Designation: E3249 – 21

Standard Guide for Remedial Action Resiliency to Climate Impacts[1]

1. Scope

1.1 The potential for increasing climate and extreme weather impacts requires more attention be given to their effect on sites where chemicals have been released. All stages of remediation planning and implementation should consider and address potential climate and extreme weather impacts, such as flooding and wildfires, that may affect remedy sustainability, continued protection of human and ecological receptors, the surrounding community, and the environment. Both resiliency to current extreme weather impacts as well as adaptation to longer-term impacts due to the changing climate should be considered. Consideration of climate and extreme weather impacts during stabilization, remedial investigation, feasibility studies, remedial design, remedial action implementation, long-term operations and management, and site stewardship may lead to the use of innovative technologies and more robust remediation strategies.

1.2 The conceptual site model is designed to inform all aspects of site decision making, inclusive of the investigation, feasibility study, design and implementation. It may be the most important mechanism to integrate consideration of climate impacts. The conceptual site model should be continuously developed and refined, while considering new knowledge about climate factors and potential impacts to the site.

1.3 This ASTM resiliency guide identifies the best management practices for incorporating resiliency and vulnerability assessment into all stages of the site cleanup process. Historically, resiliency was primarily considered or contemplated in the final stages of the cleanup process, such as in the operation and maintenance stage, after a remedy was completely in place at a site. Gradually, resiliency has extended to earlier stages of the cleanup process. This may include initial vulnerability assessment for site stabilization and extending into the remedial investigation and feasibility stage. This guide will enable site project managers and others involved in site clean up to incorporate resiliency more robustly into the early stages of the cleanup process, and thereby improve resilience to current potential impacts as well as prepare for anticipated future impacts due to the changing climate.

1.4 The scope of this guide is generally based upon experience in site management in the US, however it may also apply to sites in other countries, regions and continents.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

E3136 Guide for Climate Resiliency in Water Resources

2.2 *ISO Standards:*[3]

ISO 14001:2015 Environmental Management Systems Version Dec. 2016 SC1 website

3. Terminology

3.1 *Definitions:*

3.1.1 *adaptive capacity*—the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change.

3.1.1.1 *Discussion*—Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes.

3.1.2 *barrier assessment*—an evaluation of fences, walls, caps and other physical structures, natural obstacles, or other measures and impediments to restrict activity and use and eliminate or reduce exposure pathways.

3.1.3 *best management practices (BMPs)*—activities that, if applicable to the situation, typically will reduce the environmental footprint of a cleanup activity.

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.07 on Climate and Community.

Current edition approved April 15, 2021. Published May 2021. DOI: 10.1520/E3249–21.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

3.1.3.1 *Discussion*—Methods that have been determined to be the most effective and practical means of improving or increasing the resiliency of a particular cleanup.

3.1.4 *chemicals of concern*—any spill or leak to, or detection of hazardous materials in, environmental media other than permitted discharges. **E1689**

3.1.5 *ecosystem services*—a way to characterize the natural system in a context of direct relevance to the benefits people derive from nature (Summers (**1**)). [4]

3.1.6 *environmental justice*—the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (USEPA, 2020 (**2**)).

3.1.7 *extreme events*—Climate change impacts that increase the potential for and frequency of weather and natural occurrences, outside of historical norms.

3.1.8 *resilience*—adaptive capacity of an organization in a complex and changing environment.

3.1.8.1 *Discussion*—A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment. This refers to risks under both current and future, anticipated climate conditions. Some experts describe vulnerability as the opposite of resiliency. **E3136**

3.1.9 *site assessment*—the cleanup phase in which the site is characterized to determine if the concentrations and distribution of chemicals released pose a potential risk to human health or the environment.

3.1.9.1 *Discussion*—More specifically, this cleanup phase involves collecting data on: soil, soil vapor, groundwater, air, surface water, and/or sediment quality; site characteristics (for example, subsurface geology, geochemistry, soil properties and structures, hydrology, and surface characteristics); land and resource use; and potential human and ecological receptors. The site assessment generates data to develop a conceptual site model and inform decisions regarding the cleanup, if necessary (which may include a risk assessment). Regulatory requirements for site assessment may vary by program. In the environmental remediation industry, site assessment is also referred to as remedial investigation, site investigation, or site characterization.

3.1.10 *Superfund*—The Federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) 42 U.S.C. Section 9601 *et seq.*

3.1.11 *vulnerability assessment*—the process for evaluating all stages of the remedial site cleanup process' exposure to climate or weather hazards of concern, such as high floodwater or soil subsidence.

3.1.11.1 *Discussion*—An evaluation of the remedial site's sensitivity to the hazards of concern and likelihood for the hazards to reduce remedy effectiveness.

3.2 *Acronyms:*

3.2.1 *DTSC*—Department of Toxic Substances Control, California

3.2.2 *FEMA*—Federal Emergency Management Agency

3.2.3 *IPCC*—Inter Governmental Panel on Climate Change

3.2.4 *ITRC*—Interstate Technology and Regulatory Council

3.2.5 *NOAA*—National Oceanic and Atmospheric Agency

3.2.6 *SSFL*—Santa Susana Field Laboratory, California.

3.2.7 *SURF*—Sustainable Remediation Forum

3.2.8 *USACE*—United States Army Corps of Engineers

3.2.9 *USEPA*—United States Environmental Protection Agency

3.2.10 *USGAO*—United State Government Accountability Office

3.2.11 *USGS*—United States Geological Survey

4. Significance and Use

4.1 This guide outlines various techniques for evaluating and mitigating the impacts of climate change and weather extremes on remediation systems, activity and use limitations, stewardship and remediation activities.

4.2 Users include: local, state, federal, tribal, and international agencies; the military; environmental consultants; developers; financial institutions; non-governmental organizations; environmental advocacy groups; commercial businesses, industries, and the interested public.

4.3 A 2018 ITRC survey of 45 state environmental agencies found key Best Management Practices (BMPs) and adaptation strategies for resilient cleanup. These include remedy infrastructure and disaster planning for chemical releases as an important part of the state's clean-up program. In some cases, such considerations are now required by state regulations and included in policy and guidance (ITRC, 2018 (**3**)).

4.4 Adaptation is important because it is about considering and addressing the changing frequency and intensity of extreme events. Adaptation differs from resiliency by anticipating, planning and preparing for impacts under both current and future climate conditions.

4.5 There are many models and different strategies on adapting to climate and weather extremes, including those in the European Union (European Union, 2013 (**4**), IPPC, 2001 (**5**)).

4.6 The USGAO has reported benefits from evaluating climate risks for large projects. (USGAO, 2019 (**6**)) GAO found most Superfund sites have not factored the increasing frequency and severity of extreme weather events and climate impacts into the design of remedies. This has resulted in unplanned releases of chemicals into the environment at some sites.

4.7 Companies and organizations operating in accordance with ISO 14001-2015 may find this guide useful for meeting the long-term compliance obligation requirements of Clause 5.2 (ISO 14001-2015)

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

4.8 This guide should be integrated into the fundamentals of an organization's management system in order to support an organization's strategies, plans, and operations. For example, ISO, Risk, or Conformity Assessment references may influence integrating risk management into significant activities and functions. ((ISO 14001-2015))

4.9 Users also include: owners of Superfund sites; oil, gas and chemical companies; owners of land upon which oil, gas and chemical companies operate; design/build consultants and other industrial users who can include principles of this standard into their design and operation procedures and risk evaluation protocols. These are well -recognized management control programs within the chemical industry, and as such are highly relevant to how companies manage the resilience of physical systems. (ACC, 2014 (7))

4.10 Climate factors discussed in this standard guide can result in the unplanned or unexpected release of chemicals of concern into the environment. These releases may adversely affect human and ecological receptors and impact cultural resources and infrastructure.

5. Climate Evaluation for Remediation Stages (Fig. 1 and Fig. 2)

5.1 *Site Assessment*—Sites being investigated for potential chemical releases should include screening of considerations for contaminant migration, assuming expected extreme events related to climate locally.

5.1.1 Once site discovery determines the need for a preliminary assessment, the assessment should consider the proximity of previously flooded areas or of the frequency and nature of other extreme weather events, as the potential trigger for migration of any contaminants from the site. The assessment should also consider the likelihood of floods or other extreme weather events anticipated as the climate changes.

5.1.2 If the preliminary assessment determines the need for a site inspection, sampling and evaluation should consider areas of impact and migration of contaminants from past and anticipated future flooding and other extreme weather events, such as hurricane force winds or excessive local groundwater extraction due to droughts. Additional factors may include, but not limited to, erosion due to droughts and high wind events, as well as impacts to on-site engineered systems and infrastructure.

5.1.3 If a hazard ranking system score and documentation are prepared, in anticipation of a proposed listing on the National Priority List, or a state's confirmed chemical release sites list, documentation should include groundwater and surface water use areas which have been subject to flooding and potential migration for site contaminants. It should also include other extreme weather events, such as drought, wind

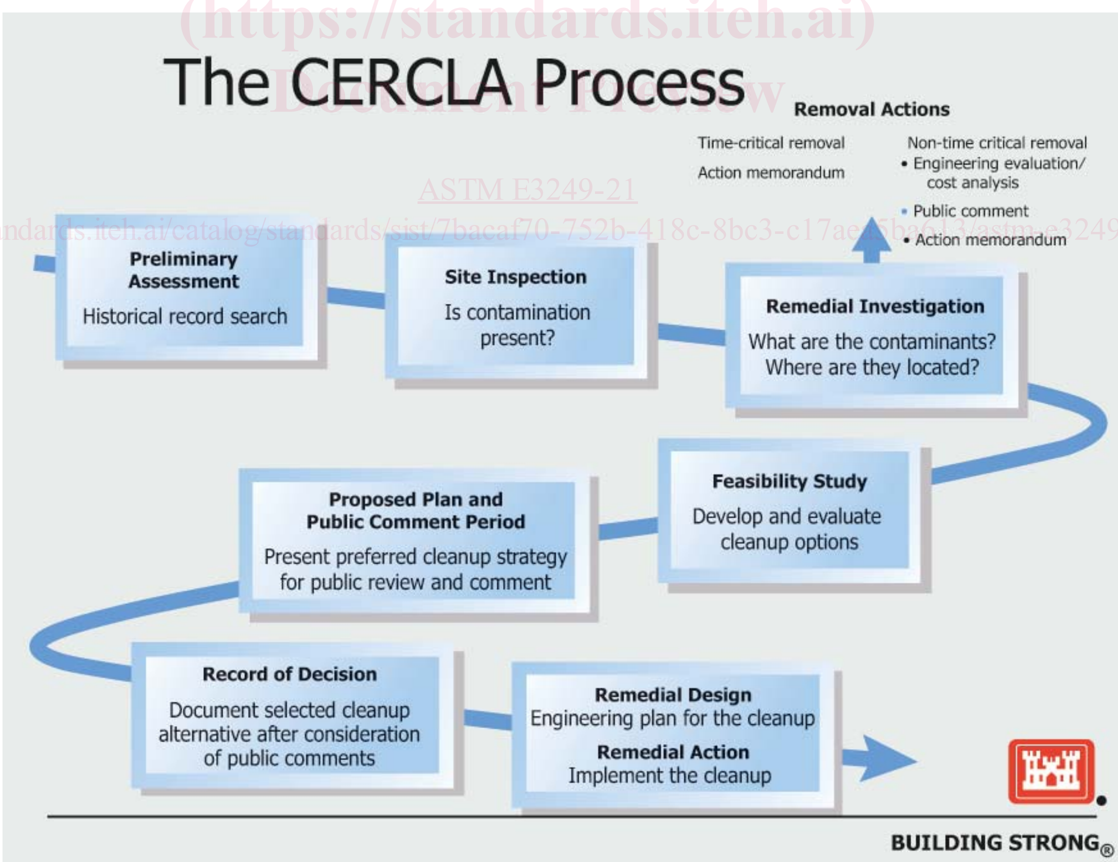

FIG. 1 The CERCLA Process. Source, US Army Corps of Engineers (8)

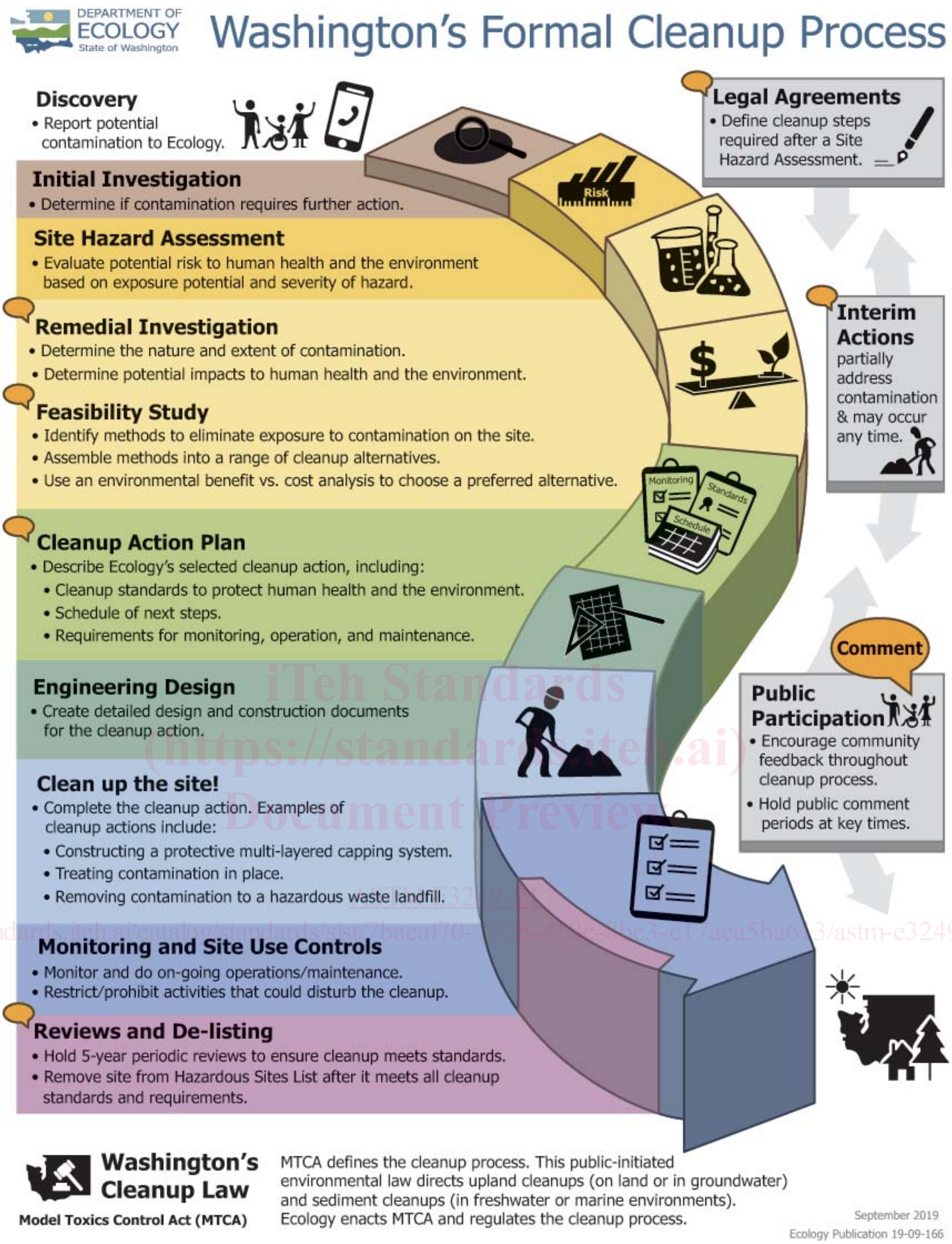

FIG. 2 Example flow chart for State-directed site remediation, Source WDOE. (9)

scour, extreme high or low water table, and fire, anticipated now and into the future, considering the changing climate.

5.1.4 Assessments of ecosystem services that include those benefits people and the built environment receive from nature, could strengthen site assessment efforts. (Summers, 2012 (1)) For example, an assessment of the flood protection services in and around a site provides an additional level of information beyond just consideration of proximity to previously flooded areas. In another example, an effort to characterize natural areas (for example, nearby wetlands) that provide a critical wind buffering service informs identification of areas of potential impact from hurricane force winds and tidal surges.

5.2 *Remedial Investigation and Feasibility Study*—As shown in Fig. 1 and Fig. 2 these stages of remedial action are important parts of site cleanup. Portions of the RI/FS that should be evaluated for climate resiliency include:

5.2.1 Identification of viable, potential, responsible parties. (PRPs),

5.2.2 Preparation of the RI/FS Statement of Work (SOW) by USEPA staff,

5.2.3 PRP or USEPA develops RI/FS work plan based on the SOW,

5.2.4 *RI Start*—sampling of various media to learn the nature and extent of contamination and exposure pathways,

5.2.5 *FS Start*—Development of various cleanup alternatives and evaluating their resiliency,

5.2.6 Draft RI/FS report is written,

5.2.7 Review/comment on draft RI/FS report,

5.2.8 Develop Final RI/FS Report, and

5.2.9 Site project manager writes a proposed plan which includes the selected remedy.

5.3 Remedial Investigation evaluates the risks and resiliency of the site as it currently exists, prior to stabilization, unless emergency action is immediately required. It should evaluate all relevant, current and future potential climate or extreme weather impacts for the local area to determine risks and resiliency following any initial site stabilization as planning moves forward. This evaluation should use the most updated FEMA flood maps, regional climate data (local if available), climate event forecast model(s), and coastal flooding models (if applicable). Long-term historic average climate data may misrepresent the present climate dynamics at the site. More recently, rainfall patterns have changed, with events being of shorter duration but stronger rainfall. This information should be used for remedy decision-making, and include records of local and regional flooding, evaluated for potential site implications.

5.3.1 FEMA flood maps may be multi-years old and reflect data that doesn't represent extreme events. These maps should be used with caution, and verified with local information if at all possible.

NOTE 1—The *user* is advised to evaluate the potential impact of derecho storms on the site.

5.3.2 At site cleanups, users should evaluate the current and future risk, likelihood of occurrence and intensity of the hazard, to human health and the environment from site contamination. This includes the evaluation of proposed remedy options against the worst-case scenario, whether it be flooding, tornadoes, hurricanes, subsidence, drought, loss of permafrost, or fire. The design of the cleanup will be based on those risk factors. Users should also assess potential secondary effects of increased rainfall and rain intensity at areas subject to period fires. These secondary effects include landslides and mudslides which can bury remediation equipment or expose previously undisturbed areas that contain released chemicals of concern.

5.3.3 Many projects, including the design and implementation of a site cleanup remedy, benefit from a vulnerability assessment. (Adaptation Community, 2018. (**10**)) A cleanup remedy vulnerability assessment examines the expected remedy protection level, given the physical and environmental vulnerabilities. An initial step of a vulnerability assessment is to understand risk by conducting a hazard and climate assessment. The process involves identifying which hazards could impact the area of study, identifying the intensity of each hazard, the frequency and probability of occurrence, the area of impact, and the duration of impact. The extent to which this planning activity should be documented will depend upon anticipated impacts on any remedy. If there are multiple and serious extreme events anticipated, a separate, resiliency or adaptation plan document may be required. Otherwise these impacts can be included as a discretely identifiable section in response planning documents

5.3.4 Using vulnerability assessment tools, users should evaluate the risk (likelihood of occurrence and intensity of the hazard) to human health and the environment from chemical releases at the remediation site. Users should evaluate proposed remedy options, considering current and future climate expectations, including those that involve activity and use limitations against the worst-case scenario, whether it is flooding, tornadoes, hurricanes, fire or otherwise. The design of the remediation and stewardship should be based on those risk factors.

NOTE 2—The vulnerability assessment should include the secondary effects of climate change and weather extremes. For example, loss of utility services to the remediation site due to extreme heat or cold.

5.3.5 The risk to human and ecological receptors posed by a site will evolve over time due to changing climate conditions and anticipated extreme events. The current parameters of a 1, 5, 10, 100 and 500- year event are evolving rapidly. Instead of a one-hundred-year event (a 1 % chance of an event happening in a given year) as currently defined, it may be necessary to plan for a five-hundred-year event (a 0.2 % chance of an event happening in a given year), multiple times, during the lifetime of the remedy. Determining the level of acceptable risk is critical to designing the appropriate level of protectiveness of the desired remedy.

5.3.6 There are interactive resources to help local governments anticipate, plan, and prepare while continuing to deliver services effectively to their communities, even as the climate changes. and respond to extreme events. (NOAA and USACE, 2018 (**11**)) Decision makers can create an integrated package of information tailored specifically to their needs. Climate projection tools and maps like these are critical to understanding the changing environmental conditions at a site, including any structures that may be exposed during the service life of the remedy.

5.3.7 Users should evaluate the fate of past site cleanup remedies that have experienced a natural disaster and apply the lessons learned for resiliency and mitigation techniques. (Appendix X1)

5.3.8 Early in the process, users should evaluate process options and select remedies that will incorporate resiliency and adaptation so that they are carried forward into the planning process.

5.3.9 Users should consider the role of natural ecosystems for community resiliency. Ecosystem services have the ability to influence many of community's vulnerability and recoverability characteristics (Summers et al. (**1**)).

5.4 *Feasibility Studies (FS)*—The FS is the stage where different cleanup alternatives for a site are considered using established, standard evaluation criteria. Resiliency to a future natural disaster or change in climate should be considered during this stage. The earlier resiliency is considered in the cleanup process, the stronger and more resilient the remedy.

5.4.1 Remedy selection criteria should include the concept of a resilient remedy that is resistant to extreme events or new normal, such as sea level rise.

5.4.2 As a best management practice, users should avail themselves of a variety of tools to assess potential, worst-case, climate impacts to a site cleanup remedy (Guide E3136).

5.4.3 FEMA's online database can provide a history of disasters for the area in question, while climate projection tools such as NOAA's Sea Level Rise Viewer and the U.S Climate Resilience Toolkit's Climate Explorer (NOAA and USACE, 2018 (**11**)) provide maps that anticipate future environmental changes that may increase hazard risk. USEPA also provides a climate adaptation tool, ARC-X (USEPA, 2019 (**12**))

5.4.4 To address climate adaptation, users should: screen site remedies for climate related vulnerabilities; conduct sensitivity analysis to screen out low probability/low impact vulnerabilities; evaluate adaptation measures available and applicable to address vulnerabilities; and increase remedy resilience by implementing adaptation measures. This includes activities such as those listed in section

5.4.5 *Primary Considerations:*

5.4.5.1 Identify the type of chemical releases present and the hazards that could be left in place, as may be impacted by climate events.

5.4.5.2 Forecast the amount of waste at any given time that will be on-site.

5.4.5.3 Identify the region where the site is located (that is, Northwest, Southwest, Alaska, Great Plains, Midwest, Northeast, Southeast, Caribbean, Hawaii and Pacific Islands, Fig. 3.) In many cases the resolution of available climate models may allow the user to fine tune the site location using latitude and longitude, and calibrate the assessment of climate impacts to the site.

5.4.5.4 Identify the kind of natural disasters common for that area and identify how climate might change the frequency, severity, or types of natural disasters.

5.4.5.5 Identify how climate is likely to affect the protectiveness of the remedy, and proposed actions.

5.4.5.6 Estimate the projected lifespan of the remedy.

5.4.5.7 Identify the remedy's critical functional requirements before, during, and after a possible hazard strike.

5.4.5.8 List the possible risk mitigation measures if there is a compromise of the remedy.

5.4.5.9 Identify an area for temporary storage in case of a disaster and a removal and response strategy when a disaster does occur.

5.4.5.10 Review the reduction of toxicity, mobility and volume evaluation and identify the residual mass that could be left in place, either permanently or during the alternative lifespan. Predict how this mass might be affected by an extreme event and how the toxicity or mobility assumptions may be compromised.

5.4.5.11 List the conditions where off-site resources may be required if the site were to be impacted, and their likely availability, depending on whether the site, surrounding area, or region is impacted. These resources may include off-site

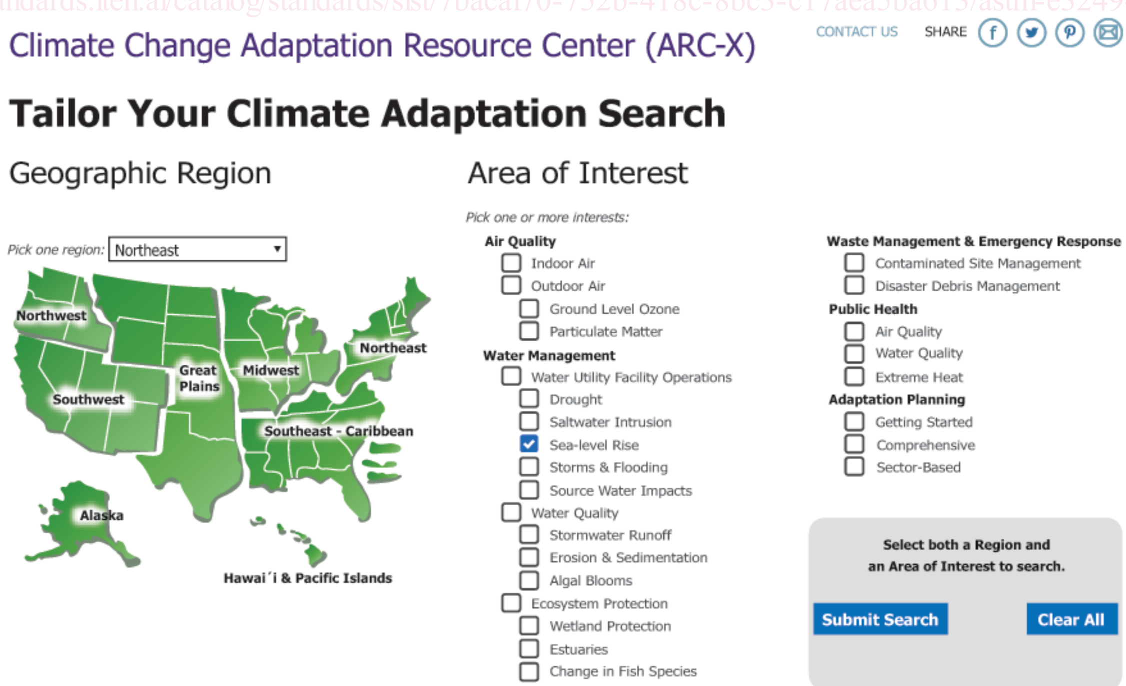

FIG. 3 Example from USEPA's ARC-X program

storage capabilities, or the ability to mobilize heavy equipment and personnel to the site if transportation access is compromised.

5.5 *Remedial Design, Action and Implementation*—Evaluate process options and anticipate remedies to maximize resiliency.

5.5.1 Incorporate redundancy and flexibility into designs.

5.5.2 Site design assumptions should be reviewed for expected extreme events, especially the 100-year flood plain designation (the 1 % chance of flooding in a given year) in vulnerable areas. The emphasis should be prevention of increased risks from remedy degradation due to extreme events related to climate. Lessons learned from past damages to similar remedial action sites should guide future designs. (Appendix X1)

5.5.3 Design documents and assumptions for sites near the coast should use the most recent Sea Level Change Curve Calculator (NOAA and USACE, 2018 (**11**)).

5.5.4 *Implementation of New Remedies*—All stages of investigation, feasibility study, implementation, and remedy review should account for expected extreme events, as influenced by current trends in the local and regional climate.

5.5.5 *Remedy evaluation*—Ecosystem services might be relevant in the evaluation of process options and design of remedies to maximize resiliency. Checking a remedy or suite of remedies against current ecological services in the area of a site might help identify if there are changes as a result of that remedy. A negative change could infer a potential decrease in overall resilience.

5.5.6 For existing remedies, users should evaluate all existing remedial clean up actions underway or recently complete for risk and vulnerability issues, given recent and anticipated regional, extreme events related to climate. This will include factors such as how long ago the remedy was completed, the location of the remedy relative to various extreme event risks and the nature of the remedy.

5.6 *Operation and Maintenance (O&M), Operational Integrity, and Optimization:*

5.6.1 *Operation and Maintenance*—During operation and maintenance activities, ongoing barrier assessments should be conducted to determine potential impacts to public health and the environment from systems failures, resulting in chemical releases. Remedial activities may also impact environmental quality outside the boundaries of the site. Users should evaluate the potential for a site, its physical barriers, and related off-site activities to result in environmental impacts and damage during an extreme event. This is especially important during five-year or other periodic reviews of remedies that assess the continued protectiveness of remedial actions. It should include the evaluation of any activity and use limitations, in relation to anticipated extreme events, as influenced by climate.

NOTE 3—This includes effects on sites where chemicals are stored.

5.6.2 *Operational Integrity Considerations:*

5.6.2.1 Build contingencies into decision documents, including options identified for critical system components and operational dependencies.

5.6.2.2 Review and affirm remediation system dependencies, such as the integrity of power, key support systems and availability of supplies.

5.6.2.3 Put fail-safe processes and procedures in place.

5.6.3 *Optimization*—Optimization should be geared toward automation, self-reliance and reduced reliance on physical prevention and mitigation barriers to contain wastes. For example, reducing reliance on above ground berms, piping, and generators can minimize threats to critical system components from tornados, fire, flood debris, hail storms and incidental contact.

5.6.3.1 Where possible, automate systems for monitoring, operations, and contingent measures. Provide for auxiliary power generation, and back up plans for manual checks on systems. Users should emphasize remote monitoring capabilities, their redundancy for critical systems, and their survivability during an extreme event.

5.6.3.2 Where possible, build in power independence such as green energy, and site sourced energy for redundancy to remotely supplied energy.

5.7 *Remedy Review*—Parties responsible for sites where chemical releases remain should evaluate remedy effectiveness and any new, climate-related guidance from regulatory agencies. This will include any changes in land use regulation.

5.7.1 The NCP (**13**) states that alternatives shall be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. USEPA suggests the application of an adaptation approach that considers climate as part of ongoing site management. See Fig. 4. .

5.7.2 In 2016 USEPA provided additional clarification to the CERCLA 5-year review process. The protectiveness of a remedy should specifically consider vulnerabilities that may be related to climate impacts that were not apparent during remedy selection, remedy implementation or O&M. This may include sea level rise, changes in precipitation, increasing risk

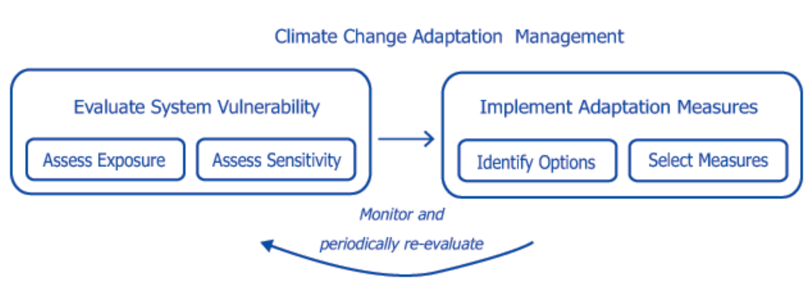

FIG. 4 USEPA Climate Adaptation Management