

Renewing FRTR to Meet Future Remediation Technology Needs of Member Agencies

8 May 2023



Table of Contents

1. Executive Summary.....	1
2. Introduction and Purpose.....	2
3. Background.....	2
3.1. Charting FRTR’s Future.....	3
3.2. May 19th Session Focused on “Grand Challenges”.....	3
3.3. May 26 th Session Focused on “Advancing New Technologies”.....	4
3.4. Leadership Questionnaire.....	5
4. Grand Challenges of FRTR Member Agencies.....	5
4.1. Technical Challenges.....	6
4.2. Barriers to Advancing New Technologies.....	7
4.3. Organizational and Resourcing Challenges.....	7
5. FRTR Future Efforts.....	7
6. Connecting Future Efforts to Common Agency Goals.....	8
6.1. Continued Information Exchange.....	8
6.2. Leverage Ongoing Efforts to Increase Technical Reach and Impact.....	9
6.3. Facilitate Collaboration.....	10
6.4. Promote Workforce Development.....	11
7. FRTR Future Efforts: Achievable Short-term Goals and Ambitious Long-Term Goals.....	12
8. A Stepwise Approach to Achieving FRTR Goals.....	13

1. Executive Summary

This Executive Summary serves as a roadmap for the FRTR Steering Committee to address member agency priorities and needs pertaining to remediation technology, to focus discussions, and outline future efforts.

In preparation for the FRTR 30-year anniversary and associated public meetings (centered on grand remediation challenges and technical needs), the Steering Committee distributed a questionnaire to member agencies soliciting information on needs, challenges, and priorities.

The FRTR Steering Committee collated stakeholder feedback to reveal three overarching topics: technical challenges, barriers to advancing new technologies, and organizational and resourcing challenges. They further refined the topics into common interagency goals, specifically 1) addressing emerging contaminants, 2) advancing technology for contaminant source and site characterization, 3) enhancing technology transfer of cleanup technologies/approaches, and 4) addressing remedy resilience under evolving climatic conditions.

To achieve identified goals, the FRTR will proceed in a stepwise manner—identifying resources, sharing information, focusing on education, and tailoring topic selections to specific audience. This approach assures future actionable tasks are measured and intentional.

FRTR will continue the legacy information exchange activities and continue leveraging its communication and knowledge sharing platforms. In keeping with the stepwise approach, FRTR can also begin identifying achievable interagency action items for conversion into fundable projects. The following are for immediate consideration:

- To increase technical reach and impact, compile a list of programs, resources, and working groups supporting efforts consistent with FRTR interests and priorities. Each FRTR member agency contributes to the outcome by acting as liaison with affiliated working groups to exchange relevant information. Creating a repository for member agencies to post case study results and demonstration-validation information would also help increase technical reach and impact in the near-term.
- To facilitate agency collaboration, convene an FRTR ad hoc work group to identify agency technology development programs, and best approaches and procedures for providing access to agency sites for technology demonstration or testing.
- To promote workforce development, begin sponsoring and sharing training opportunities among member agencies using typical tools and mechanisms typically available (e.g., AFIT, Navy RITS, and EPA's CEC/Trainex).

Addressing the grand remediation challenges faced by FRTR member agencies requires substantial efforts and resources. By sharing technical information, fostering collaboration, and leveraging limited resources across agencies, member agencies can combine and enhance overall performance and eventually move sites to closure for both legacy and emerging chemicals.

2. Introduction and Purpose

The Federal Remediation Technologies Roundtable (FRTR) is an interagency collaboration advancing the use of innovative technologies to clean up hazardous waste contamination. Since its inception in 1990, the FRTR has been a forum to share information, advance the application of innovative site cleanup technologies, and leverage federal technology investments and lessons learned through technology transfer activities. The FRTR is guided by a Steering Committee comprised of representatives of each member agency. The Steering Committee helps to determine the common technical challenges among the member agencies and to identify collaborative activities which will advance deployment of innovative technologies and improve federal approaches to site-cleanup across all agencies. It also distributes remediation technology information within FRTR member agencies.

The FRTR 30-year anniversary and associated public meetings provided an ideal opportunity to (1) review past successes, (2) seek input from agency leadership and other stakeholders for current needs, and (3) identify collaborative activities that will advance innovative technologies and improve federal approaches to site cleanups. The results of this effort are described in this document—essentially refreshing and re-imagining the FRTR vision.

This executive summary identifies current and future focus areas for upcoming FRTR activities, based on a synthesis of information, insights and technical needs presented by senior leaders of the FRTR member agencies at the May 2021 public meeting sessions “FRTR at 30 Years: Grand Challenges and Opportunities for Advancing Remediation Technologies”. This document also identifies focus areas for interagency cooperation both in addressing shared remediation challenges and in advancing innovative site cleanup technologies.

This document will be used as a roadmap by the FRTR Steering Committee to:

- Address the top priorities and needs of FRTR member agencies related to remediation technology,
- Identify and guide discussions on topics, and
- Develop future actionable items for implementation.

3. Background

For over 30 years, the FRTR has fostered scientific and engineering knowledge transfer activities that have improved our approach to site cleanups and advanced deployment of technologies across all agencies. Our improved understanding of current technologies and cutting-edge methods for contaminant source and site characterization, modeling, treatment, and remedy optimization is helping us respond to challenges at complex sites. Use of advanced and high-resolution site characterization methods has promoted better definition of subsurface features, better understanding of conditions, processes, and effects of natural and human-induced events. This understanding is in turn helping to build better conceptual site models (CSMs) that improve selection and optimization of effective

FRTR Spring 2021 Webinars and Meeting
FRTR at 30 Years: Grand Challenges and Opportunities for Advancing Remediation Technologies

Session 1: Grand Challenges
May 19, 2021 1:00 to 3:30 PM (EDT)

Session 2: Advancing New Technologies
May 26, 2021 1:00 to 3:30 PM (EDT)

remedies. A systematic approach, incorporating the lessons learned and applying them throughout the life-cycle of a cleanup project, supports faster, better, and cost-effective site cleanups.

Technology transfer efforts have included:

- Cost and performance of remediation technologies
- Site characterization and investigation methods
- Remedy alternatives and innovative technologies
- Remedy optimization and system evaluations
- Improved data gathering and management
- Data visualization and presentation
- Green remediation practices and implementation

These technology transfer efforts have been deployed through semi-annual FRTR meetings, open to public participation, and through the FRTR web site (FRTR.gov). As web-based resources for technology transfer have improved, and to provide more detailed information concerning remediation technologies, the FRTR developed “FRTR Presents...”, a series of webinars delivered on Environmental Protection Agency’s (EPA) Contaminated Site Clean-Up Information (CLU-IN) website. These webinars expanded FRTR’s existing technology transfer to a wider audience. Proceedings and presentations of FRTR’s meetings are archived on FRTR.gov and provide a resource to anyone seeking information on innovative technologies.

Throughout its 30-year history, FRTR collaboration among member agencies has advanced innovative technologies to become state-of-the-practice for site investigation, cleanup, and remedy optimization. Collaboration has provided opportunities to discuss and solicit input on agency-specific complex issues which, in turn, helped identify acceptable practical solutions leveraging the combined efforts of all agencies. It also has promoted a more consistent, unified federal approach to technology evaluation and regulatory acceptance through sharing a variety of technology transfer tools and other information resources.

3.1. Charting FRTR’s Future

The FRTR Steering Committee used the two sessions of the May 2021 semi-annual meeting to solicit input from FRTR member agencies on the following:

- Charting future directions and topic areas for FRTR efforts,
- Better understanding the remediation priorities of the member agencies over the next decade,
- Identifying the top remediation challenges facing each agency, and
- Emphasizing the role of new technologies or approaches for improving site cleanups.

Prior to the May 2021 meeting, FRTR sought written input from leadership through a questionnaire. Below is a description of the informative meeting, questionnaire, and discussions of other input received.

3.2. May 19th Session Focused on “Grand Challenges”

During the May 19th session, senior FRTR agency representatives met to discuss topics generated from a questionnaire of the FRTR member agencies. The session agenda identified the presenters (with links to

their presentations) in response to the questionnaire. The agenda and presentations are accessible from the FRTR.gov web site ([May 19th Session Focused on “Grand Challenges”](#)). Presentations and a recording of the full session is available through the CLU-IN web site ([audio recording of May 19th session](#)). Senior-level leaders from FRTR member agencies discussed challenges and needs for technology innovation, identifying overarching priorities, such as:

Priorities Identified by Most Member Agencies

- Environmental Justice and environmental health disparities
- Climate Change, including resiliency of remedies to impacts of climate
- Per-and polyfluoroalkyl substances (PFAS) and other emerging contaminants, munitions response, complex groundwater issues
- Challenges of remediation at complex sites – more expensive and time-consuming

Priorities Identified by One or a Minority of Member Agencies

- Land revitalization, redevelopment, and reuse
- High-resolution site characterization
- Life-cycle conceptual site models
- Collaboration of agencies in shaping the cleanup practices
- Timely validation of technologies and stakeholder buy-in
- Innovative technology transfer needs
- Use of artificial intelligence and machine learning for predictive remediation solutions
- Systems approach in decisions in totality
- Establishment of consensus-based guidance
- Abandoned mines and industrial legacy sites
- Overcoming the “Valley of Death” for new and promising technologies

3.3. May 26th Session Focused on “Advancing New Technologies”

During the May 26th session, senior remediation technologists from FRTR agencies participated in a discussion of agency perspectives on advancing promising remediation research and applying new technologies at field-site scales. The agenda and presentations are available from the FRTR.gov web site ([May 26th session focused on “Advancing New Technologies”](#)). Presentations and a recording of the meeting is available through the CLU-IN web site ([CLU-IN web link to the May 26th sessionhttps://clu-in.org/conf/tio/FRTR-Grand1_051921/](https://clu-in.org/conf/tio/FRTR-Grand1_051921/)). Overarching priorities identified by agency technologists included:

- Collaboratively sharing and building on information and use at multiple sites is more effective than demonstration and verification at individual sites
- Technology development—a collaborative process from idea/proof-of-concept to acceptance of a technology
- Innovation is not a linear process—requires an iterative approach and course corrections to improve throughout the process

- Leveraging research and decisions through collaborative sharing can help by reducing duplication and building technologies as applicable
- Strategically identify short-term, medium-term, and long-term goals for interagency collaboration and technology transfer

3.4. Leadership Questionnaire

Prior to the May 2021 FRTR meetings, the FRTR Steering Committee developed and distributed a questionnaire to senior leadership of member agencies remediation programs. The questionnaire solicited information on agency-specific needs, challenges, and priorities and provided a basis for subsequent inter-agency discussions during the May meetings. Questionnaire results identified several potential topics and areas of collaboration. Table 1 outlines the questionnaire results.



The most widely noted technology challenges for current and future remediation efforts, research gaps and challenges for the next decade include:

- Emerging contaminants – identification, characterization, sampling, and analytical methods to measure, remediation strategies, and regulatory acceptance of innovative technologies;
- Use of modern tools such as high-resolution site characterization methods, robotic and unmanned systems for data acquisition, improved sensors, remote and real-time monitoring;
- Understanding and developing viable, sustainable, and resilient remedies under evolving climate conditions;
- Resources and technology sharing;
- Environmental justice issues related to design and implementation of remediation technologies; and
- Assessing and addressing vulnerabilities associated with emerging contaminants for groundwater resources.

Based on the collective experience of senior leadership, these challenges represent the critical needs of federal agencies for future collaboration across agencies to advance innovative technologies and improve federal approaches to site cleanups.

4. Grand Challenges of FRTR Member Agencies

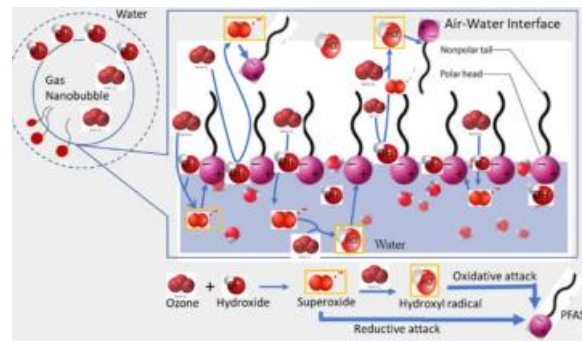
Information gathered by the FRTR Steering Committee has provided an improved understanding of the grand remediation challenges faced by all FRTR member agencies and specific technology needs across programs. The information was compiled from the presentations and discussions of the May 2021 FRTR public meetings, senior leadership questionnaire, input provided by other meeting attendees during and after the May meetings, and other sources. Broadly, the remediation challenges and technical needs have been grouped into three overarching topics:

- Technical challenges;
- Barriers to advancing new technologies; and

- Organizational and resourcing challenges.

4.1. Technical Challenges

Emerging contaminants. As new science improves understanding of human health and environmental risks associated with chemicals, federal agencies are facing new and growing challenges related to emerging contaminants. All member agencies recognize emerging contaminants as a major technical challenge for cleanup programs. Specific technical challenges identified by agencies include lack of understanding of risk, fate and transport processes, and effective treatment technologies.



Source: https://frtr.gov/pdf/meetings/nov2022/02_tamashiro_presentation.pdf

Large, complex, and difficult-to-remediate groundwater sites. Experience of recent years has shown member agencies the difficulty of meeting remediation program goals at large, complex groundwater sites. Specific technical challenges identified by agencies include complex hydrogeological conditions such as fractured rock, higher concentration source areas, lower permeability heterogeneous unconsolidated geology, complex surface-subsurface hydrology, vulnerable groundwater resources, and recalcitrant contaminants. At many sites, these technical challenges often result in estimate times of decades or longer to fully remediate contaminant plumes. Technology selection and use of flexible integrated strategies is a second major challenge related to complex site remediation. Several agencies identify transitioning technologies from active to passive approaches as an important aspect of this challenge.

Evaluating remedial efficacy. Several member agencies noted a need to develop or improve techniques and tools for predicting remediation timeframes and evaluating long-term uncertainty of estimating time to complete site cleanups. A second major challenge related to remediation efficacy is selection and verification of performance monitoring programs to evaluate and confirm remediation performance.

Climate change and climate resiliency. Member agencies broadly recognize the challenge of building climate resilience into site cleanup programs. The challenge to FRTR is to provide forums to share information on (1) approaches and tools to evaluate climate resilience and screen climate vulnerabilities of site cleanup projects, and (2) technologies and methodologies to assure remedy protectiveness in light of impacts associated with climate change and severe weather.

Other specific challenges. Member agencies identified additional challenges including:

- Cost-effective contaminant source and site characterization/source reduction technologies;
- Limitations of current cleanup technologies to achieve all cleanup goals;
- Use of scale-appropriate tools to interpret hydrogeology and geochemistry processes to build better CSMs;
- Treatment of mining-influenced water contamination;
- Addressing dangerous site conditions with remote sensing tools for large sites, including robotics surveillance and use; and

- Increase use of artificial intelligence and machine learning to analyze large data sets, guiding development or selection of remediation technologies and/or analyze data across multiple sites.

4.2. Barriers to Advancing New Technologies

Barriers to advancing new technologies from research and development to full-scale commercialization and broad use at remediation sites continue to provide a grand challenge to FRTR member agencies. Several specific challenges have been identified as barriers to advancing new technologies. It is expected that solutions to these specific challenges will be interrelated. Specific challenges include:

- Lack of field demonstration and verification opportunities for new and innovative technologies;
- Difficulty of moving new technologies from research and pilot phases into commercialization and full-scale field implementation;
- A mismatch between technology development initiatives and technology needs for addressing site complexities;
- Challenges to test new technologies on sites associated with regulatory and time commitment constraints;
- Reluctance by a range of stakeholders to adopt new technologies in site cleanup efforts that are not widely demonstrated and validated as effective at field scales under similar site conditions;
- Large resource requirements needed to test technologies across a range of conditions, to scale and improve technologies for full scale, commercial viability; and
- Lack of guidance for quality assurance and quality control (QA/QC) reviews that address use of new technologies to support remediation decisions (e.g., what would happen if a new technology went to litigation?). Some agencies noted support for development of industry consensus standards such as those of the American National Standards Institute.



Source:
https://frtr.gov/pdf/meetings/nov2022/02_tamashiro_presentation.pdf

4.3. Organizational and Resourcing Challenges

FRTR member agencies face ongoing organizational and resourcing challenges that may be appropriate to address as part of the FRTR mission. Specific challenges include:

- Limited resources (e.g., funding for testing, funding for site-specific treatability testing, time, staff),
- Loss of expertise with retirement and other attrition factors, and
- Training new personnel, including Remediation Program Managers (RPMs) and technical support staff.

5. FRTR Future Efforts

Addressing the grand remediation challenges faced by FRTR member agencies will require substantial efforts and resources. The FRTR commits to assisting these efforts by sharing technical information, fostering collaboration, and leveraging resources across agencies. As the FRTR Steering Committee has

reviewed and evaluated the information summarized in sections 2 and 3 of this report, several recurring topics or cross-cutting themes were identified. These topics or themes provide a basis for specific goals for upcoming FRTR activities. By focusing FRTR action on these goals, FRTR will be able to address our commitment and mission in an effective manner. FRTR actions to address a particular goal are expected to have a positive impact on several of the grand challenges. The key cross-cutting themes or goals that will provide focus for FRTR activities in the next several years are identified in Table 2.

As FRTR seeks to address the cross-cutting themes or common goals identified in Table 2, FRTR will assist member agencies by:

- Continuing information exchange through FRTR meetings, web-based resources, and networking platforms for subject matter expertise,
- Leveraging ongoing efforts to increase technical reach and impact of FRTR member agencies, professional organizations and working groups,
- Facilitating new ways to collaborate across FRTR member agencies, professional organizations and working groups, and
- Promoting workforce development by providing technology transfer, identifying training opportunities and identifying subject matter expertise within member agencies.

6. Connecting Future Efforts to Common Agency Goals

Future FRTR Efforts	Common Goals
Continued information exchange Leverage ongoing efforts Facilitate collaboration Promote workforce development	Address emerging contaminants Advance technology for contaminant source and site characterization Enhance technology transfer of cleanup technologies and approaches Address remedy resilience under evolving climatic conditions

Figure 1. Comparison of Future Efforts and the Common Agency Goals

Many agencies expect to allocate resources and time within their organizations to address the four agency goals listed in Figure 1. Although FRTR receives no funding separate from member agencies, collaborative action by FRTR can serve to leverage individual agency resources and time to the mutual benefit of all. A brief description follows the types of future FRTR efforts and collaborations that can be undertaken.

6.1. Continued Information Exchange

The FRTR will continue sharing lessons learned, case studies, and updates on innovative technology, and across similar sites and contaminant sources. As part of this process, FRTR will continue to take advantage of communication and knowledge sharing platforms such as:

- [FRTR Semiannual Meetings](#) and [“FRTR Presents” seminars on the EPA CLU-IN Website](#)

- Continue to update the FRTR website. Updates will emphasize the [Technology Screening Matrix](#), [Remediation Optimization information](#) and [Decision Support Tools](#).
- Develop new technology-transfer products and outreach materials.
- Continue to be a resource for collaboration, networking and showcasing the subject matter expertise across FRTR member agencies when technical information needs arise within member agencies.



Source:

<https://frtr.gov/decisionsupport/default.cfm>

6.2. Leverage Ongoing Efforts to Increase Technical Reach and Impact

FRTR member agencies maintain memberships with several ongoing federal, state, and professional society working groups (e.g., Strategic Environmental Research and Development Program, Environmental Security Technology Certification Program [SERDP/ESTCP], Interstate Technology and Regulatory Council [ITRC], National Groundwater Association [NGWA], American Chemical Society [ACS], Organisation for Economic Co-operation and Development/Nuclear Energy Agency [OECD/NEA], International Atomic Energy Agency [IAEA]). The FRTR’s multi-agency structure makes it ideal to accelerate information exchange from these existing working groups focusing on PFAS, other emerging contaminants, climate change, and other priority issues.

Liaisons for existing working groups. Seek opportunities for FRTR members to serve as liaisons between working groups and FRTR to exchange relevant information when appropriate. The FRTR meetings could be valuable opportunities for updates from interagency working groups, particularly as agencies seek federal stakeholder input. Several promising opportunities to leverage ongoing efforts with issue-specific working groups are outlined in Table 2. Specific functions that FRTR can provide include:

- Compiling a list of programs, resources, and working groups supporting efforts consistent with FRTR interests and priorities. Senior Leader input and presentations from the May 2021 FRTR meeting provides a starting point for this compilation. Information from the [National Academy of Sciences](#) could also help identify ongoing programs.
- Identifying points of contact (POCs) to interagency working groups from within the FRTR Steering Committee, as well as member agency staffs. This potentially could include POCs from staff of agency programs currently not actively represented within the FRTR Steering Committee (e.g., [EPA Brownfields](#) or [Resource Conservation and Recovery Act](#) programs).
- As need arises or on an ad hoc basis, inviting POCs from agency programs and interagency working groups not represented directly within the FRTR Steering Committee to participate in monthly Steering Committee meetings and activities. For example, stronger coordination with the [ITRC Quickening Environmental Solutions and Training \(QUEST\)](#) working group currently provides as an opportunity to enhance FRTR outreach and increase awareness of FRTR news and activities within a broader community of State and private ITRC stakeholders.

FRTR participation in professional societies. Enhance efforts to collaborate with major national professional societies to move cross-cutting initiatives forward. For example, FRTR may be able to coordinate FRTR technology transfer forums such as “FRTR Presents” with the agendas developed by professional societies for emerging contaminants meetings. Professional societies currently addressing emerging contaminants include engineering industries and professional societies [e.g., [ACS](#), [ASCE](#),

[NGWA](#)], as well as international groups [e.g., [OECD/NEA](#) and [IAEA](#)]. This would be an effective way to engage more with academia to exchange knowledge and information related to the state of science for remediation efforts.

[Big] Data management, analysis and visualization, and processing metadata. Big data, simply defined as collection and use of larger more complex data sets, especially from multiple new data sources, is both a technical challenge and an opportunity. Several FRTR senior leaders identified data sharing as an opportunity for future efforts. As technology development in these areas continue to advance, FRTR will follow the trends and promote information exchange, particularly for artificial intelligence software to process and analyze environmental monitoring, and as part of real-time monitoring. Specific functions that FRTR can provide include:

- Inventory ongoing efforts, working groups and resources.
- Provide a forum for dialog among technologists such as semi-annual FRTR meeting topics, and webinars of case examples.
- Form an ad hoc FRTR working group focused on technical aspects of big data to advise FRTR and address member agencies challenges related to big-data technology applications.

FRTR senior leaders also recognized a need to share agency experiences and guidance through enhanced exchange of case studies to facilitate timely technical expert exchanges. Currently there is no up-to-date repository for case study results. The FRTR can address this need by:

- Posting case study successes and demonstration-validation information from agency projects using new tools and guidance within [CLU-IN](#) and FRTR websites (e.g., [Groundwater Modeling resources bibliography](#) located within FRTR Website), and
- Providing a forum for sharing and collaborating with federal agencies and other organizations involved with big data collection, analysis, and visualization.

6.3. Facilitate Collaboration

The FRTR provides a forum for agencies to work together and collaborate. Where there are no existing interagency working groups (see previous section) to leverage for key cross-cutting themes, FRTR will seek opportunities to enhance collaboration and information exchange within the FRTR format.

The FRTR is well-positioned to serve as an interagency forum for advancing and fostering innovative remediation technologies, tools, and methodologies from research to widespread practice. Several senior leaders recognized challenges for technology developers to advance innovative approaches to field applications and readiness for commercialization. The FRTR can address these challenges by developing and maintaining web-based tools for tracking:

- Technology development status,
- Resources and programs for advancing technology, and
- Communicating federal agency needs and opportunities for advancing technology innovation.

As a practical matter, facilitating agency collaboration is likely to require the following: convening an FRTR ad hoc work group to identify agency technology development programs; discussing best approaches and procedures for providing access to agency sites for technology demonstration or testing; and obtaining samples for research phase testing and evaluation. An ad hoc work group also could foster infusion of modern technology tools such as artificial intelligence, machine learning, remote sensing, and robotics in solving the environmental problems.

Tracking technology development status. Technology status could be tracked by compiling lists of technology demonstrations at federal facilities (e.g., Department of Energy research and legacy management clean-up sites). FRTR could provide a centralized dashboard cataloging the status of innovative remediation technologies from successful research to field-scale deployment and commercialization. Such a dashboard requires long-term commitment and resources of member agencies. Centralized dashboard, updated on a regular basis, would provide greater value to site managers than similar efforts scattered within individual agencies.

Resources and programs for advancing technology. Resources for advancing innovative technology could include an inventory of current Agency technology development and transfer programs and a technology transfer “roadmap” to identify resources for advancing new technologies. This roadmap could be supported by materials to help researchers and vendors better understand the types of information needed to determine “readiness” for full scale field application. The roadmap could be developed by FRTR to seek opportunities for shepherding technologies from research, development, test, and evaluation programs to full implementation. FRTR can serve as an informal clearinghouse for members to network regarding ideas/needs for Agency technology development programs, as well as to identify potential field test sites for Agency test programs if no suitable internal sites can be identified.

Specific information outlets for communicating federal agency needs include [Department of Energy National Laboratories](#), NGWA publications such as [Groundwater Monitoring & Remediation](#), [ACS Chemical & Engineering News](#), and other industry news outlets.

6.4. Promote Workforce Development

The FRTR member agencies offer a wealth of training opportunities—many of which are publicly available—and will continue to promote these valuable resources. Nonetheless, member agency senior leaders were able to pinpoint a few unmet training needs. The FRTR can further promote workforce development by leveraging resources across member agencies to:

- Identify opportunities to meet training needs, and
- Transfer knowledge and experience from subject matter experts.

Identify opportunities to meet training needs. For internal training (feds only), FRTR will share training opportunities among member agencies. For external training, FRTR will engage with current and next generation remediation professionals to apply and review innovative remediation technologies using the tools and mechanisms typically available to FRTR agency staff and their contractors (e.g., Air Force Institute of Technology [AFIT], Navy Remediation Innovative Technology Seminar [RITS] and EPA’s Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] Education Center [CEC]/Trainex). To promote continuing education on new and innovative technologies and approaches, FRTR will consider designating identified training gaps as themes for FRTR meetings or for “FRTR Presents” seminars (e.g., a clearinghouse of information and possible training opportunities for characterization and performance monitoring methods using robotic sensors; and exchange information of remediation work plans at the field scale for complex sites).

7. FRTR Future Efforts: Achievable Short-term Goals and Ambitious Long-Term Goals

Based on discussion in previous section, the FRTR proposes dividing the common goals into achievable short-term goals and more ambitious long-term goals. Ambitious long-term goals are aspirational and would require a broad approach to pool agency resources with a long-term perspective. Figure 2 outlines executable activities in the proposed timeframes.

	Achievable Short-Term Goals	Ambitious Long-Term Goals
Address Emerging Contaminants	Exchange information and knowledge for newly emerging contaminants of concern.	Accelerate scientific understanding of PFAS risk to people and the environment; communicate validated methods for sampling and analyzing PFAS, and advance characterization/remediation approaches.
Contaminant Source and Site Characterization	Share knowledge and experiences in contaminant source and sit characterization. Encourage continual review, testing, and updating of CSMs to accurately reflect current knowledge of contaminant sources, site conditions, and exposure pathways.	Contaminant source and site characterization. Increase understanding of applying new tools to interpret hydrogeology and geochemistry data to build better CSMs and inform monitoring programs.
Cleanup Technologies/Approaches	Identify strategies and successful experiences for transitioning technologies from laboratory to field demonstrations and full-scale implementation. Identify strategies and successful experiences for optimizing remedies, and for transitioning remedial technologies/approaches when warranted.	Cleanup technologies/approaches. Identify cost effective alternatives for difficult to remediate sites. Large complex and difficult to cleanup groundwater. Evaluating remedy efficacy.
Address Remedy Resilience	Foster an understanding of how changing climate conditions affect remediation performance and identify data necessary to inform stakeholders decisions.	Address remedy resilience. Leverage efforts by existing climate change working groups/initiatives to enhance understanding of potential site condition changes and benefits of assessment and mitigation efforts. Transfer technology from climate change working groups to FRTR member agencies.

Figure 2. Short-Term and Long-Term Goal Activities to Achieve Interagency Goals

8. A Stepwise Approach to Achieving FRTR Goals

To assure that future efforts are measured and intentional, FRTR efforts outlines a 3-step approach, with actionable tasks or items, to achieving short and long-term goals as shown in Figure 3.

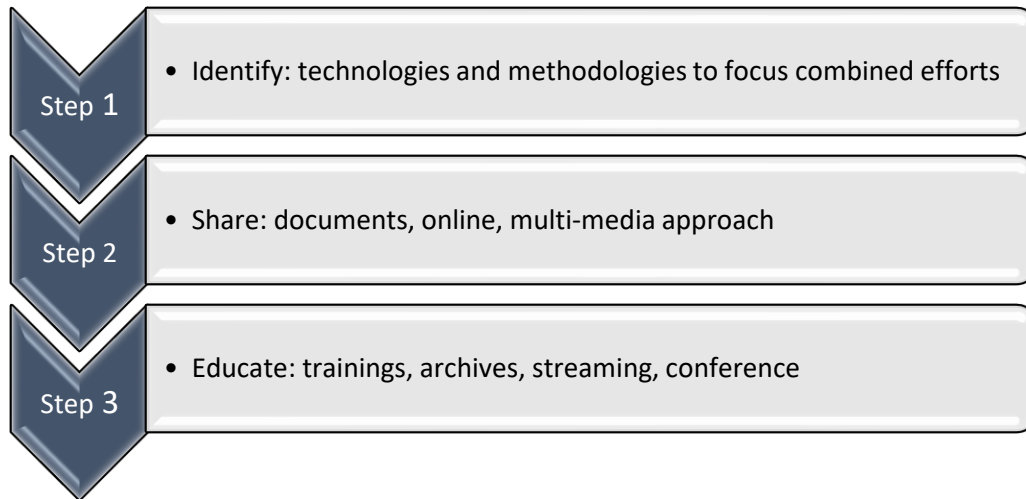


Figure 3. A Stepwise Approach to Future FRTR Efforts in Achieving the Common Goals

The following further expands on the four actionable tasks outlined in Figure 3:

First, identify current and potential resources where resources and knowledge can be shared. FRTR must continue what it does best: identifying topics and areas where the agencies can readily cooperate and work together to develop and rank the common focus areas; identifying specialty needs and enhancing areas of cooperation; and focusing on cost-effective source characterization and cleanup technologies.

Second, share available information, developing special sharing sessions as needed. Share training opportunities (e.g., AFIT, Navy RITS, and EPA’s CEC/Trainex).

Third, focus on educating and training. Through the use of the FRTR website and development of other forms of communications, identify weblinks and contact information for internal Agency and outside training resources and other reference materials to promote technology transfer.

For this effort, proposed FRTR focus areas include:

- Identify cost-effective source characterization and cleanup technologies and share
- Use resources to pursue cleanup of emerging contaminants
- Develop CSMs to fit site and scale – share ideas to enhance the CSMs
- Identify and share field demonstration opportunities – Broad Agency Announcements or Site Remediation Programs
- Promote use of modern technologies (artificial intelligence, machine learning, robotics, etc.) in management and cleanup of contaminated sites

Table 1. Technology Needs, Research Gaps, and Challenges Identified by FRTR Senior Leaders

Emerging Contaminants
<ul style="list-style-type: none"> • Data and information: toxicity and behavior data • Interim guidance • Expanded research • Methods for sampling, analyzing contaminants • Treatment technologies
Contaminant Source and Site Characterization
<ul style="list-style-type: none"> • Cost-effective characterization at an appropriate scale for large sites • Dynamic CSM tools for remedy design • Source reduction technology development • Robotic field sampling/monitoring methods • Improved inventory of resource extraction sites (e.g., abandoned mines) and features • Improved understanding of the necessary balance between modeled assumptions and actual field data • Improved sensors and real-time monitoring • Improved subsurface characterization
Cleanup Technologies/Approaches
<ul style="list-style-type: none"> • Understand limitations of current cleanup technologies (e.g., for bioremediation, DCE incomplete remediation stall) • Technology selection/use of flexible strategies • Cost/benefit analyses into the context of risk analysis • Optimization - Focus on enhancing safety, environmental protection, cost and time reduction, and optimization of remediation performance
Remedy Resilience Under Evolving Climatic Conditions
<ul style="list-style-type: none"> • Treatment and containment strategies that can function in changing weather climate events. Integrated climate, topographic, geologic, geophysical, hydrologic, and biologic models of watersheds for more accurate modeling of site cleanup impacts • Predicting future climate conditions in different U.S. regions • Better understanding of sea- level rise on remedies near shorelines • Role of renewables on remediation
Challenges
<ul style="list-style-type: none"> • Resources to fund technology transfer of innovative technologies • Identify and address Environmental Justice issues related to designing and implementing remediation programs • Understand and assess groundwater vulnerabilities to emerging contaminants (e.g., PFAS and co-generated organic and radionuclide contaminants) • Identify promising source reduction technologies and assist in their development, application, and information exchange

Table 2. Cross-cutting Themes or Goals for FRTR for Next 5-10 Years

<p>Address Emerging Contaminants</p>
<ul style="list-style-type: none"> • Accelerate scientific understanding of PFAS risk to people and the environment; communicate validated methods for sampling and analyzing PFAS, and advance characterization/ remediation approaches. • Exchange information and knowledge for newly emerging contaminants of concern.
<p>Advance Technology for Contaminant Source and Site Characterization</p>
<ul style="list-style-type: none"> • Share knowledge and experiences in contaminant source and site characterization. • Increase understanding of applying new tools to interpret hydrogeology and geochemistry data to build better CSMs and inform monitoring programs. • Encourage continual review, testing, and updating of CSMs to accurately reflect current knowledge of contaminant sources, site conditions, and exposure pathways.
<p>Enhance Technology Transfer of Cleanup Technologies and Approaches</p>
<ul style="list-style-type: none"> • Identify cost-effective alternatives for difficult to remediate sites. • Identify strategies and successful experiences for transitioning technologies from laboratory to field demonstrations and full-scale implementation. • Identify strategies and successful experiences for optimizing remedies, and for transitioning remedial technologies/approaches when warranted.
<p>Address Remedy Resilience Under Evolving Climatic Conditions</p>
<ul style="list-style-type: none"> • Foster an understanding of how changing climate conditions affect remediation performance and identify data necessary to inform stakeholder decisions. • Leverage efforts by existing climate change working groups/initiatives to enhance understanding of potential site condition changes and benefits of assessment and mitigation efforts. Transfer technology from climate change working groups to FRTR member agencies.