DOE Climate Change Vulnerability and Adaptation Planning: Three Relevant Case Studies
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ABSTRACT

Executive Order 13653, *Preparing the United States for the Impacts of Climate Change*, was issued in 2013. The President emphasized the importance for federal agencies to take action to enhance climate preparedness and resilience. The U.S. Department of Energy released the *DOE Climate Change Adaptation Plan* in 2014 to build resilience and mitigation across the Department, and to assure inclusion of climate change adaptation as part of its planning and operations.

DOE's Office of Environmental Management has an important mission to manage safe cleanup of environmental legacy contamination brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research. Specifically, Environmental Management is responsible for remediation of soil and groundwater, deactivation and decommissioning of facilities, and disposal of hazardous and radioactive waste.

Three case studies are discussed in this paper that demonstrate the cost benefit and importance for Environmental Management to assess climate change vulnerability and implement planning procedures:

1. Los Alamos National Laboratory in New Mexico has experienced $0.5 billion in unanticipated costs as a result of climate-related events including: extreme drought, wildfires, deluge rains, and historic flooding over the past 15 years.
2. The U.S. Environmental Protection Agency American Cyanamid Superfund Site, situated on the New Jersey coast was hit by Hurricane Irene in 2011. Three major contaminated, solvent impoundment berms were breached within the 100-year floodplain, causing major damage to the facility.
3. For radioactive waste disposal facilities in low-lying areas in proximity to groundwater, climate change vulnerability and assessment is

prudent for operational management. One such Superfund hazardous and radioactive waste disposal facility, the Environmental Management Waste Management Facility located at the DOE Oak Ridge Reservation in Tennessee, has documented surface and ground water management challenges since construction began in 2001, driven by changing regional weather patterns.

INTRODUCTION

Executive Order (EO) 13653, *Preparing the United States for the Impacts of Climate Change*, was issued in 2013. The President emphasized the importance for federal agencies to take action to enhance climate preparedness and resilience. The U.S. Department of Energy (DOE) released the *DOE Climate Change Adaptation Plan* in 2014 [1] to build resilience and mitigation across the Department, and to assure inclusion of climate change adaptation as part of its planning and operations. As part of the Executive Order implementation, DOE established the Climate Adaptation Collaborative across the program offices to centralize training, policy, implementations, studies, and lessons learned from the Headquarters to the Field Sites.

DOE's Office of Environmental Management (EM) has an important mission to manage safe cleanup of environmental legacy contamination brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research. Specifically, EM manages remediation of soil and groundwater, deactivation and decommissioning of facilities, and disposal of hazardous and radioactive waste.

As part of its Fifth Assessment Report in 2013 [2], the Intergovernmental Panel on Climate Change documented recent climate changes impacts on human and natural systems. A summary of observational trends includes: the increase of global average air and ocean temperatures, rising of average sea level, heavier flooding, melting of snow glaciers, longer drought periods, increase threats from wild fires, and severe weather.

Three case studies are discussed in this paper that demonstrate the cost benefit and importance for EM to proactively assess climate change vulnerability and implement planning procedures:

1. Los Alamos National Laboratory in New Mexico has experienced $0.5 billion in unanticipated costs as a result of climate-related events including: extreme drought, wildfires, deluge rains, and

historic flooding over the past 15 years. These events prompted a change in management strategy to a proactive plan for the site to mitigate climate change impacts. Of interest is proactive radioactive waste management to assure that operational areas and containers are not at risk to future fires and flooding.

2. With the imminent vulnerability that climate change presents to contaminated sites, the U.S. Environmental Protection Agency (EPA) now requires a climate change vulnerability assessment and adaptation plan for all regulated cleanup programs to prioritize its adaptation efforts. One example is the American Cyanamid Superfund Site in New Jersey. After Hurricane Irene hit the coast of New Jersey in 2011, three major contaminated, solvent impoundment berms were breached within the 100-year floodplain, causing major damage to the facility. The most significant adaptive measure implemented after site flooding caused by Hurricane Irene is to require all future engineered caps to be designed to withstand a 500-year flood event, at a minimum.
3. The Oak Ridge Reservation (ORR) near Knoxville, Tennessee is one of DOE's 12 major cleanup sites across the U.S. The Environmental Management Waste Management Disposal Facility (EMWMF) at ORR is an onsite, near-surface landfill that receives hazardous and low-level radioactive waste (mixed low-level waste, MLLW) from cleanup of the historical weapon's complex and is approved under the Superfund Program by federal and state environmental regulators. The EMWMF has struggled with surface and ground water management challenges since construction began in 2001, which have been exacerbated by historic wet periods exceeding the average 55 inches per year, and rising groundwater levels adjacent to and under the facility. The site geology is shale and limestone karst, characterized by natural discharge from seasonal streams and springs below the landfill.

LOS ALAMOS NATIONAL LABORATORY CLIMATE CHANGE CHALLENGE CASE STUDY

Climate Change Challenges

The coveted GreenGov "Climate Champion" Presidential Award for 2015, was awarded to the LANL team which documented "Climate Change Realities at

LANL." The subject case study summarized here is extracted from "Climate Change and the Los Alamos National Laboratory: the Adaptation Challenge" [3].

Los Alamos, New Mexico (NM), hosts the namesake DOE national laboratory located 35 miles northwest of Santa Fe in the high desert (Figure 1).

FIGURE 1. LOS ALAMOS, NM, SITUATED 35 MILES NORTHWEST OF SANTA FE [3].

Besides a workforce of over 11,000, the site holds several metric tons of nuclear material and 140,000 chemical containers, on a footprint about the size of Washington DC. LANL is surrounded by the Santa Fe National Forest, San Ildefonso Indian Reservation, and Bandelier National Monument. The nearby cities of Los Alamos and White Rock house workers at the national laboratory, and other small businesses.

In the past 3 decades, the region has been subject to an onslaught of severe climate-related events: pine bark beetle infestation, drought, devastating wildfires, and historic flooding. LANL and the surrounding communities have integrated climate change mitigation strategies into their operations and long-term plans by increasing coordination and communication between the Federal, State, and local agencies in the region; identifying and aggressively managing forested areas in need of near-term attention; addressing flood control and retention issues; and other long term mitigation planning.

Severe drought struck the Pajarito Plateau for two decades beginning in the 1990s. Massive infestation by the pine bark beetle followed as forest health declined killing millions of pinyon-juniper and Ponderosa pine trees over millions of acres in Arizona and New Mexico. Megafires followed beginning in 2000, with the Cerro Grande fire burning about 45,000 acres in the Santa Fe National Forest, and causing $1 billion in damages. Sixty-seven LANL buildings were destroyed, with damage to 45 more. Other notable damage included 235 homes lost in the area, and 400+ families displaced. LANL was evacuated and closed for about two weeks. No structures with radioactive or chemical inventories were burned. However, 308 potential release sites and areas with low levels of surface contamination were burned and left with increased erosion potential. Damages to LANL totaled about $331 million. The following monsoon season of increased rainfall was mild; no major floods occurred.

FIGURE 2. LAS CONCHAS FIRE, LOS ALAMOS, NM [3].

In 2011, the Las Conchas Fire raged as the largest recorded wildfire in New Mexico history. Destruction was estimated at $160 million: 154,000 acres were burned, 63 structures destroyed, and LANL was closed for 9 days. The proximity and intensity of the Las Conchas Fire to radioactive waste management areas prompted the Laboratory and New Mexico Environmental Department to accelerate removal of 3706 cubic meters of stored aboveground transuranic waste offsite. Funds for cleanup activities were shifted to waste relocation totaling over $150 million.

The monsoon rains in 2011 brought flash flooding of high intensity due to depletion of vegetation and hydrophobic soil developed following the Las Conchas Fire. Mitigation measures were taken prior to the floods to remove bridges to facilitate channel flow and divert water to holding areas. Also, water repellent material was used to protect historic buildings, with some key buildings being sand-bagged. LANL was successful in reducing damage due to runoff and took additional proactive measures by planting willow trees along stream banks and in wetlands.

In September 2013, Los Alamos experienced a 1000-year flood event, recording up to 18 inches of rain in 24 hours at higher elevations. This event caused $17.4 million in infrastructure damage and more importantly, extensive damage of stream banks and wetlands, which are important systems for stabilization of contaminated sediment as it leaves the site. Potential contaminant transport offsite requires resampling of canyons damaged by the flooding. Plans were then made to repair 130 sites damaged by the flood.

Weather assessment is an important part of safety planning at LANL to mitigate fires. Outdoor operations, such as explosives testing, cannot be conducted on days where winds gusts exceed 20 miles per hour and relative humidity drops below 15%: these are termed "Red Flag" days. The number of Red Flag days in a year has steadily increased from the observational period 1990-2014.

Polar vortex events in recent years indicate ongoing vulnerability to extended periods of cold in the high desert of Northern New Mexico. In February 2011, record cold temperature (i.e., -13 to -15 degrees Fahrenheit) over two weeks in the Southwest United States left Los Alamos without natural gas, as production was shut down in many states. At the lab, pipes and infrastructure froze causing work stoppage. Burst water pipes resulted in extensive damage.

Responding and Preparing

The Cerro Grande fire served as the wake-up call for LANL, prompting a change in management strategy to proactively plan for the site to mitigate climate change impacts. A high priority is assuring that radioactive waste operational areas and containers are not at risk to future wild fires and flooding. Contaminated materials and transuranic waste was shipped offsite.

A shut down of LANL costs about $15 million per week in lost productivity. Proactive measures taken at the site before the Las Conchas fire resulted in lower costs for cleanup of damaged property and faster recovery to resume operations.

The Laboratory appointed a Climate Change Adaptation Team Leader as part of the Long Term Strategy for Environmental Stewardship and Sustainability. This Team works actively with Federal, State, and local governments to improve communication during extreme weather events and restoration activities. In the future, LANL will work with regulators, Tribal, and government leaders on integration of Climate Action Plans as they are developed by each entity.

AMERICAN CYANAMID SITE, NEW JERSEY, SUPERFUND CLIMATE ADAPTATION CASE STUDY

Climate Change Challenges

The number of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or “Superfund” sites along U.S. coastlines is considerable: 289 Superfund sites are in varying stages of remediation and within 9 miles of shorelines [4]. The five states with the most coastal Superfund sites are [4]: New Jersey (55), Florida (40), California (33), and Washington (25), and New York (25). In 2014, EPA released its Climate Change Adaptation Report [5] and 17 plans developed by Regional and Program Offices, partly in response to lessons learned from Hurricane Sandy in October 2012. Flood waters and storm surge threatened citizens living in coastal communities (greater than 40% of the U.S. population) and adjacent to Superfund hazardous and radioactive sites [4]. The language and underlying policies of CERCLA require that climate change analysis be incorporated into remediation and management of new and existing Superfund sites.

FIGURE 3. RARITAN RIVER FLOODING AMERICAN CYANAMID SITE NORTH AREA WITH FIVE FEET STANDING WATER [6].

The subject case study, “Hurricane Irene Flooding and Adaptation at the Cyanamid Site,” is summarized in this paper from the 2014 EPA Technology News and Trends Issue No. 65, written by Joe Battipaglia, EPA Region 2 [6].

American Cyanamid is a 435-acre site located along the Raritan River (Figure 3) in central New Jersey’s Somerset County. From 1915-1999, pharmaceuticals, chemical intermediates, petroleum-based products, dyes, and pigments were manufactured at the site. The site has over 100 acres of waste disposal areas adjacent to the Raritan River, and is largely located within a flood hazard area. Thus, an 8- to 10-foot-high flood control berm was designed and installed to protect the site from a 100-year flood event.

The site has 27 impoundments. Onsite soil and groundwater are contaminated with volatile organic compounds (VOCs), semi-VOCs, and metals; benzene, benzene byproducts and naphthalene are the primary contaminants. The two most contaminated impoundments contain are 13- to 16-feet deep, and cover about 2 acres. Since 1988, hydraulic containment was controlled with groundwater extraction and discharge to a nearby treatment system.

FIGURE 4. FLOODING OF IMPOUNDMENTS FROM HURRICANE IRENE AT AMERICAN CYANAMID SITE [6].

Flood waters entered the site after Hurricane Irene struck the coast of New Jersey in late August 2011. About 214 million gallons of standing water remained in the North Area of the site after the floodwaters receded (Figure 4). An inoperative mechanical sluice gate prevented floodwaters from exiting the flood control berm, creating a bathtub effect. Eventually, floodwater was issued to adjacent waterways through sampling and controlled release after it was determined that there would not be a negative impact on water quality. The remaining 62 million gallons of standing water was captured by the storm water management system, evaporated, or infiltrated to groundwater.

Other impacts included destruction of flood control berms, office trailers, and site records. Electrical power was out of service, so the hydraulic containment system did not operate for a month. Contaminants traveled about 160 feet in groundwater before recapture when the system was restarted.

Catastrophic failure of the berms around two contaminated impoundments on the south side of the site was a concern during the flood; they are located about 700 feet from the Raritan River, and outside the main flood control berm. Sampling of surface water and berm inspections indicated that a significant release did not occur.

Responding and Preparing

The most significant adaptive measure taken after site flooding from Hurricane Irene was to require all future engineered caps to be designed to withstand a 500-year flood event, at a minimum. In addition, caps are to be designed and constructed to ensure resilience to climate/hazards posing potential threats, such as inadequate drainage, groundwater encroachment, slope stability, erosion, freeze/thaw cycle effects and altered surface vegetation. In addition, the Site's remedial design is being altered to minimize loss of floodwater storage capacity so that flooding to downstream communities is not exacerbated. Removal of the flood control berm is being considered to replace it with a natural storm water management system.

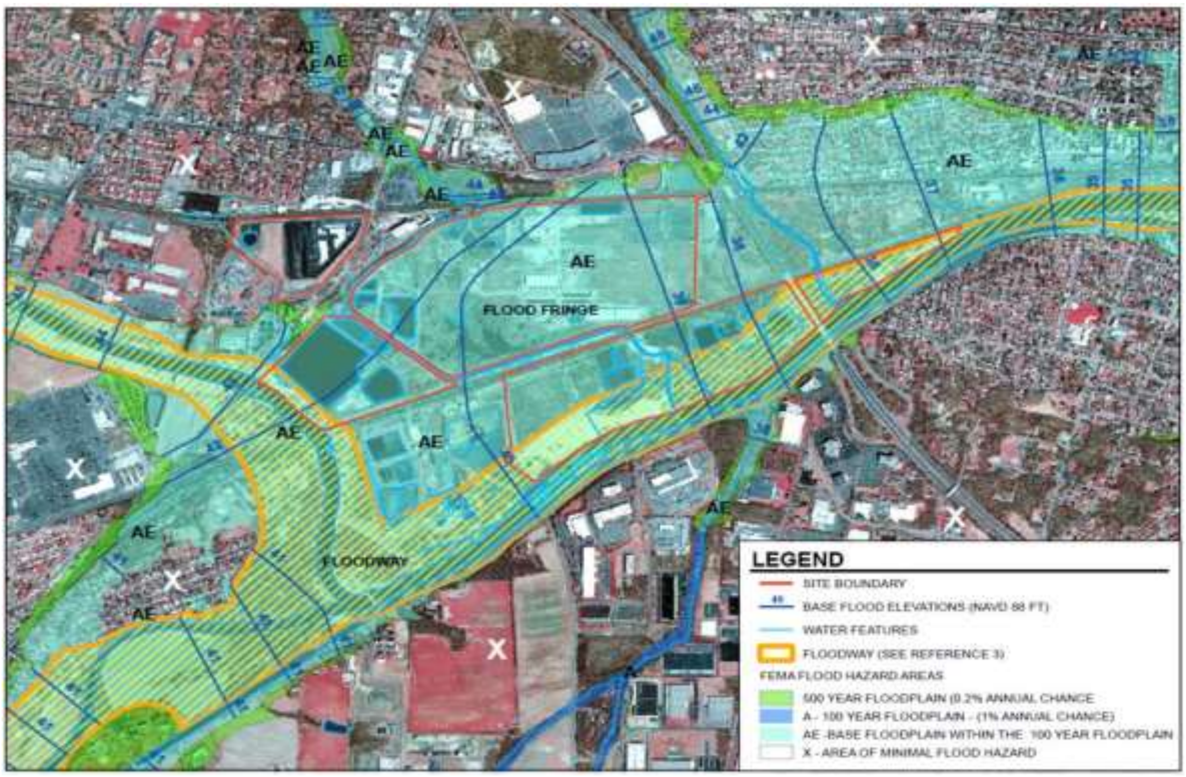

FIGURE 5. FLOOD HAZARD MAP FOR AMERICAN CYANAMID SITE WITH 100- AND 500-YEAR FLOOD PLAINS [6].

Based on an updated flood hazard map for the site (Figure 5), EPA approved a Flood Emergency Preparedness Plan (FEPP) and Response Plan that provides control measures and procedures to protect the site, personnel and equipment. The FEPP includes guidelines for flood alerts, warnings, security procedures, and evacuation plans. The Flood Management and Response Plan includes inspection and maintenance procedures for structures and engineered facilities, as well as pre- and post-flood site entry, recovery, and restoration procedures.

To assure that electrical power is retained during future storms, critical electrical infrastructure was elevated to 5 feet higher than Hurricane Irene flood levels. Submersible pumps were installed in bedrock wells to assure that hydraulic control is maintained by uninterrupted pumping during floods. An elevated ground water treatment system, 1 foot above the Irene flood level, treats groundwater captured at a collection trench before discharge to the Raritan River. Onsite security and staff trailers were relocated to outside the flood hazard area, with access to a motorized boat to aid future emergency/recovery flood efforts.

Earthen berms surrounding the two most contaminated waste impoundments were reinforced. A turf reinforcement mat was installed on berm banks to serve as soft armor for erosion control and vegetation stabilization. Covers were placed on impoundments to reduce the potential for waste mobilization during future flooding events. The sluice gate was repaired to enable rapid site drainage and the spill way was reinforced with concrete-grouted rip rap. A new drum storage area was built so that containerized wastes are stored outside the flood hazard area.

DOE LOW-LEVEL RADIOACTIVE AND MIXED WASTE DISPOSAL FACILITY SITING AND DESIGN CASE STUDY

The mission of DOE EM is cleanup of the historical wastes produced by the nation’s nuclear weapons complex, including safe and isolated disposal of mixed, low level radioactive waste (MLLW) in near surface facilities over an assessment period of 1000 years. The majority of EM’s cleanup program is regulated under CERCLA, the Resource Conservation and Recovery Act (RCRA), and a number of internal DOE Directives. Under the Atomic Energy Act (AEA) of 1954, DOE has self-regulatory authority for the management, treatment, and disposal of radioactive wastes. The Department uses DOE Order 435.1, *Radioactive Waste Management*, to establish requirements for disposal of defense-generated material. The AEA is a United States federal law that is the fundamental law governing both civilian and military uses of nuclear materials.

With the imminent vulnerability that climate change presents to contaminated sites, the EPA now requires a climate change vulnerability assessment and adaptation plan for all regulated cleanup programs under CERCLA to prioritize its adaptation efforts. For radioactive waste disposal facilities in low-lying areas in proximity to groundwater, climate change vulnerability and assessment is prudent for operational management. In the past 20 years, some facilities have measured increases in annual precipitation, higher-magnitude flooding and discharge events, and rising groundwater levels within the underlying geologic buffer of the disposal facility. These responses to recent climate change events will be assessed though annual maintenance, monitoring plans, as well as updates to the facility's performance assessment (PA). Predictive data from www.climate.gov, supported by the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration, will be used to update PA models through re-evaluation of reasonable and foreseeable features, events, and processes.

Oak Ridge, Tennessee Current and Future MLLW Disposal Facilities Regulated Under CERCLA

The current MLLW disposal facility that receives CERCLA wastes from cleanup of the ORR is the EMWMF, located in Bear Creek Valley (Figure 6).

FIGURE 6. EMWMF LOCATED IN BEAR CREEK VALLEY, ORR, TN.

The EMWMF has capacity for 1.44 million cubic yards of waste and a regulatory life of 1000 years (based on DOE Order 435.1) with a RCRA-compliant liner and cap. The CERCLA Record of Decision was issued in November 1999, and operations began in 2002 [7].

Disposal facilities are expected to degrade over time, with the engineered barriers (i.e., closure cap, leachate collection system, underdrain, etc.) unlikely to function as designed for more than 500 years [8]. For these reasons, the Nuclear Regulatory Commission (NRC) and Tennessee Land Disposal of Radioactive Waste licensing requirements emphasize the need for disposal sites to meet minimum technical requirements for geologic, hydrologic, and demographic characteristics of a site to provide reasonable assurance of long term protectiveness and isolation of wastes from the accessible environment and receptors [8].

In 2012, with the EMWMF at about 50% capacity, the DOE Oak Ridge Environmental Management (OREM) Office began documenting water management challenges with the EPA, Tennessee Department Environmental and Conservation (TDEC), and DOE Headquarters. Much more storm water, contact water, and leachate was produced, handled, treated, and discharged than originally designed and approved based on release criteria, associated with heavy rainfall and closure of the leachate collection system valves to control the flow of leachate [8]. For example, the Action Leakage Rate for the Leak Detection System was increased approximately 4-fold due to exceedances [9]. Historically, average annual precipitation is about 55 inches of rain of year, with more recent years creeping up to 65-70 inches. For over a decade, EMWMF has managed 20-24 million gallons of water annually. In response, TDEC asked OREM to prepare a long term Water Management Focused Feasibility Study [10] under CERCLA, in addition to other corrective actions.

FIGURE 7. EMWMF WASTE CELL 2 FLOODING [8].

EMWMF has struggled with surface and ground water management since construction began in 2001. In the first 12 months of operation from 2002-2003, a historical wet period prevailed with 77 inches of rain and a storm with a 67-year recurrence interval [8]. Waste cells flooded (Figure 7), containment berms were washed out (Figure 8), and seeps developed in one cell berm.

FIGURE 8. EMWMF REPAIRED CELL BERM [8].

Around the 2003 timeframe, tributary stream NT-4 to Bear Creek (Figure 9), issuing from the up gradient Pine Ridge headwaters to the northwest, was backfilled with low permeability material. This was done to fill in the stream's natural valley up gradient of the EMWMF. To restore stream NT-4 flow below the EMWMF, the underdrain was constructed. The underdrain was a mitigated measure to protect the liner [8] due to rising groundwater levels through the 10-foot geologic buffer below the facility to levels near and/or above the liner.

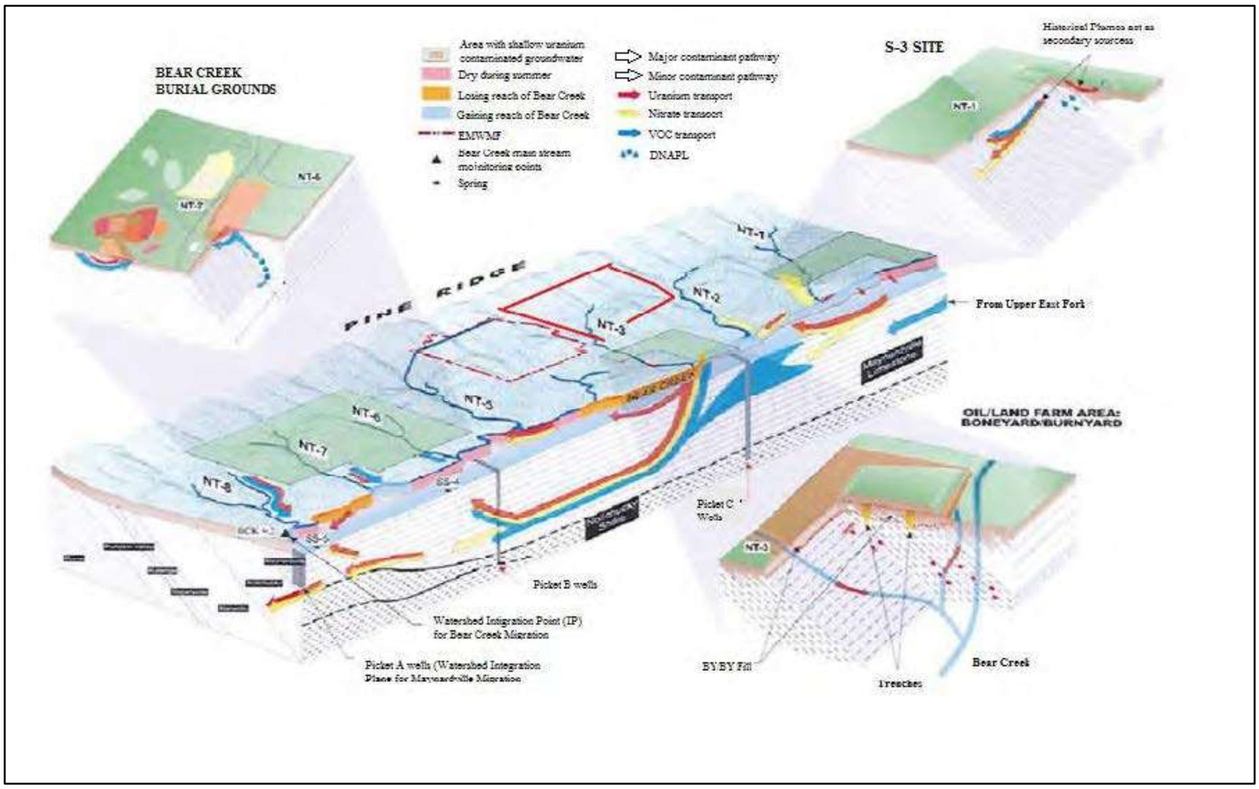

FIGURE 9. STREAM NT-4 IS THE LOCATION OF THE EMWMF UNDERDRAIN IN THIS CONCEPTUAL FLOW DIAGRAM [8].

Despite the construction of the underdrain, in 2013, groundwater levels in proximity to the historical NT-4 drainage had risen 5-7 feet into the 10-foot

–thick geologic buffer zone, just below the impermeable clay layer. This situation is the focus of ongoing monitoring and engineering studies to determine cause and effect to better predict operational performance of the liner and leachate collection system in the out years. As a lesson learned in designing future landfills at ORR, the environmental regulators have documented that groundwater intrusion beneath the EMWMF will necessitate re-evaluation of the thickness of the geologic buffer from 10 feet to the required 50-feet-thick under the Toxic Substances Control Act landfill guidance to assure water level fluctuations can be accommodated well below the liner [7]. This design feature will be important for water level fluctuations in response to future historical wet periods, flooding, or extreme weather events associated with climate change.

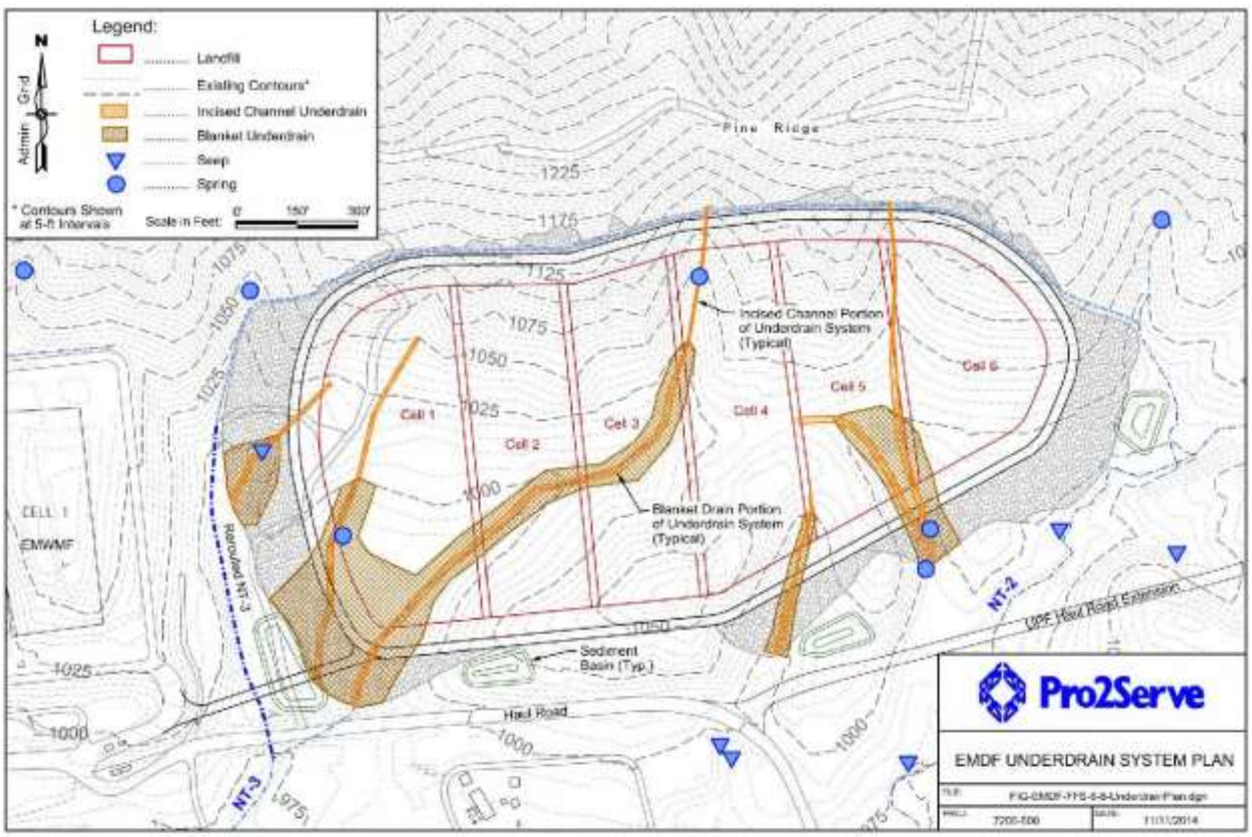

FIGURE 10. UNDERDRAIN SYSTEM FOR THE FUTURE MLLW DISPOSAL FACILITY, THE EMDF [9].

Since the EMWMF is close to capacity, and DOE OREM is planning for continued decommissioning and decontamination of the Y-12 and other facilities, a new MLLW disposal unit (Figure 10) is proposed for about 2.5 million cubic yards of waste: the Environmental Management Disposal Facility (EMDF) [9]. It would be located beside the EMWMF in similar shale and limestone karst hydrology, with an extensive underdrain system (Figure 10) to engineer natural discharge from adjacent Pine Ridge as seeps and springs.

The location of the EMDF is proposed on the southern flanks of Pine Ridge (Figure 11), as depicted in the series of cross sections below [9].

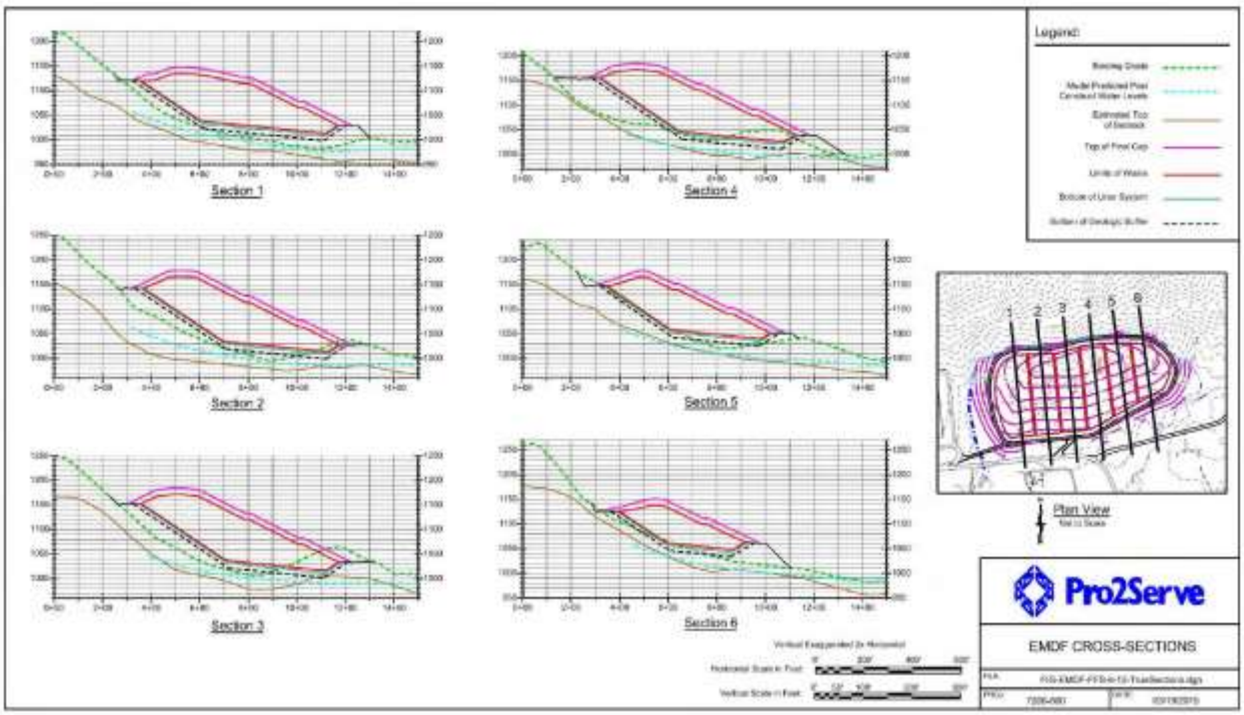

FIGURE 11. CROSS SECTIONS OF THE PROPOSED EMDF ON PINE CREEK RIDGE TO THE LEFT [9].

Responding and Preparing

The Nuclear Regulatory Commission's preference to dispose of radioactive waste in the arid west is a long-preferred practice: "high and dry." The combination of 20-24 million gallons of water passing through the EMWMF annually for over a decade and rising ground water below the clay layer of the engineered base, create a potential risk for long term performance and stability of the facility. The Water Management Plan Focused Feasibility Study [10], close monitoring, and engineering design changes to the EMWMF all serve to mitigate potential future risks. For radioactive waste disposal facilities in low-lying areas in proximity to groundwater, climate change vulnerability and assessment is prudent for operational management.

Per EO 13653, DOE EM Headquarters is requesting the cleanup sites to begin climate change vulnerability screening and assessments by 2016. The

Department is learning from the water management challenges from EMWMF PA, design, construction, and operation to assure that the impacts of climate change will be incorporated into future siting and compliance decisions.

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