, ORP, and WRPS of two journal publications with potential negative impact on EM – both resulted from collaborations between university researchers and PNNL scientists. Although research conducted directly for EM is regularly vetted with EM clients prior to approval for public release, there are research programs sponsored by others (e.g., SC, NE) with potential implications to EM that are not always identified prior to release. PNNL notified EM of both publications as soon as we were aware of their content and potential implications for the EM mission. One publication discussed new research results on increased glass dissolution rates at the interface with a steel container, and the other publication discussed iodine-129 measurements in tank waste. PNNL worked with EM management to keep them informed of evolving developments, including notification of subsequent media inquiries on glass dissolution, and review of PNNL media releases drafted to counter misinformation being spread in the media. With EM concurrence, PNNL agreed to contribute to a news publication to assure that a technically-balanced perspective on the glass corrosion results was presented. PNNL also worked carefully with the research collaborators to identify statements in these publications that were inaccurate or easily misinterpreted relative to EM mission implications. PNNL's suggested edits to the glass corrosion paper were not adequately addressed by the lead authors prior to publication. However, the collaborators responded positively on a subsequent paper, accepting PNNL suggestions prior to publication to avoid unnecessary sensitivities, and in the separate research on I-129 measurements, the authors retracted a paper when it was determined analytical interference had resulted in a false conclusion. PNNL continues working to improve collaborative research communications, including early identification of research efforts and results that may have direct and indirect implications on the EM mission.
- **PNNL Sector Manager helps coordinate EM topics at annual WM Symposia.** PNNL's Environmental Management Sector Manager Tom Brouns also serves as a co-chair for the HLW/TRU/Spent Fuel track of WM Symposia, and has sponsored and co-organized with EM staff a regular panel session on challenges in tank waste management. For the 2020 Waste Management Symposia, Tom worked closely with EM's Kurt Gerdes and Craig West to coordinate potential conflicts and overlap between planned sessions and several new EM leadership priority sessions, with

the goal of assuring the collection of EM sessions and presentations were well organized, unique, and successful. Hanford is the featured site for the 2021 Waste Management Symposia, and Tom has begun working with RL and ORP leadership in coordinating between the Waste Management Symposia and Hanford in planning for next year's conference.

Appendix A – FY20 Publications

A.1 FY20 Publications Supporting Waste Processing

Note: In addition to the publications listed below, PNNL has produced 48 limited distribution publications in support of waste processing in FY20, which are not included in the lists below.

A.1.1 Abstracts

Arm S.T. 2020. “Management Systems and Culture Important for Sustained Operations.” Abstract submitted to 2020 American Institute of Chemical Engineers Annual Meeting, San Francisco, California. PNNL-SA-152679.

Boglaienko D., O. Qafoku, L. Kovarik, R.K. Kukkadapu, H.P. Emerson, Y. Katsenovich, and T.G. Levitskaia. 2020. “Unique Geological Formations in the Iron Based Tc-99 Reductive Removal Aqueous Media.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-151783.

Boglaienko D., T.G. Levitskaia, R.K. Kukkadapu, J.A. Soltis, Y. Du, H.P. Emerson, and Y. Katsenovich. 2020. “Heterogeneous Tc4+ Sequestration by Iron Granules.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-151634.

Boglaienko D., Y. Katsenovich, H.P. Emerson, and T.G. Levitskaia. 2020. “Enhanced Reductive Sequestration of 99Tc7+ by Silica Presence in Fe0.” Abstract submitted to ACS Spring 2020 National Meeting & Expo (cancelled), Baltimore, Maryland. PNNL-SA-148302.

Bottenus C., S.D. Branch, G.A. Gill, C.R. Myers, K.A. Muller, and M.S. Fountain. 2020. “Mercury Speciation of Hanford 241 AP 105, 241 AP 107, and 241 AN 102 Tank Waste Samples.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154994.

Bryan S.A., M.J. Minette, H.M. Felmy, K.M. Denslow, M.S. Fountain, K.D. Boomer, and A.M. Lines, et al. 03/08/2021. “Application of On-Line Monitoring and Real-Time Characterization of Actual Low-Level Hanford Tank-Waste Samples.” Abstract submitted to WM Symposia 2021, Phoenix, Arizona. PNNL-SA-154849.

Cornelison J.K. 2020. “300 Word Abstract For Microsoft Azure's Data Sync Tool.” Abstract submitted to DOE WARS website, Online Conference. PNNL-SA-154842.

Cornelison J.K. 2020. “Microsoft Azure’s Data Sync Tool.” Abstract submitted to Virtual Symposium, Online Conference. PNNL-SA-154408.

Crum J.V., B. Parruzot, J.F. Bonnett, S.N. Kerisit, S.K. Cooley, and R.C. Daniel. 2020. “Long-Term Occurrence and Evolution of an Accelerated Alteration Rate for Nuclear Waste Glasses in Repository Conditions.” Abstract submitted to Goldschmidt Virtual 2020, Online. PNNL-SA-151320.

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A.1.2 Conference Papers

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A.1.4 Journal Articles

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Levitskaia T.G., and E. Lee. 2020. "Protective Coatings for Management of Contaminated Surfaces at Nuclear Sites: a Review." *Journal of Environmental Chemical Engineering* (Submitted). PNNL-SA-153166.

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Luksic S.A., R. Pokorny, J.L. George, P.R. Hrma, T. Varga, L.R. Reno, and A.C. Buchko, et al. 2019. “In-situ characterization of foam morphology during melting of simulated waste glass using X-ray Computed Tomography.” *Ceramics International* (Submitted). PNNL-SA-150049.

Marcial J., R. Pokorny, J. Klouzek, J. Klouzek, M. Vernerova, S. Lee, and P.R. Hrma, et al. 2020. “Effect of water vapor and thermal history on nuclear waste feed conversion to glass.” *International Journal of Applied Glass Science* (Submitted). PNNL-SA-152445.

McCloy J.S., J. Marcial, J.S. Clarke, M. Ahmadzadeh, J.A. Wolff, E.P. Vicenzi, and D.L. Bollinger, et al. 2020. “Reproduction of Melting Behavior for Vitrified Hillforts based on Amphibolite, Granite, and Basalt Lithologies.” *Nature Communications*(Submitted). PNNL-SA-152607.

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Plymale A.E., J.R. Wells, C.I. Pearce, C.J. Brislawn, E.B. Graham, T. Cheeke, and J.L. Allen, et al. 2019. “Niche partitioning of microbial communities at an ancient vitrified hillfort: implications for vitrified radioactive waste disposal.” *ISME* (International Society for Microbial Ecology, published by Nature, Submitted). PNNL-SA-150253.

Pokorny R., P.R. Hrma, S. Lee, J. Klouzek, M.K. Choudhary, and A.A. Kruger. 2020. “Modeling batch melting: Roles of heat transfer and reaction kinetics.” *Journal of the American Ceramic Society* 103(2):701-718. doi:10.1111/jace.16898

Reynolds J.G., M. Dembowski, T.R. Graham, and C.I. Pearce. 2020. “Nitrate and Nitrite Incompatibility with Hydroxide Ions in Concentrated NaOH Solutions: Implications for Hydroxide and Gibbsite Reactivity in Alkaline Nuclear Waste.” *Fluid Phase Equilibria* (Submitted). PNNL-SA-154145.

Saslow S.A., C.I. Pearce, M.E. Bowden, W.W. Lukens, D. Kim, A.A. Kruger, and W. Um. 2020. “Kinetics of Co-Mingled 99Tc and Cr Removal During Mineral Transformation of Ferrous Hydroxide.” *ACS Earth and Space Chemistry* 4(2):218-228. doi:10.1021/acsearthspacechem.9b00277

Skidmore C.H., J.D. Vienna, T. Jin, D. Kim, B.A. Stanfill, K.M. Fox, and A.A. Kruger 2019. “Sulfur Solubility in Low Activity Waste Glass and its Correlation to Melter Tolerance.” *International Journal of Applied Glass Science* 10(4):558-568. doi:10.1111/ijag.13272

Stanfill B.A., G.F. Piepel, J.D. Vienna, and S.K. Cooley. 2020. “Nonlinear Logistic Regression Mixture Experiment Modeling for Binary Data Using Dimensionally Reduced Components.” *Quality and Reliability Engineering International* 36(1):33-49. doi:10.1002/qre.2558

Wang G., M.J. Olszta, S.A. Saslow, D. Kim, M.E. Bowden, W. Um, and J. Wang, et al. 2020. “Visualizing Technetium Distribution Within Iron Oxides.” *Nature Communications* (Submitted). PNNL-SA-151082.

A.1.5 Presentations

Allred J.R., J. Geeting, S.K. Fiskum, H.A. Colburn, A.M. Rovira, R.A. Peterson, and K.A. Colosi. 03/09/2020. “Tank Side Cesium Removal for Hanford Tank Waste – Actual Waste Demonstrations.” Presented by J.R. Allred at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150703.

Asmussen R.M. 07/14/2020. “Cementitious Materials in the Hanford Mission.” Presented by R.M. Asmussen at ORP Tutorial Series, Richland, Washington.

Asmussen R.M. 12/11/2019. “Getters for Cementitious Materials: History, Progress and Opportunities.” Presentation for technical discussion and SRNL Cementitious Technology Exchange, Augusta, Georgia. PNNL-SA-150194.

Asmussen R.M., G.L. Smith, J.V. Ryan, J.V. Ryan, J.J. Neeway, J. Crum, and S.A. Saslow, et al. 03/11/2020. “Testing Update for Maintenance of the Long-Term Performance Assessment of Immobilized Low-Activity Waste Forms.” Presented by R.M. Asmussen at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150208.

Asmussen R.M., Y. Fang, G.D. Tartakovsky, X. Song, J.H. Westsik, G.L. Smith, and E.E. Brown, et al. 03/09/2020. “Defining a Metric to Assess Leachability of Contaminants from Cementitious Waste Forms in Lab Testing Related to Hanford.” Presented by R.M. Asmussen at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150908.

Bates W., M.E. Stone, and T.M. Brouns. 10/24/2019. “FFRDC Overview – Analysis of Supplemental Treatment Approaches for Low-Activity Waste at the Hanford Nuclear Reservation.” Presented by T.M. Brouns, W. Bates, M.E. Stone at Senate Armed Services Committee Briefing (teleconference). PNNL-SA-148598.

Brouns T.M., C.J. Freeman, L.A. Mahoney, J. Liu, M.J. Minette, R.M. Stoner, and P.L. Jones, et al. 03/10/2020. “Respirator Cartridge Performance on Mixed Vapors from Hanford Tank Headspaces and Exhausters.” Presented by Z.K. Way at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151228.

Brouns T.M., J.E. Flaherty, L.A. Mahoney, E.C. Golovich, J.E. Meacham, and S.E. Killoy. 03/10/2020. “Hanford Tank Vapors in Worker Breathing Zones: Source, Dispersion, and Receptor Data.” Presented by T.M. Brouns at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150879.

Brouns T.M., W. Bates, and M.E. Stone. 10/31/19. “FFRDC Overview – Final Report on Analysis of Supplemental Treatment Approaches for Low Activity Waste at the Hanford Nuclear Reservation.” Presented by T.M. Brouns at NAS Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation Meeting, Richland, Washington. PNNL-SA-148599.

Cornelison J.K. 2020. “Microsoft Azure’s Data Sync Tool.” Online Conference. PNNL-SA-154550.

Denslow K.M., T.L. Moran, G.K. Boeringa, S.W. Glass, K.D. Boomer, T.A. Wooley, and J.R. Gunter, et al. 03/11/2020. “Progress on Advancing the Robotic Air-slot Volumetric Inspection System (RAVIS) for Hanford Under-tank Inspection.” Presented by K.M. Denslow at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151106.

Dixon D.R., W.C. Eaton, M.A. Hall, J.J. Venarsky, C.M. Stewart, D.A. Cutforth, and J.B. Lang, et al. 03/11/2020. “Laboratory-Scale Melter Systems for Simulated and Real AP-107 Tank Waste.” Presented by D.R. Dixon at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151076.

Eaton W.C. 12/09/2019. “DFLAW Glass Discussion Group.” Presented by W.C. Eaton at DOE ORP - DFLAW Glass Discussion Group Meeting, Savannah River, South Carolina. PNNL-SA-150085.

Eaton W.C., M.A. Hall, A.W. Abboud, D. Guillen, D.R. Dixon, C.D. Lukins, and C.M. Stewart. 03/11/2020. “Melter Optimized for Fast Turnover, Steady State Testing.” Presented by W.C. Eaton at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150309.

Enderlin C.W., C.B. Smith, G.J. Grant, and K.M. Denslow. 12/10/2019. “Go/No-Go Assessment of Cold Spray Technology for Tank Repair.” Richland, Washington. PNNL-SA-150003.

Enderlin C.W., C.B. Smith, G.J. Grant, K.M. Denslow, K.D. Boomer, and T.A. Wooley. 03/10/2020. “Cold Spraying Mild-Steel Powder onto Mild-Steel Substrate for Development of Waste Tank Repair System.” Presented by C.W. Enderlin at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151755.

Fountain M.S., C. Bottenus, G.A. Gill, and S.D. Branch. 03/09/2020. “Mercury Speciation of Hanford 241 AP 107 Tank Waste Feed and Treated Samples.” Presented by M.S. Fountain at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151077.

George J.L. 2020. “Glass: A Common Material Solving An Uncommon Problem – How Do We Immobilize Nuclear Waste?” Presented by J.L. George at PNNL’s Community S&T Virtual Seminar Series, Richland, Washington. PNNL-SA-153388.

Gervasio V., J.D. Vienna, J. Crum, B.J. Riley, and J.L. George. 2020. “Liquidus Temperature: Assessing Standard Glasses for Furnace Calibration.” Presented by V. Gervasio at 2020 Glass and Optical Materials Division Annual Meeting (postponed), New Orleans, Washington. PNNL-SA-149178.

Katsenovich Y., D. Boglaienko, H.P. Emerson, J. Williams, A.A. Maria, A.T. Gebru, and S. Kandel, et al. 03/08/2020. “Investigation into reductive separation of Tc-99 from low activity waste off-gas condensate by zero valent iron materials.” Presented at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151626.

Lonergan C.E., R.L. Russell, and J.D. Vienna. 03/10/2020. “Development of Enhanced Low-Activity Waste Glass Formulations in Support of the WTP.” Presented by C.E. Lonergan at WM Symposia 2020, Phoenix, Arizona. PNNL-SA-150214.

Marcial J., S.A. Luksic, S. Lee, L. Nemec, R. Pokorny, J. Klouzek, and J. Klouzek, et al. 2020. “In-situ visual observation of glass melting process.” Presented by J. Marcial at ACerS Virtual Glass Summit/ Symposium: S4: Glass Technology and Cross-Cutting Topics/ Challenges in Manufacturing, Online Meeting. PNNL-SA-154927.

Matthews B.E., B.W. Arey, C.I. Pearce, and A.A. Kruger. 2020. “Characterization of Ancient Glass Alterations in Various Environments at Broborg, a Vitrified Swedish Hillfort.” Presented by C.I. Pearce at Microscopy & Microanalysis 2020 Meeting, Online. PNNL-SA-154904.

Meyer P.D. 10/31/2019. “IDF Test Platform – Status and Operational Plan.” Presented by R. Mabrouki at meeting with Washington River Protections Solutions, Richland, Washington. PNNL-SA-148843.

Meyer P.D., R.M. Asmussen, J.J. Neeway, J.N. Thomle, R. Ekre, D.H. Bacon, and G.L. Smith, et al. 03/12/2020. “Field-Scale Lysimeter Studies of Glass and Cementitious Waste Forms at the Hanford Site.” Presented by P.D. Meyer at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150909.

Miracle A.J. 2020. “Developing a colorblind-friendly style guide.” Online Conference. PNNL-SA-154656.

Neeway J.J., C.I. Pearce, L. Nava-Farias, and L.M. Seymour. 2020. “Comparing Alteration Layer Characteristics of Ancient Hillfort Glasses Corroded in the Field and Laboratory.” Presented by J.J. Neeway at Goldschmidt Virtual 2020, Online Conference. PNNL-SA-154181.

Plymale A.E., C.I. Pearce, J.R. Wells, C.J. Brislawn, E.B. Graham, T. Cheeke, and J.L. Allen, et al. 2020. “Niche Partitioning of Microbial Communities at an Ancient Vitrified Hillfort: Implications for Vitrified Radioactive Waste Disposal.” Presented by C.I. Pearce at Goldschmidt Virtual 2020, Online Conference. PNNL-SA-153562.

Saslow S.A., C.I. Pearce, B.N. Gartman, and H.P. Emerson. 2020. “How APS Sector 20 Helps PNNL Develop Nuclear Waste Forms that Immobilize ^{99}Tc for the Hanford Site.” Presented by S.A. Saslow at APS Sector 20 Talk, Online Conference. PNNL-SA-154054.

Schonewill P.P. 02/17/2020. “Long-Term Storage & Disposition of Crystalline Silicotitanate.” Richland, Washington. PNNL-SA-151125.

Schonewill P.P., H.A. Colburn, P.A. Gauglitz, C. Bottenus, A.M. Rovira, C. Burns, and S.A. Bryan, et al. 03/10/2020. “Testing of Crystalline Silicotitanate to Support Tank-Side Cesium Removal System Operations.” Presented by P.P. Schonewill at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150883.

Schonewill P.P., R.C. Daniel, C. Burns, R.W. Shimskey, and R.A. Peterson. 11/12/2019. “Particle Back Transport Mechanisms in Crossflow Filtration with Nuclear Waste Simulants.” Presented by P.P. Schonewill at 2019 AIChE Annual Meeting, Orlando, Florida. PNNL-SA-149086.

Simpson B.C., M.B. Triplett, E.L. McCann, N.J. Betzsold, R.J. Toth, S.R. Clingenpeel, and M.L. Zabel. 03/10/2020. “Conducting Industrial Hygiene Exposure Assessments at Scale Using Non-Parametric Upper Tolerance Limits at the Hanford Site.” Presented by B.C. Simpson at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150935.

Triplett M.B. 02/28/2020. “PNNL Tank Closure Support.” Presented by M.B. Triplett at meeting with GAO, Richland, Washington. PNNL-SA-151792.

Wang G., M.J. Olszta, S.A. Saslow, D. Kim, M. Bowden, W. Um, and J. Wang, et al. 2020. “Visualizing Technetium Incorporation within Iron Oxides through Mineral Transformation with/without Ni Doping.” Presented by G. Wang at Goldschmidt Virtual 2020, Online Conference. PNNL-SA-153580.

Zink C.W. 09/11/2020. “Ember.JS: An Introduction.” Presented by C.W. Zink at PNNL TechFest 2020, Richland, Washington. PNNL-SA-152210.

Zink C.W. 09/11/2020. “Synchronization of Databases in Azure for the Development Pipeline.” Presented by C.W. Zink at PNNL TechFest 2020, Richland, Washington. PNNL-SA-152128.

A.1.6 Other

Asmussen R.M. 2019. “Display Lysimeter Poster for Facility.” Richland, Washington. PNNL-SA-149419.

Cannon L., S.E. Blackburn, and E.J. Engel. 2019. “PHOENIX GIS Explorer tutorial.” Video, PNNL-SA-150206. Richland, WA: Pacific Northwest National Laboratory.

Engel E.J., S.E. Blackburn, and L. Cannon. 2019. “PHOENIX GIS Explorer Search tutorial.” Video, PNNL-SA-150207. Richland, WA: Pacific Northwest National Laboratory.

Engel E.J., S.E. Blackburn, and L. Cannon. 2020. “PHOENIX GIS Explorer Layers tutorial.” Video, PNNL-SA-151074. Richland, WA: Pacific Northwest National Laboratory.

A.2 FY20 Publications Supporting Environmental Remediation

Note: In addition to the publications listed below, PNNL produced 19 limited distribution publications in support of environmental remediation in FY20, which are not included in the lists below.

A.2.1 Abstracts

Blackburn S., L. Garavelli, J. Connor, and B.J. Bellgraph. 2020. “Bull Trout and Westslope Cutthroat Trout movement in the Pend Oreille River basin.” Abstract submitted to Montana Chapter of the American Fisheries Society Annual Meeting, Kalispell, Montana. PNNL-SA-150478.

Borde A.B., H.L. Diefenderfer, V.I. Cullinan, D.A. Jay, S.A. Zimmerman, and R.M. Thom. 2020. “Understanding ecohydrology of tidal wetland plant communities to inform restoration.” Abstract submitted to National Conference on Ecosystem Restoration (postponed), Portland, Oregon. PNNL-SA-151309.

Bunn A.L., J.L. Downs, B.A. Napier, M. Mac Donnell, M.J. Truex, and V.L. Freedman. 2020. “Visualizing and Communicating Human Health Risks for Adaptive Management of Low-Energy Beta Emitters in Hanford Groundwater.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154786.

Di Pietro S., H.P. Emerson, and Y. Katsenovich. 2020. “Uranium Partitioning Upon Ammonia Gas Treatment on Phyllosilicate Minerals.” Abstract submitted to Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150774.

Di Pietro S., H.P. Emerson, Y. Katsenovich, N. Qafoku, and J.E. Szecsody. 2020. “Effect of alkaline treatment and variable redox conditions on phyllosilicate mineral transformations.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-151761.

Di Pietro S., H.P. Emerson, Y. Katsenovich, N. Qafoku, and J.E. Szecsody. 2020. “Effect of alkaline treatment and variable redox conditions on phyllosilicate mineral transformations.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-151761.

Diefenderfer H.L., A.B. Borde, and V.I. Cullinan. 2020. “Wetland Channel Morphology and Sediment Characteristics of the Lower Columbia River and Estuary Floodplain.” Abstract submitted to Columbia River Estuary Conference 2020, Astoria, Oregon. PNNL-SA-151160.

Diefenderfer H.L., A.B. Borde, and V.I. Cullinan. 2020. “Wetland Channel Morphology and Sediment Characteristics of the Lower Columbia River and Estuary Floodplain.” Abstract submitted to National Conference on Ecosystem Restoration (postponed), Portland, Oregon. PNNL-SA-151194.

Diefenderfer H.L., I.A. Sinks, S.A. Zimmerman, A.B. Borde, and V.I. Cullinan. 2020. “Designing Topographic Heterogeneity.” Abstract submitted to National Conference on Ecosystem Restoration, Portland, Oregon. PNNL-SA-151068.

Emerson H.P., C.I. Pearce, B.A. Powell, K.J. Cantrell, C.H. Delegard, M. Snyder, and M. Thomas, et al. 2020. “Influence of source term chemistry on tetravalent actinide interaction with sediments.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-152071.

Emerson H.P., J.E. Szecsody, C.D. Halter, A.R. Lawter, J.N. Thomle, K.A. Muller, and C.E. Bagwell, et al. 2020. “Spectral Induced Polarization for Monitoring and Characterization of Remediation at DOE’s Hanford Site.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154823.

Emerson H.P., J.E. Szecsody, C.D. Halter, A.R. Lawter, K.A. Muller, C.E. Bagwell, and A.R. Mangel, et al. 2020. “Monitoring environmental remediation with reductive iron amendments via complex electrical conductivity.” Abstract submitted to American Geophysical Union Annual Meeting 2020, Online. PNNL-SA-154940.

Franklin T.P. 2020. “Going Serverless in the AWS Cloud.” Abstract submitted to PNNL TechFest 2020, Richland, Washington. PNNL-SA-152271.

Freedman V.L., and B.G. Fritz. 2020. “Design Guidance for Monitoring of Extended Spatial and Temporal Scale Plumes.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154895.

Freedman V.L., K.P. Lee, D.H. Bacon, and Y. Fang. 06/23/2020. “Identifying the Technical Basis to Represent Long-term Radioactive Waste Form Behavior in Performance Assessments.” Abstract submitted to Goldschmidt Virtual 2020, Online Honolulu, Hawaii. PNNL-SA-151444.

Freedman V.L., P.D. Royer, N.J. Huerta, J.J. Garza, T.P. Franklin, X. He, and E. Fabricatore, et al. 2020. “Tracking Restoration And Closure (TRAC): Status Update on Story Maps for Communicating Site Cleanup Progress and Closure Status.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154824.

Garavelli L., and M.C. Freeman. 2020. “Co-locating wave energy resource with offshore aquaculture.” Abstract submitted to 2020 International Conference on Ocean Energy (postponed), Washington, DC. PNNL-SA-149517.

Huerta N.J., and V.L. Freedman. 2020. “Online Tool for Identifying Risk Associated with Contaminant Inventories.” Abstract submitted to Waste Management Symposia 2021, Phoenix,, Arizona. PNNL-SA-154989.

Jaysaval P., J.L. Robinson, T.C. Johnson, and V.L. Freedman. 2020. “Airborne electromagnetic imaging of stratigraphy at the Hanford Site, Washington.” Abstract submitted to American Geophysical Union Annual Meeting 2020, Online. PNNL-SA-154899.

Johnson C.D. 2020. “SOCRATES: A Web-based Application for Environmental Data Analytics.” Abstract submitted to Twelfth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (rescheduled), Portland, Oregon. PNNL-SA-148296.

Kang J., T.G. Levitskaia, and W. Um. 2020. “Iodine (I- and IO3-) Sequestration and Removal by CoAl and NiAl Layered Double Hydroxides.” Abstract submitted to Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-151621.

Khangaonkar T.P., A. Nugraha, and M. Premathilake. 2019. “Addition of eelgrass and zooplankton interactions to the Salish Sea Model towards improved ecological predictions.” Abstract submitted to 2020 Salish Sea Ecosystem Conference, Vancouver, BC, Canada. PNNL-SA-148703.

LaPier J.K., and C.D. Johnson. 2020. “Analytical Functions for 200 West Pump-and-Treat SCADA Sensor Data.” Abstract submitted to PNNL Gold Experience Symposium 2020, Richland, Washington. PNNL-SA-154460.

Loschiavo A.J., B. Evans, M.C. Harwell, and H.L. Diefenderfer. 2020. “Assessing the Compounding Effects of Restoration on the Food Web and Species Recovery in the Greater Florida Everglades.” Abstract submitted to National Conference on Ecosystem Restoration (postponed), Portland, Oregon. PNNL-SA-151426.

McKeon M., D.A. Jay, T.A. Stefan, and H.L. Diefenderfer. 2020. “Evaluating historical changes in suspended sediment loading throughout the Columbia River Basin.” Abstract submitted to Columbia River Estuary Conference 2020, Astoria, Oregon. PNNL-SA-151147.

Pearce C.I., H.P. Emerson, C.H. Delegard, K.J. Cantrell, M. Snyder, M. Thomas, and S.A. Saslow, et al. 2020. “Characterizing Technetium and Plutonium in Subsurface Sediments for Contaminant Remediation.” Abstract submitted to Spring 2020 ACS National Meeting & Expo (cancelled), Philadelphia, Pennsylvania. PNNL-SA-148624.

Premathilake M., and T.P. Khangaonkar. 2020. “Model of Outfall Plumes Effluent Dilution and Dynamic Lagrangian Transport in the Salish Sea.” Abstract submitted to 2020 Salish Sea Ecosystem Conference, Vancouver, BC, Canada. PNNL-SA-148713.

Robinson J.L., J.N. Thomle, M.L. Rockhold, T.C. Johnson, and V.L. Freedman. 2020. “An Evaluation of Electrical Resistivity Tomography for Stratigraphic Characterization of Paleochannels at the Hanford Site.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154822.

Robinson J.L., M.L. Rockhold, K. Parajuli, T.C. Johnson, and V.L. Freedman. 2020. “Characterization and Monitoring of a Contaminated Perched Water Aquifer using Electrical Resistivity Tomography.” Abstract submitted to Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP 2020, rescheduled), Denver, Colorado. PNNL-SA-148055.

Robinson J.L., T.C. Johnson, R.D. Mackley, and V.L. Freedman. 2020. “Evaluating the utility of electrical resistivity tomography in the presence of metallic infrastructure.” Abstract submitted to American Geophysical Union Annual Meeting 2020, San Francisco, California. PNNL-SA-154641.

Royer P.D., and V.L. Freedman. 2020. “A Remote Sensing Image User Interface (ARIUS) for Elevation Change Detection and Characterization of Flux along the Groundwater/Surface Water Boundary.” Abstract submitted to Waste Management Symposia 2021, Phoenix, Arizona. PNNL-SA-154938.

Sackman B., K. Whitehead, M. Premathilake, and T.P. Khangaonkar. 2020. "All Microplastics are not Created Equal: Refining Depositional Footprints of Microplastics in Sediments of Puget Sound, Washington." Abstract submitted to International Conference on Remediation and Management of Contaminated Sediments, Nashville, Tennessee. PNNL-SA-154073.

Saslow S.A., C.I. Pearce, and V.L. Freedman. 2020. "Materials for Targeted 99Tc Capture: From Nuclear Waste Form to Environmental Remediation." Abstract submitted to Spring 2020 ACS National Meeting & Expo (cancelled), Philadelphia, Pennsylvania. PNNL-SA-148551.

Sinks I., A.B. Borde, H.L. Diefenderfer, and G.E. Johnson. 2020. "Field Experiment of Reed Canarygrass Control Methods in Two Tidal Freshwater Wetlands." Abstract submitted to Columbia River Estuary Conference 2020, Astoria, Oregon. PNNL-SA-151222.

Sinks I., A.B. Borde, H.L. Diefenderfer, and G.E. Johnson. 2020. "Field Experiment of Reed Canarygrass Control Methods in Two Tidal Freshwater Wetlands." Abstract submitted to National Conference on Ecosystem Restoration (postponed), Portland, Oregon. PNNL-SA-151150.

Sockwell A.K., F. Zengotita, A. Vento, D.T. Reed, J. Swanson, and J. Dickson. 2020. "Mobility of actinides (+3, +4, and +6) in the presence of dolomite – Effect of EDTA and ionic strength." Abstract submitted to Clay Minerals Society Meeting, Richland, Washington. PNNL-SA-152072.

Sockwell A.K., F. Zengotita, A. Vento, D.T. Reed, J. Swanson, and J. Dickson. 2020. "Mobility of actinides (+3, +4, and +6) in the presence of dolomite – Effect of EDTA and ionic strength." Abstract submitted to Clay Minerals Society Meeting, Richland, Washington. PNNL-SA-152072.

Vento A., H.P. Emerson, A.K. Sockwell, and F. Zengotita. 03/08/2020. "Culebra Dolomite Dissolution of Relevance to the Waste Isolation Pilot Plant Near Carlsbad, NM." Abstract submitted to Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150767.

Zengotita F., H.P. Emerson, F. Stanley, T. Dittrich, M.K. Richmann, D.T. Reed, and L. Lagos, et al. 03/08/2020. "Potential for Biocolloid Transport of Cesium at High Ionic Strength." Abstract submitted to Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-150770.

A.2.2 Conference Papers

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Truex M.J. 03/09/2020. “ITRC Adaptive Site Management Perspective.” Presented by M.J. Truex at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151896.

Freedman V.L., and L. Bates. 03/10/2020. “The Incorporation of Pump-and-Treat Data in the New Tracking Restoration and Closure (TRAC) Web-Based Mapping Tool. Presented by V.L. Freedman at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151117.

Freedman V.L., K.D. Gerdes, and G.S. Chamberlain. 03/10/2020. “Status Update on TRAC: A DOE-EM Tool for Tracking Groundwater Cleanup and Progress Toward Site Closure.” Presented by V.L. Freedman at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151130.

Freedman V.L., P.D. Royer, and M.J. Truex. 03/12/2020. “Opportunities for an Integrated Web-Based Workbench for Data Access and Analysis.” Presented by V.L. Freedman at Waste Management Symposia 2020, Phoenix, Arizona. PNNL-SA-151109.

Freedman V.L., and Z. Zhang. 03/17/2020. “Monitoring the Prototype Hanford Barrier.” Reston, Virginia. PNNL-SA-152268.

Douville T.C., and D. Bhatnagar. 03/25/2020. “Project Status--Grid Value of OR Offshore Wind Energy.” Online Conference, Oregon. PNNL-SA-152272.

Vavrinec J. 05/19/2020. “Critical Habitat in the Salish Sea – Understanding Eelgrass for Restoration and Resilience.” Presented by J. Vavrinec at PNNL’s Community Science & Technology Virtual Seminar Series, Online Conference. PNNL-SA-153265.

Khangaonkar T.P., M. Premathilake, and A. Nugraha. 05/20/2020. “An Overview of the Salish Sea Model and its Applications.” Online. PNNL-SA-153324.

Rockhold M.L., and V.L. Freedman. 06/02/2020. “Modeling to Support TI Waiver Evaluation for I-129 in 200-UP-1.” Presented by M.L. Rockhold at business meeting, Richland, Washington. PNNL-SA-153672.

Garza J.J. 06/04/2020. “Controlling Cloud Costs with Automation.” Presented by J.J. Garza at PNNL TechFest 2020, Richland, Washington. PNNL-SA-152269.

Khangaonkar T.P., and A. Nugraha. 06/11/2020. “Towards an Operational Forecast System for the Salish Sea – Operational Inputs & FVCOM4.3 Upgrade.” Presented by T.P. Khangaonkar at NOAA FVCOM Workshop 2020, Online. PNNL-SA-153649.

Szecsody J.E., H.P. Emerson, A.R. Mangel, and J.N. Thomle. 06/15/2020. “Use of Spectral Induced Polarization to Characterize Clay Redox Reactivity.” Presented by J.E. Szecsody at Clay Minerals Society 2020 Meeting, Richland, Washington. PNNL-SA-152137.

Emerson H.P., M.J. Truex, and V.L. Freedman. 06/16/2020. “Environmental Remediation of the Hanford Site’s Central Plateau Vadose Zone.” Abstract submitted to Clay Minerals Society Meeting 2020, Richland, Washington. PNNL-SA-152378.

Douville T.C., and D. Bhatnagar. 06/17/2020. “Webinar: Exploring the Grid Value Potential of Oregon Offshore Wind Energy.” Online. PNNL-SA-153751.

Royer P.D., P.J. Weidert, and D. Lewis. 07/14/2020. “ARIUS (Advanced Remote-sensing Image USer-interface).” Presented by P.D. Royer at 2020 ESRI User Conference, Online, San Diego, California. PNNL-SA-149036.

LaPier J.K., and C.D. Johnson. 07/30/2020. “Analytical Functions for 200 West Pump-and-Treat SCADA Sensor Data.” Presented by J.K. LaPier at SULI Gold Experience July Virtual Symposium, Online. PNNL-SA-154825.

Franklin T.P. 08/04/2020. “Going Serverless in the AWS Cloud.” Presented by T.P. Franklin at TechFest 2020, Online. PNNL-SA-154838.

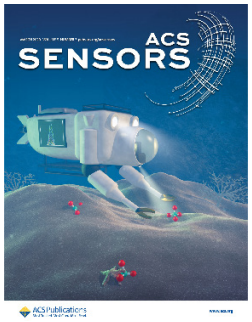
A.2.6 Other

Freedman V.L., C.D. Johnson, P.D. Royer, and B.C. Simpson. 2020. “Data Access & Analytics for Remedial Decision Making.” Flyer, PNNL-SA-151987. Richland, WA: Pacific Northwest National Laboratory.

Khangaonkar T.P., A. Nugraha, and M. Premathilake. 2020. “Vignette: The Salish Sea Model – for diagnostic biophysical assessments supporting ecosystem restoration and water quality management.” In *State of the Salish Sea Report*. PNNL-SA-153193.

Zhang Z., N. Bugosh, T.K. Tesfa, C. Liao, Y. Fang, Y. Sunakawa, and S. Sun. 2020. “Hydrology-Based Design of Geomorphic Evapotranspiration Covers for Reclamation of Mine Land.” Flyer, PNNL-SA-152067. Richland, WA: Pacific Northwest National Laboratory.

Appendix B – FY20 Journal Covers



American Chemical Society Sensors; March 2020, Volume 5, Number 3, www.pubs.acs.org/acssensors

The future of groundwater contamination measurement? The large thiol claws of PNNL's subsurface probe with custom gold tips detect and measure pertechnetate in aqueous environments. Cover illustration by Rose Perry, PNNL.

Technetium (Tc) is a high yield fission product from nuclear reactors which is radioactive, long lived and environmentally mobile. While the environmental safety surrounding nuclear technology is taken very seriously in the modern age, historical releases of Tc into the environment have occurred. Unfortunately, the methods used to detect and quantify Tc in environmental water samples are time consuming and expensive. PNNL has developed novel sensor technology that simultaneously detects and quantifies the dominant chemical form of Tc, pertechnetate, in environmental groundwater samples. This is achieved rapidly (in minutes) and with limits of detection below the EPA drinking water guidelines This work has recently been published, ACS Sensors 2020, 5 (3), 674-685, and was highlighted in a journal cover which show an artistic representation of the sensor material – depicted as a submarine – seeking and cataloguing pertechnetate ions.

Physical Chemistry Chemical Physics. 2020, Volume 22, Number 8

Dembowski, M.; Snyder, M. M.; Delegard, C. H.; Reynolds, J.G.; Graham, T. R.; Wang, H.-W.; Leavy, I. I.; Baum, S. R.; Qafoku, O.; Fountain, M. S.; Rosso, K. M.; Clark, S. B.; Pearce, C. I. Ion-ion interactions enhance aluminum solubility in alkaline suspensions of nano-gibbsite (α-Al(OH)3) with sodium nitrite/nitrate. Phys. Chem. Chem. Phys. 2020, 22 (8), 4368-4378. DOI: 10.1039/c9cp05856g. Inside front cover art.

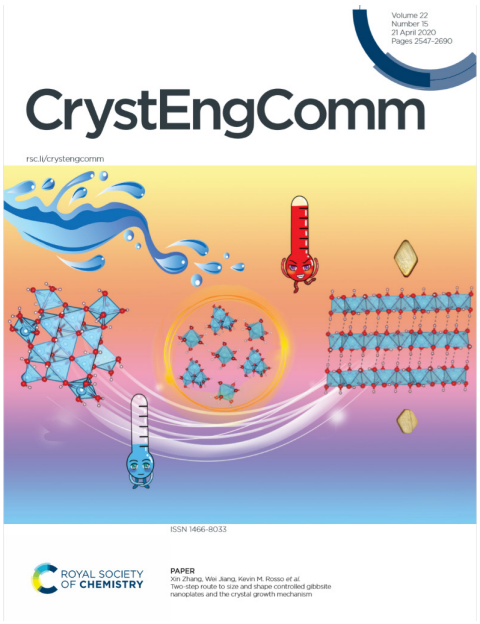
Why is aluminate concentration uncommonly high in Hanford tank waste solutions? Collaborative research between PNNL, the IDREAM EFRC and WRPS shows that the prominent waste solution salts sodium nitrate and sodium nitrate are at least partially responsible, first by making hydroxide ion more chemically active to dissolve aluminum hydroxide by denying it solvent water and then by stabilizing aluminate in solution by ion-ion interactions. In three panels, PNNL's Rose Perry shows "happily" solvated hydroxide, "unhappy" hydroxide competing with sodium, nitrate, and nitrite for water, and "invigorated" hydroxide pulling gibbsite into solution as aluminate stabilized by sodium, nitrate, and nitrite. sodium, nitrate, and nitrite ions stabilize aluminate by ion-ion interactions. These findings, published in Physical Chemistry Chemical Physics 2020, 22, 4368-4378, are featured in the journal cover art showing, in three panels, "happily" solvated hydroxide ion in water alone, "unhappy" hydroxide ion competing with sodium nitrate and nitrite for solvent water, and "invigorated" hydroxide ion pulling gibbsite into solution as aluminate to be joined by sodium, nitrate, and nitrite ions.

Aluminum as the dissolved aluminate ion and as solid gibbsite are major constituents in strongly alkaline nuclear processing wastes at the US Department of Energy's Hanford Site. In simple sodium hydroxide solutions, aluminate concentrations from dissolving gibbsite predictably increase with sodium hydroxide concentration. However, Hanford waste solution aluminate concentrations are many times greater than would be expected based solely on sodium hydroxide concentration. PNNL and the IDREAM EFRC, in collaboration with WRPS, has found the accompanying prominent waste solution components sodium nitrate and nitrite have appreciable impacts, acting in two ways to enhance aluminate concentration. First, the dissolved nitrate and nitrite salts occupy solvent water, making it less available to solvate hydroxide and making hydroxide more chemically active to dissolve gibbsite as aluminate. Second, the supplemental sodium, nitrate, and nitrite ions stabilize aluminate by ion-ion interactions. These findings, published in *Physical Chemistry Chemical Physics* **2020**, 22, 4368-4378, are featured in the journal cover art showing, in three panels, "happily" solvated hydroxide ion in water alone, "unhappy" hydroxide ion competing with sodium nitrate and nitrite for solvent water, and "invigorated" hydroxide ion pulling gibbsite into solution as aluminate to be joined by sodium, nitrate, and nitrite ions.

Industrial & Engineering Chemistry Research, 2019, Volume 58, Number 47

Lines, A.M., P. Tse, H.M. Felmy, J.D. Wilson, J. Shafer, K. Denslow, A.N. Still, C.K. King, S.A. Bryan. "On-line, real-time analysis of highly complex processing streams: Quantification of analytes in Hanford tank sample," Ind. Eng. Chem. Res., 2019, 58, 47, 21194-21200. http://dx.doi.org/10.1021/acs.iecr.9b03636, featured on cover.

Processing of hazardous materials is a crucial example where online monitoring can significantly reduce operation risk, cost, and time. This is particularly true in the case of the Hanford site, where nuclear materials from the Cold War era are being processed for environmental cleanup efforts. In exceedingly complex streams such as those at Hanford, online and real-time monitoring can be challenging due to the complexity of instrument signals. Further obstacles are imposed by the caustic nature of processing streams, as well as the radiation damage inflicted on instruments and probes. Online monitoring based on Raman spectroscopy enables the detection of many Hanford tank species of interest. Nine chemical species that comprise the majority of tank waste by volume, including $Al(OH)_4^-$, $C_2O_4^{2-}$, CO_3^{2-}, CrO_4^{2-}, NO_3^-, NO_3^-, OH^-, PO_4^{3-}, and SO_4^{2-}, were detected and quantified. Real-time analysis of Raman signal allows for immediate quantification of target analytes and was successfully accomplished through the use of chemometric models. Furthermore, irradiation tests revealed that Raman monitoring systems can effectively continue to operate even after receiving 1×107 rad of γ dose. The online, real-time monitoring system developed here was successfully used to simultaneously quantify nine target analytes in a real sample collected from Hanford tank AP-105.



CrystEngComm, 2020, Volume 22

Wang, S.; Zhang, X.; Graham, T. R.; Zhang, H.; Pearce, C. I.; Wang, Z.; Clark, S. B.; Jiang, W.; Rosso, K. M. Two-step route to size and shape-controlled gibbsite nanoplates and the crystal growth mechanism. CrystEngComm. 2020. 22, 2555-2565. Cover art.

This is work done by Suyun Wang and Xin Zhang in PCSD for Kevin Rosso's Research Theme 2 (interfacial structure and reactivity) of the IDREAM EFRC. This work has expanded understanding of how Al coordination changes between dominantly tetrahedral in the electrolyte and octahedral in many of the solid forms (see Figure 2 in the word document).

Gibbsite (α-$Al(OH)_3$) is a significant component of the high-level nuclear waste stored in large quantities at the Hanford Site. Industrial-scale processing of gibbsite requires an understanding of its behavior in highly alkaline solutions (often called Bayer liquors); processing of slurries and precipitates from these liquors is facilitated by controlling gibbsite size and morphology. Here, building on our prior work, we report an additive-free two-step route to size and morphology-controlled gibbsite nanoplatelets. The research demonstrates that long-standing questions about nucleation barriers of gibbsite in saturated, highly alkaline solutions relate to the dynamics of aluminate cluster formation. Thermal manipulation of nucleation and crystal growth regimes led to controlled properties with shorter reaction times. We introduced an initial aging step at low temperature to slow the nucleation regime, followed by crystal growth at higher temperature to improve the rate and extent of reaction, and produce gibbsite nanoplates with various sizes and morphologies. Detailed multi-method characterization enabled insights into the nucleation and crystal growth mechanisms of the gibbsite nanoplates.

This work was supported by IDREAM (Interfacial Dynamics in Radioactive Environments and Materials), an Energy Frontier Research Center funded by the U.S. Department of Energy (DOE), Office of Science, Basic Energy Sciences (BES). Materials characterization was completed using EMSL, a national scientific user facility sponsored by the DOE Office of Biological and Environmental Research and located at Pacific Northwest National Laboratory (PNNL).

Computed tomography cover photograph for the issue of JACerS (Volume 103, Number 2, February 2020, Pages 701-718):

Pokorný, R, Hrma, P, Lee, S, Klouzek, J, Choudhary, MK, Kruger, AA. Modeling batch melting: Roles of heat transfer and reaction kinetics. *J Am Ceram Soc*. 2020; 103: 701– 718. https://doi.org/10.1111/jace.16898.

Artistic representation of glass batch melting on the top of molten glass. Sophisticated mathematical models of glass-melting furnaces have been developed and successfully applied in recent decades to reduce the unit cost of manufacturing, optimize the stringent quality requirements, and design new products and processes. The next step in this remarkable development is designing a realistic model of the batch blanket.

Physical Chemistry Chemical Physics, Volume 22, Number 11

Jon M. Schwantes, Jacob L. Bair, Edgar C. Buck, Ram Devanathan, Sean H. Kessler, Timothy G. Lach, Jason M. Lonergan, Bruce K. McNamara, Camille J. Palmer, Richard A. Clark. A New Non-diffusional Gas Bubble Production Route in Used Nuclear Fuel: Implications for Fission Gas Release, Cladding Corrosion, and Next Generation Fuel Design Phys. Chem. Chem. Phys., January 28, 2020. doi.org/10.1039/C9CP05363H. PNNL-SA-144695.

Researchers at PNNL are removing a shroud of mystery surrounding the behavior of certain metal particles in nuclear fuel. The team's findings could improve future fuel designs for more efficient and safe production of nuclear energy.

In a recent experiment, researchers connected tellurium-containing particles in uranium dioxide fuel to the subsequent formation and rupture of high-pressure gas bubbles. Ruptures can damage the fuel and its protective outer layer known as cladding. The findings are detailed in a research paper featured on the cover of the March 21 edition of *Physical Chemistry Chemical Physics*.

The team's experiment was sponsored by PNNL's Nuclear Process Science Initiative (NPSI). The research is the latest in a series of NPSI-funded inquiries that have produced insights about noble metal phase (NMP) particle behavior in nuclear fuel during reactor operations.

Appendix C – Parameterized Literature Searches

To provide insight into the impact of PNNL's publications to the technical community and toward DOE's mission goals, and to assess how PNNL ranks relative to other national laboratories, a parameterized literature search was conducted in two technical areas: (1) waste form development and (2) nuclear waste glass corrosion. This metric provides insight into how PNNL expertise, core competencies, and stewarded capabilities provide scientific solutions to complex waste management challenges within the Office of Environmental Management (EM) complex. This effort was underpinned by initially defining specific search terms for each technical area, all journal articles / citations falling within the search parameters were identified from all the laboratories included in the search. High-impact journal articles were defined based on the number of citations in a specific scientific area as measured by Clarivate, the creator of Web of Science. All the citations within each scientific are were then divided into four quadrants based on the number of citations. A Quartile 1 (Q1) journal has more citations than a Quartile 2 (Q2) and so on.

C.1 Glass Waste Form Development (May 2020)

PNNL continues to lead the national laboratories in high-impact publications in the area glass waste form development.

High-Impact Journals

The majority of PNNL publications are in high-impact journals as shown in Figure C.1. A high-impact journal is based on the number of citations in specific scientific areas measured by Clarivate, the creator of Web of Science. All citations are gathered, for each scientific area, and then divided into four quadrants. A Quartile 1 (Q1) journal has more citations than a Quartile 4 (Q4).

PNNL continues to lead the national laboratories in high-impact publications in the area of glass waste form development.

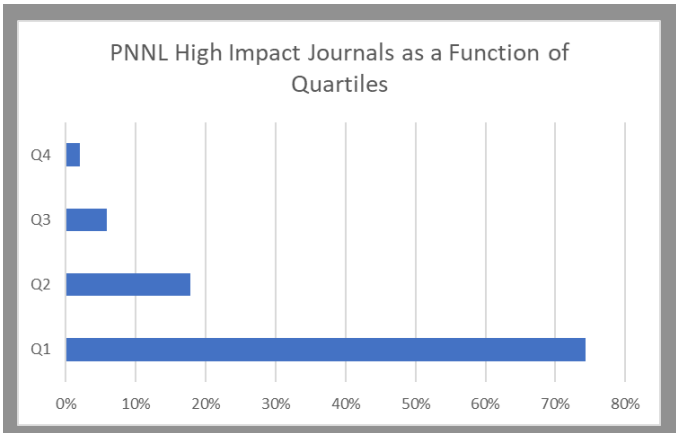


Figure C.1. PNNL Publications

Quartile 1 Publications Across National Laboratories

PNNL also leads the national laboratories in the number of high impact, Quartile 1 publications as shown in Figure C.2.

Quartile 1 Top 10% Publication Citations

PNNL also leads the national laboratories in the top 10% publication citations (see Figure C.3).

Search Parameters

- Period of Review: 2013-2020 (May)
- National Laboratories: PNNL, SRNL, ANL, SNL, ORNL, and Catholic University of America, Vitreous State Laboratory (VSL)
- Search Terms: Tailored waste forms, enhanced nuclear waste glasses, metal organic frameworks (other key words may include: iodine and technetium adsorption, materials by design, moly containing aluminoborosilicate glass-ceramics, rare earth incorporation)
- Publications include: Review articles, journal articles, book chapters, and conference papers

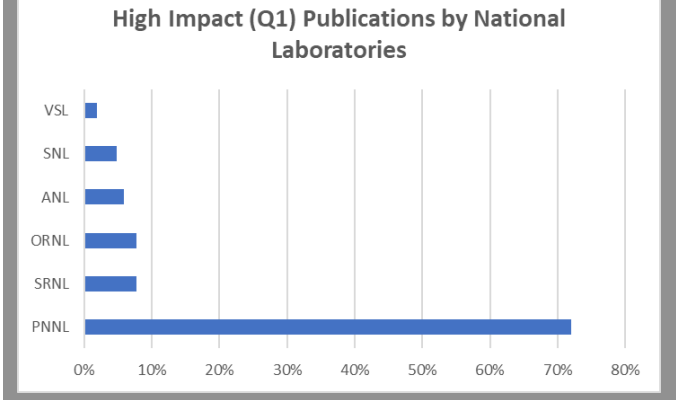


Figure C.2. Quartile 1 Publications Across National Laboratories

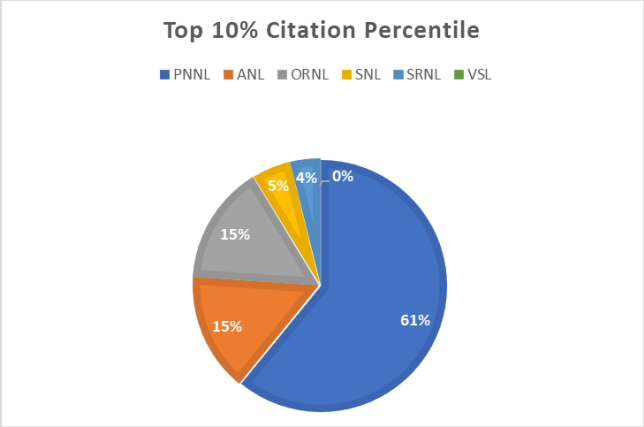


Figure C.3. Top 10% Citation Percentile

C.2 Nuclear Waste Glass Corrosion (May 2020)

PNNL continues to lead the national laboratories in high-impact publications in the area of nuclear waste glass corrosion.

High-Impact Journals

The majority of PNNL publications are in high-impact journals as shown in Figure C.4. A high-impact journal is based on the number of citations, in specific scientific areas measured by Clarivate, the creator of Web of Science. All citations are gathered, for each scientific area, and then divided into four quadrants. A Quartile 1 (Q1) journal has more citations than a Quartile 4 (Q4).

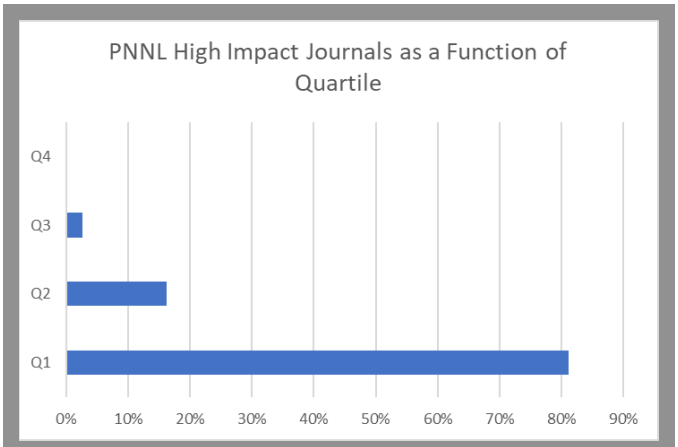


Figure C.4. PNNL Publications

Quartile 1 Publications Across National Laboratories

PNNL also leads the national laboratories in the number of high-impact, Quartile 1 publications as shown in Figure C.5.

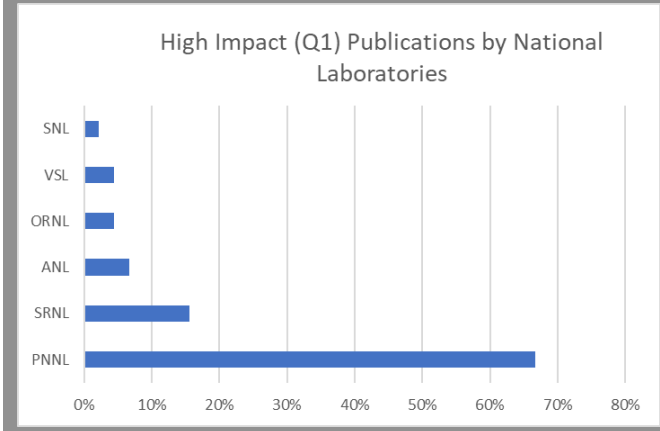


Figure C.5. Quartile 1 Publications Across National Laboratories

Quartile 1Top 10% Publication Citations

PNNL leads the national laboratories in the Top 10% publication citations (see Figure C.6).

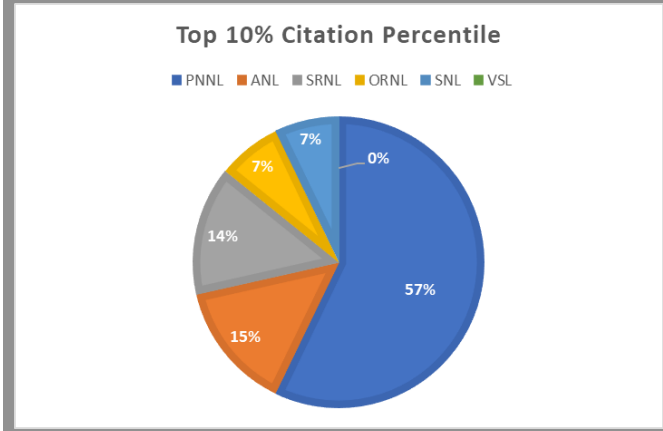


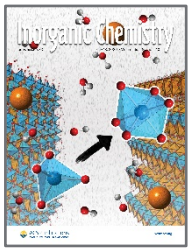
Figure C.6. Top 10% Citation Percentile

Search Parameters

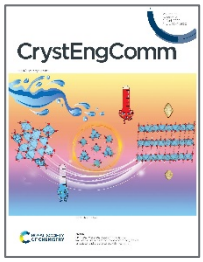
- Period of Review: 2013-2020 (May)
- National Laboratories: PNNL, SRNL, ANL, SNL, ORNL, and Catholic University of America, Vitreous State Laboratory (VSL)
- Search Terms: Nuclear waste glass corrosion (other key words may include durability, alteration, leaching, high-level waste glass, low-activity waste glass)
- Publications include: Review articles, journal articles, book chapters, and conference papers

Appendix D – FY20 EFRC IDREAM Publications

1. Wang, Z.; Walter, E. D.; Sassi, M.; Zhang, X.; Zhang, H.; Li, S X..; Chen, Y.; Cui, W.; Tuladhar, A.; Jessamy-Chase, Z. A.; Winkelman, A. D.; Wang, H.; Pearce, C. I.; Clark, S. B.; Rosso, K.M. The role of surface hydroxyls on the radiolysis of gibbsite and boehmite nano-platelets. *J. Haz. Mater*. **2020.** DOI: 10.1016/j.jhazmat.2020.122853. PNNL-SA-150311.
2. Graham, T. R.; Dembowski, M.; Hu, J. A.; Jaegers, N. R.; Zhang, X.; Clark, S. B.; Pearce, C. I.; Rosso, K. M. Intermediate Species in the Crystallization of Sodium Aluminate Hydroxy Hydrates. *J. Phys. Chem.C,* **2020.** DOI: 10.1021/acs.jpcc.0c00205. PNNL-SA-150266.
3. Cui, W.; Zhang, X.; Pearce, C. I.; Engelhard, M.; Zhang, H.; Zhang, Y.; Heald, S.; Zheng, S.; Zhang, S.; Clark, S. B.; Li, P.; Wang, Z.; Rosso, K. M. Effect of Cr(III) adsorption on the dissolution of boehmite nanoparticles in caustic solution. *Environ. Sci. Tech*. **2020,** *54* (10), 6375-6384. DOI: 10.1021/acs.est.9b07881. PNNL-SA-150322.
4. Huestis, P. L.; Graham, T. R.; Mergelsberg, S. T.; LaVerne, J. A. Identification of Radiolytically-Active Thermal Transition Phases in Boehmite. *Thermochim. Acta*. **2020,** *689*, 178611**.** DOI: 10.1016/j.tca.2020.178611. PNNL-SA-151694.
5. Krzysko, A. J.; Nakouzi, E.; Zhang, X.; Graham, T. R.; Rosso, K. M.; Schenter, G. K.; Ilavsky, J.; Kuzmenko, I.; Frith, M.; Ivory, C. F.; Clark, S. B.; Weston, J. S.; Weigandt, K. M.; De Yoreo, J. J.; Chun, J.; Anovitz, L. M. Correlating inter-particle forces and particle shape to shear-induced aggregation/fragmentation and rheology for dilute anisotropic particle suspensions: A complementary study via capillary rheometry and in situ ultra-small angle X-ray scattering. *J. Colloid Interface Sci.* **2020,** *576*, 47-58**.** DOI: 10.1016/j.jcis.2020.04.016. PNNL-SA-148317.
6. Dembowski, M.; Prange, M. P.; Pouvreau, M.; Graham, T. R.; Bowden, M. E.; N'Diaye, A.; Schenter, G. K.; Clark, S. B.; Clark, A.E.; Rosso, K. M.; Pearce, C. I. Inference of Principal Species in Caustic Aluminate Solutions Through Solid-State Spectroscopic Characterization. *Dalton Trans*. **2020,** *49* (18), 5869-5880**.** DOI: 10.1039/d0dt00229a.
7. Zhao, L.; Tao, Z.; Pavosevic, F.; Wildman, A.; Hammes-Schiffer, S.; Li, X. Real-Time Time-Dependent Nuclear-Electronic Orbital Approach: Dynamics Beyond the Born-Oppenheimer Approximation. *J. Phys. Chem. Lett.* **2020,** *11* (10), 4052-4058. DOI: 10.1021/acs.jpclett.0c00701**.** PNNL-SA-152537.
8. Weston, J. S.; Chun, J.; Schenter, G.; Weigandt, K.; Zong, M.; Zhang, X.; Rosso, K. M.; Anovitz, L. M. Connecting particle interactions to agglomerate morphology and rheology of boehmite nanocrystal suspensions. *J. Colloid Interface Sci.* **2020**, *572,* 328-339. DOI: 10.1016/j.jcis.2020.03.109. PNNL-SA-148609.

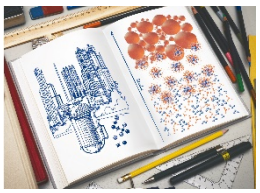


9. Graham, T. R.; Gorniak, R.; Dembowski, M.; Zhang, X.; Clark, S. B.; Pearce, C. I.; Clark, A. E.; Rosso, K. M. Solid-State Recrystallization Pathways of Sodium Aluminate Hydroxy Hydrates. *Inorg. Chem.* **2020,** 59 (10), 6857-6865. DOI: 10.1021/acs.inorgchem.0c00258. PNNL-SA-150728. Supplementary cover art.
10. Prange, M. P.; Pope, D. J.; Rosso, K. M. Electronic and Vibrational Contributions to the Bulk stabilities of Trivalent 3d Transition Metal Oxyhydroxides from Electronic Structure Calculations. *J. Phys. Chem. C.* **2020,** *124* (13), 7500-7510. DOI: 10.1021/acs.jpcc.9b12057. PNNL-SA-150354.



11. Wang, S.; Zhang, X.; Graham, T. R.; Zhang, H.; Pearce, C. I.; Wang, Z.; Clark, S. B.; Jiang, W.; Rosso, K. M. Two-step route to size and shape controlled gibbsite nanoplates and the crystal growth mechanism. *CrystEngComm.* **2020,** *22*, 2555-2565**.** DOI: 10.1039/d0ce00114g. Outside front-cover art. PNNL-SA-150680.

12. Martinez-Baez, E.; Feng, R.; Pearce, C. I.; Schenter, G. K.; Clark, A. E. ^{27}Al NMR chemical shift of $Al(OH)_4$- calculated from first principles: Assessment of error cancellation in chemically distinct reference and target systems. *J. Chem. Phys.* **2020**, *152* (13), 134303. DOI: 10.1063/1.5144294. PNNL-SA-150302



13. Servis, M. J.; Martinez-Baez, E.; Clark, A. E. Hierarchical phenomena in multicomponent liquids: simulation methods, analysis, chemistry. *Phys. Chem. Chem. Phys.* **2020,** 22 (18), 9850-9874. DOI: 10.1039/D0CP00164C. PNNL-SA-150460.

14. Sassi, M. J.; Wang, Z.; Walter, E. D.; Zhang, X.; Zang, H.; Li, X. S.; Tuladhar, A.; Bowden, M.; Wang, H. F.; Clark, S. B.; Rosso, K. M. Surface Hydration and Hydroxyl Configurations of Gibbsite and Boehmite Nanoplates. *J. Phys. Chem. C,* **2020,** *124*, 9, 5275-5285. DOI: 10.1021/acs.jpcc.0c00659. PNNL-SA-149815.

15. Dembowski, M.; Snyder, M. M.; Delegard, C. H.; Reynolds, J.G.; Graham, T. R.; Wang, H.-W.; Leavy, I. I.; Baum, S. R.; Qafoku, O.; Fountain, M. S.; Rosso, K. M.; Clark, S. B.; Pearce, C. I. Ion-ion interactions enhance aluminum solubility in alkaline suspensions of nano-gibbsite (α-$Al(OH)_3$) with sodium nitrite/nitrate. *Phys. Chem. Chem. Phys*. **2020**, *22* (8), 4368-4378. DOI: 10.1039/c9cp05856g. Inside front cover art.

Pacific Northwest National Laboratory

Energy and Environment Directorate
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