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U.S. Department of Energy
Idaho Operations Office

Draft Environmental Assessment for the Wildland Fire Management Program at the Idaho National Laboratory

June 2025

Idaho National Laboratory

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Prepared for the
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CONTENTS

FIGURES

TABLES

ACRONYMS

ACHP	Advisory Council on Historic Preservation
APE	Area of Potential Effects
ATR	Advanced Test Reactor
BLM	Bureau of Land Management
BMP	Best Management Practice
BPP	Bat Protection Plan
CAA	Clean Air Act
CCA	Candidate Conservation Agreement
CFA	Central Facilities Area
CFR	Code of Federal Regulations
CITRC	Critical Infrastructure Test Range Complex
CRMO	Cultural Resource Management Office
DOE	Department of Energy
EA	environmental assessment
EDG	emergency diesel generator
EPA	U.S. Environmental Protection Agency
ESRP	Eastern Snake River Plain
FEC	Facility Emissions Cap
GHG	Greenhouse Gas
HAP	Hazardous Air Pollutant
HeTO	Heritage Tribal Office
ICP	Idaho Cleanup Project
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
INTEC	Idaho Nuclear Technology and Engineering Center
INL	Idaho National Laboratory
MFC	Materials and Fuels Complex
MIST	minimum impact suppression tactics
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places

PM	Particulate Matter
PSD	Prevention of Significant Deterioration
PTC	Permit to Construct
RWMC	Radioactive Waste Management Complex
R&D	Research and Development
ROI	Region of Influence
SHPO	Idaho State Historic Preservation Office
SGCA	Sage-grouse Conservation Area
SMC	Specific Manufacturing Capability
SSER	Sagebrush Steppe Ecosystem Reserve
TAN	Test Area North
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile Organic Compound
WLF	Wildland Fire
WLFMC	Wildland Fire Management Committee

Draft Environmental Assessment for the Wildland Fire Management Program at the Idaho National Laboratory

1. INTRODUCTION

The Idaho National Laboratory (INL) Site is federal research and development site managed by the U.S. Department of Energy (DOE) and is located on the upper Snake River Plain in southeastern Idaho, about 50 miles west of Idaho Falls, Idaho (Figure 1). The INL Site was established in 1949 as the National Reactor Testing Station. Today, INL is a science-based, applied engineering national laboratory dedicated to supporting DOE's nuclear and energy research, science, and national defense missions. Operations at the INL Site also include the Idaho Cleanup Project (ICP). ICP has been charged with the environmental cleanup of legacy wastes generated at the INL Site from World War II-era conventional weapons testing, government-owned reactors, and spent fuel reprocessing.

The INL Site encompasses about 890 square miles (mi^2) and consists of several primary facilities, which are typically less than a few square miles in size and separated by miles of undeveloped land. The major facilities at the INL Site are the Advanced Test Reactor (ATR) Complex, Central Facilities Area (CFA), Critical Infrastructure Test Range Complex (CITRC), Idaho Nuclear Technology and Engineering Center (INTEC), Materials and Fuels Complex (MFC), Naval Reactors Facility (NRF), Radioactive Waste Management Complex (RWMC), and Test Area North (TAN), which includes the Specific Manufacturing Capability (SMC). The Research and Education Campus is in Idaho Falls, Idaho. The locations of major INL Site facilities are shown in Figure 2.

Over 50% of the INL Site is in Butte County and the remainder is distributed across Bingham, Bonneville, Clark, and Jefferson counties. Federal lands surround much of the INL Site, including Bureau of Land Management (BLM) lands and Craters of the Moon National Monument and Preserve to the southwest, Challis National Forest to the west, and Targhee National Forest to the north. Mud Lake Wildlife Management Area, Camas National Wildlife Refuge, and Market Lake Wildlife Management Area are within 50 miles of the INL Site. The Fort Hall Indian Reservation is located about 37 miles to the southeast. Currently, the INL Site employs about 10,000 people. No permanent residents reside within the INL Site boundary.

The INL Site lies within a large, relatively undisturbed expanse of sagebrush steppe. About 94% of the land on the INL Site is open and undeveloped. The INL Site has an average elevation of 4,900 ft above sea level and is bordered on the north and west by mountain ranges and on the south by volcanic buttes and open plain. Lands immediately adjacent to the INL Site are open sagebrush steppe, foothills, or agricultural fields (INL 2024).

Wildland fire (WLF) was historically a dynamic component of sagebrush steppe ecosystems, though it likely occurred infrequently before European settlement. Fire rotation intervals for Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) have been estimated to range up to 350 years. Sagebrush is not particularly well-adapted to fire, as evidenced by its lack of fire resistance, inability to resprout, and poor long-distance seed dispersal capability. As a foundation species, sagebrush modulates the local ecosystem, and the loss of sagebrush from a plant community disproportionality affects co-occurring species and overall ecosystem function. When large regions of the sagebrush steppe shift from sagebrush-dominated shrublands to grasslands or communities dominated by resprouting shrubs, substantial changes in habitat availability and ecosystem function are expected. Because sagebrush has been lost from nearly 247,105 acres of the INL Site over the past 30 years (Figure 3), much of the landscape is already undergoing extensive ecological changes (Forman, Kramer, et al. 2024).

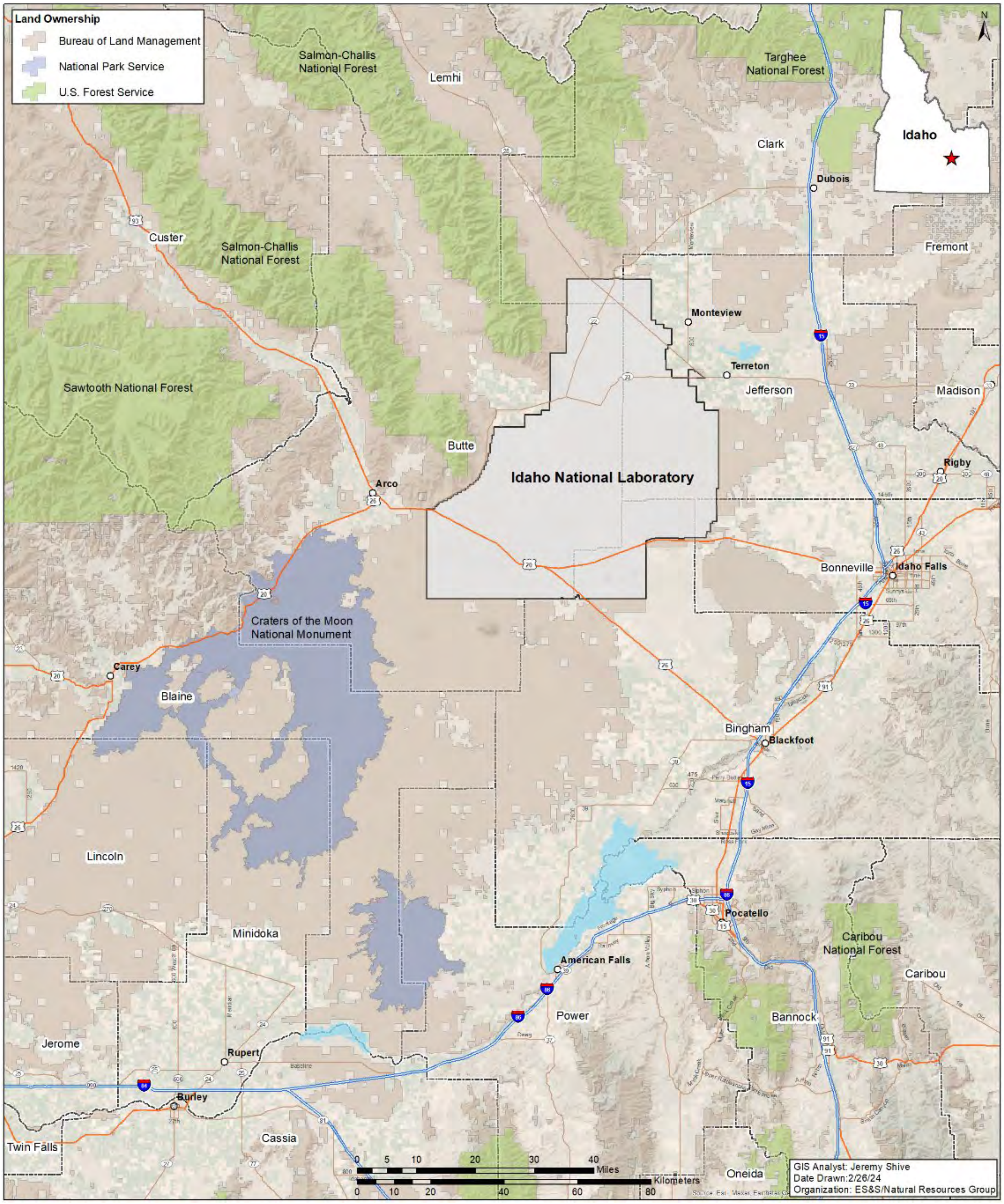

Figure 1. Site map of INL.

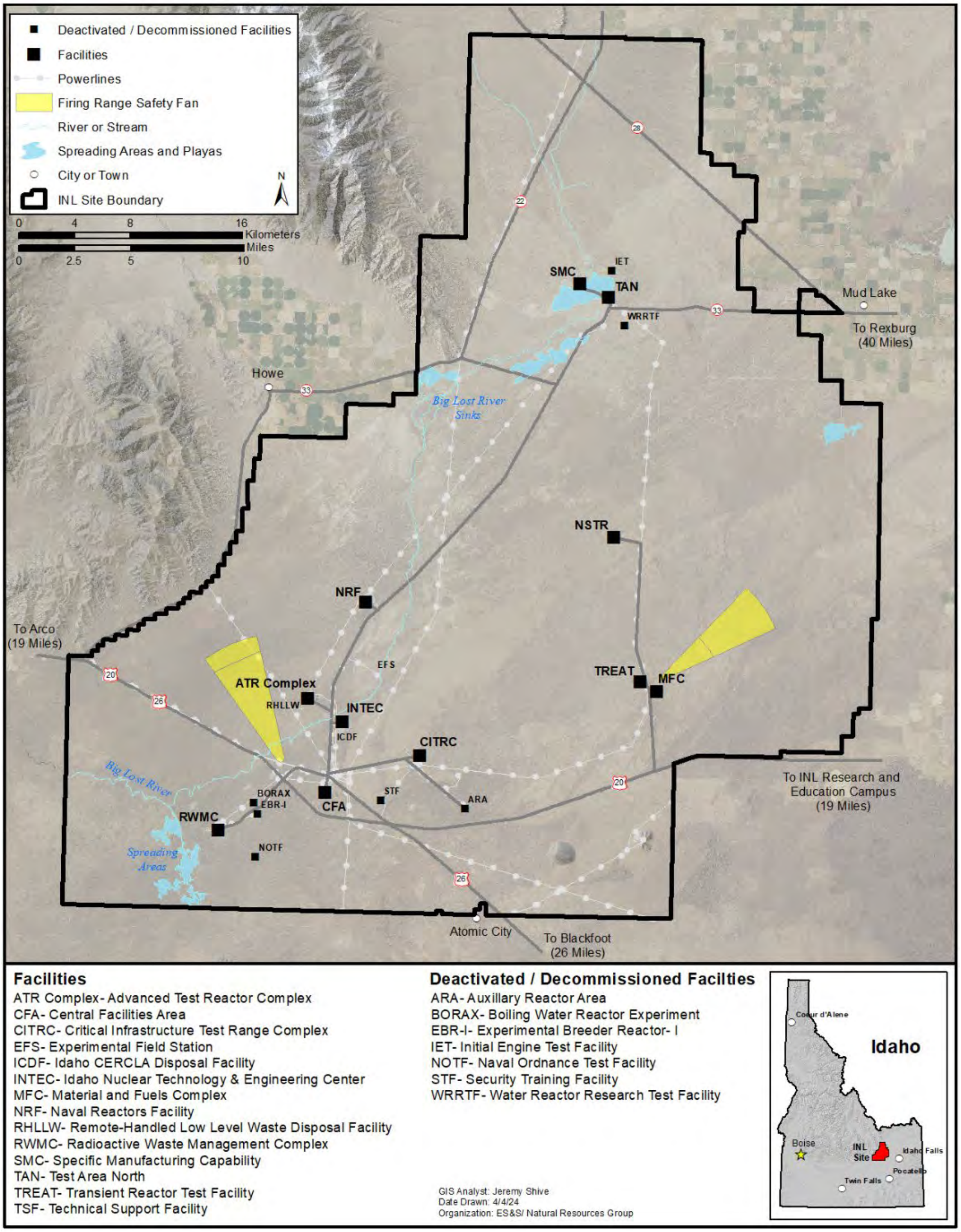

Figure 2. Location of INL Site facilities.

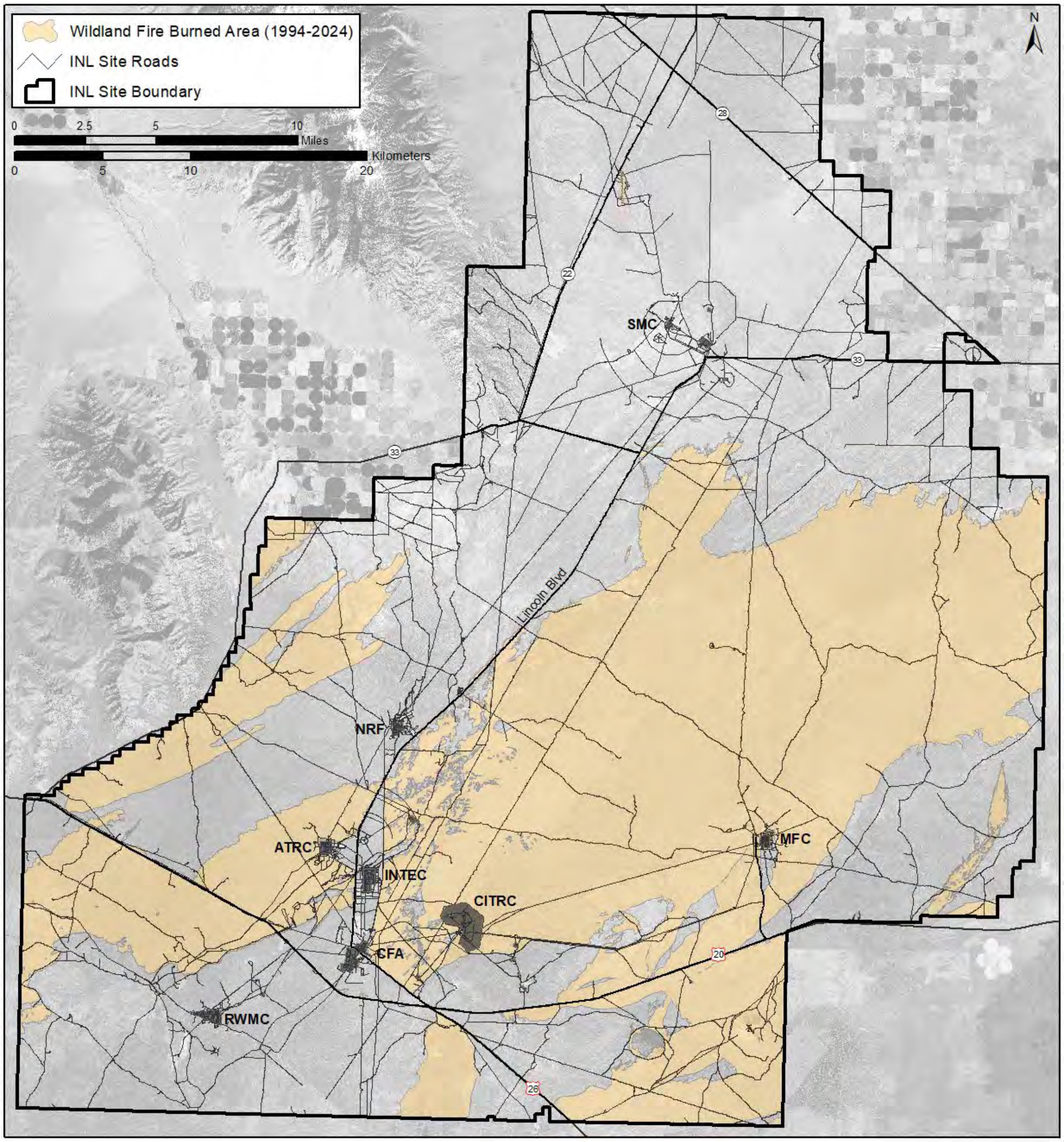

Figure 3. All areas burned from 1994–2022 on the INL Site.

INL's primary fire management priority is to ensure the safety of firefighters, workers, and the public. Infrastructure, cultural, and ecological resources are then protected based on the relative values of each resource. INL takes necessary suppression actions to minimize the threat of WLF on mission-important improved property, including protection of wildland urban interfaces and intermixes.

1.1 Background

In 2003, DOE issued the *Idaho National Engineering and Environmental Laboratory Wildland Fire Management Environmental Assessment and Finding of No Significant Impact* (DOE-ID 2003), hereafter referred to as the 2003 Wildland Fire Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), to evaluate wildland fire management options for pre-fire, fire suppression, and post-fire activities due to the important role these activities play in minimizing the conversion of native sagebrush steppe to non-native species. In the 2003 FONSI, DOE decided to create a Wildland Fire Management Committee (WLFMC) to address pre-fire and post-fire activities and to implement the following actions:

Pre-Suppression Actions

1. Mow vegetation along the following highways and roads:
    - A minimum of 10 feet to a maximum of 300 feet on each side of State Highways 20, 26, and 20/26
    - A minimum of 10 feet to a maximum of 50 feet on each side of State Highways 22, 28, and 33
    - A minimum of 10 feet to a maximum of 50 feet along these locations:
        - Each side of Lincoln Boulevard and Adams Boulevard from Lincoln Boulevard to the RWMC
        - Approach roads to the CFA Gun Range Facility, Argonne National Laboratory-West (what is now MFC), INTEC, Test Reactor Area (now the ATR Complex), NRF, Waste Reduction Operations Complex, and the SMC Site areas
    - A minimum of 100 feet to a maximum of 300 feet around the CFA Gun Range
    - A 5-to-10-foot strip along facility perimeter roads.
2. Maintain the following strategic, unimproved roads as passable for 4×4 equipment: T-12, T-13, and Main Street from the intersection of T-13 to State Highway 20/26, T-16, T-4, T-3, T-5, T-20, T-9, and the existing power line roads.
3. Provide defensible space using the following methods (except that blading, with or without sterilization will not be used, and placing gravel over areas that may require long-term weed control will be minimized):
    - Maintain a 30-to-50- foot defensible area around all INL Site buildings, structures, and significant support equipment
    - Maintain a 30-foot defensible area around parking lots, storage pads, designated buildings, designated perimeters, designated propane and fuel tanks, substations, and along the rail system within the INL Site.

Fire Suppression Actions

1. Use a staged fire suppression response and incorporate minimum impact suppression tactics (MIST) when conditions allow, as determined by the on-scene commander. Tactics include minimizing width and depth of containment lines, avoiding waterways, using cold-trail tactics, and using existing roads as containment lines.

2. Use the following direct tactics:
    - Hose line application of water or foam suppressants on burning vegetation using off- road firefighting equipment
    - Aerial delivery of water or chemical retardant using helicopters and air tankers
    - Construction of containment lines (generally up to 24 feet unless the on-scene commander determines that larger containment lines are necessary) on the fire perimeter using dozers, graders, other mechanical equipment, and hand tools.
3. Use the following indirect tactics:
    - Construct containment lines ahead of advancing fires, which generally involves the construction of a single- or double-blade containment line (generally up to 24 feet unless the on-scene commander determines that larger containment lines are necessary) using dozers, graders, and discs or the widening of existing breaks
    - Burn vegetation from a containment line to the fire edge.
4. Use the following parallel tactics:
    - Construct containment lines parallel to but further from the fire edge than in direct attack
    - Burn the fuel between the containment line and the fire edge
    - Construct containment lines only as large as necessary to effectively check the fire.

Post-Fire Actions

1. Suppress and control dust:
    - Apply a soil tackifier or mulch
    - Install water cannons or snow fences upwind of affected facilities.
2. Implement site restoration activities, as identified in Section 2.1.3, as necessary to determine impacts to cultural resources and ensure the establishment of a native plant community in areas disturbed by suppression activities. Until such time as a native plant community is established, the Idaho National Engineering and Environmental Laboratory (INEEL) will control non-native weeds, including noxious weeds and invasive species, on those areas.

In the 2003 WLF FONSI (DOE-ID 2003), DOE also decided that no fuel management activities would occur along unimproved roads and upgrading unimproved roads would be restricted to necessary segments, limited to filling ruts with gravel or dirt, and then leveling the fill materials.

Following the 2019 Sheep Fire, DOE identified several actions for addressing changing conditions on the INL Site that the agency did not implement in the 2003 WLF EA and FONSI (DOE-ID 2003). These actions include (1) better access and egress for firefighter and equipment safety during WLF response and suppression and (2) review comprehensive strategies for WLF recovery on the INL Site that evaluates the tools available to facilitate natural resource recovery and minimize the risk of unfavorable outcomes, like weed invasions or loss of ecosystem function.

1.2 Purpose and Need

DOE needs to improve fire preparedness and recovery at the INL Site, and the actions identified in the WLF EA and FONSI (DOE-ID 2003) are no longer adequate to prevent or limit the impact of a larger wildland fire on the INL Site. As noted, DOE fire management and recovery options at the INL Site are currently limited to those that were analyzed in the 2003 WLF EA and FONSI (DOE-ID 2003). New strategies are necessary to allow WLF protection strategies and recovery efforts that can offer improved asset protection, firefighter safety, and recovery of natural resources following WLF events on the INL Site.

The purpose of the proposed action is to (1) improve WLF response capabilities and firefighter safety and (2) offer adaptive capacity in WLF recovery practices. The potential for WLF poses a risk to the operational capabilities that enable INL to meet its primary mission needs. INL's primary mission includes to discover, demonstrate, and secure innovative nuclear energy solutions, other clean energy options, and critical infrastructure essential to the nation's security. Furthermore, as pressures from invasive species and anthropogenic impacts increase across the landscape in the western U.S., managing WLF recovery to promote healthy sagebrush steppe becomes an increasingly important stewardship responsibility. Consequently, DOE needs to reduce the risk of damage and injury to property, human life and health, and ecological resources at INL from WLF to protect and maintain the operational capabilities of INL and ensure that the local ecosystem is resilient to WLF and can recover from its impact.
ALTERNATIVES

In accordance with ten Code of Federal Regulations (CFR) 1021.321(c), this section describes the proposed action and No Action Alternatives. DOE considered alternatives for meeting the purpose and need for improving asset protection, firefighter safety, and recovery of natural resources following WLF events on the INL Site. For the alternatives to be feasible, the alternatives must meet the following criteria:

1. Improve access and egress for firefighters and equipment during WLF events at the INL Site.
2. Reduce the risk of noxious and invasive species spread to the extent possible.
3. Maintain the diversity and resilience of the INL Site vegetation and wildlife communities.
4. Ensure the local ecosystem can continue to provide ecosystem services by maintaining functional processes like water balance, nutrient cycling, and carbon storage.
5. Mitigate potential changes to the historical fire disturbance regime with respect to fire frequency and the annual grass feedback cycle.

The proposed action as described in this EA is strategic in nature, and DOE anticipates that the activities described may not necessarily reflect what is implemented. This EA uses a bounding approach to analyze the environmental impacts of the proposed action. The bounding approach to the analysis of environmental impacts in this EA is designed to identify the maximum range of potential impacts. Because the specific combination of actions to be implemented is unknown, the analysis of impacts in this EA is based on conservative assumptions using maximum reasonably foreseeable disturbance and impact levels. DOE could choose from many options based on changing Site conditions and could implement the options individually or in combination. Therefore, DOE did not identify other alternatives beyond implementing the proposed fire management and recovery actions or DOE taking no action.

2. ALTERNATIVES

2.1. Proposed Action

Under the proposed action, pre-suppression actions and fire suppression actions would continue as evaluated in the 2003 WLF EA (DOE-ID 2003). The program would implement prevention activities, maintain fire management infrastructure, and enact recovery efforts following a WLF. Wildland fire-fighting activities and tactics would continue to be performed by the INL Fire Department and partnering agencies following existing DOE procedures and interagency agreements. However, DOE has identified the following actions to meet the purpose and need for improving access and egress for firefighters and equipment and offering new WLF protection strategies and recovery efforts during and following WLF events on the INL Site:

To ensure safe access and egress routes, road improvements along several two-track roads would be implemented. In addition, the action includes mowing up to, and not more than, 100 feet from each edge of these roads (200 ft total) to reduce flame height during a WLF event. Mowing at a height of 6 inches would be completed using large commercial mowers attached to, or towed behind, wheeled tractor equipment to mechanically lower vegetation along the identified roadways. Roads would be improved from non-graveled two-track roads to graveled roads that are spot-graded as needed. These roads would not be widened past their existing width, and no new roads are proposed. As shown in Figure 4 and Table 1, DOE proposes the following road improvements.

Table 1. Proposed road improvements and mowing.

Road improvements and mowing	**Road improvements only (no mowing)**
T-2 T-3 (From MFC to western INL Site border)	T-3 (From eastern INL border to MFC) T-4 (Between Highway 20 and Highway 26)
T-20	T-7
T-25 (From MFC to Highway 33)	T-8
	T-22
	T-28
	T-5

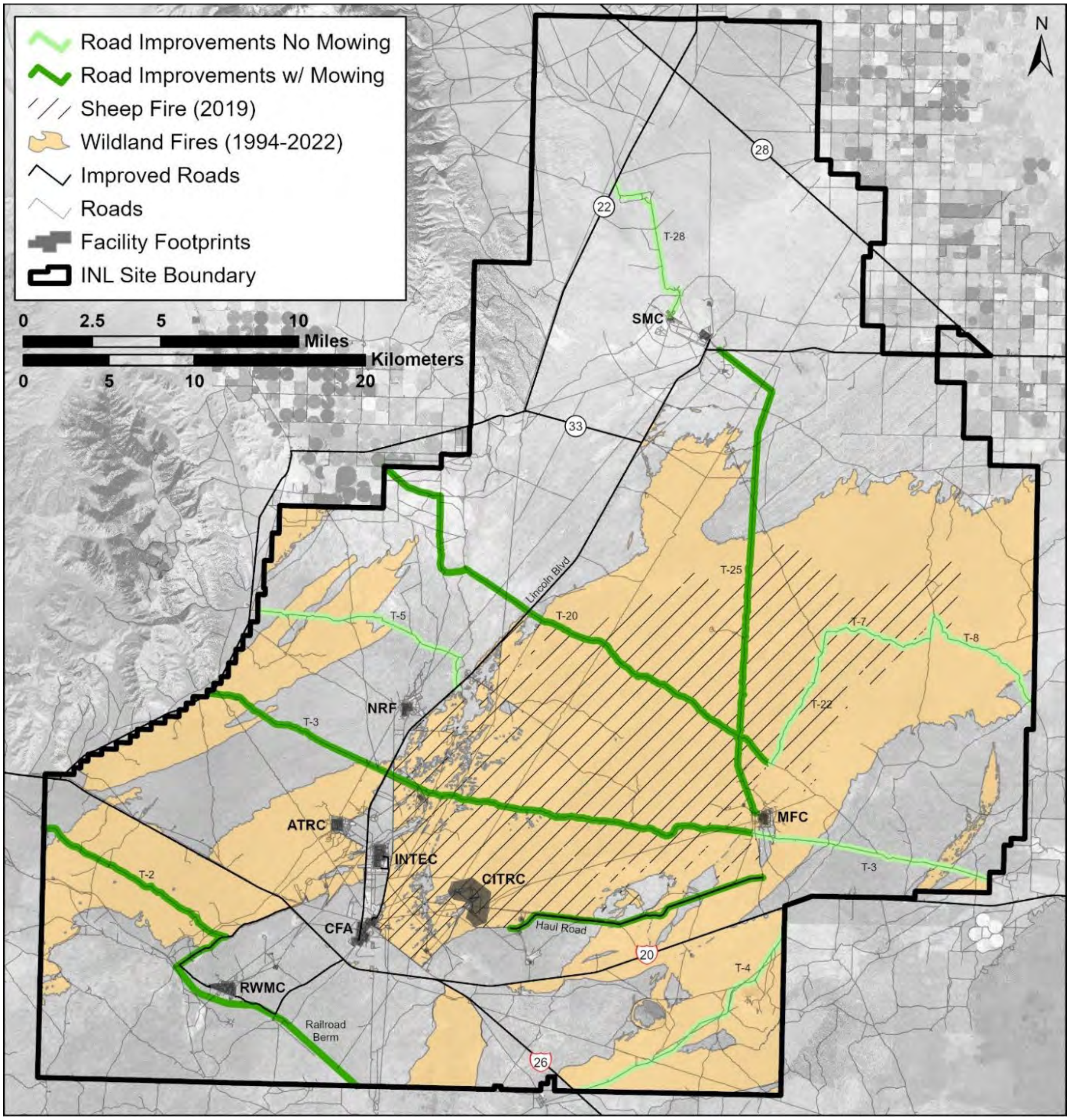

Figure 4. Proposed road improvements and mowing.

Future mowing or fuels management activities along roads identified for improvement in this EA, but not mowing are not covered by this analysis. Prior to implementing any such activities, additional NEPA analysis will be required to determine potential impacts and ensure regulatory compliance

In addition to the proposed road improvements, DOE proposes to implement a formal WLF recovery plan to facilitate the rehabilitation of burned areas following a WLF event. The *Idaho National Laboratory Site Natural Resources Wildland Fire Recovery Framework* (Forman, Kramer, et al. 2024) offers an adaptive management approach and gives recovery planners a toolbox of options to address post-fire conditions. This recovery framework is incorporated into this EA by reference and is included as Appendix A. The proposed comprehensive plan and guide is designed to address post-fire conditions quickly and effectively. DOE proposes the following treatment options for soil stabilization and erosion control, cheatgrass and noxious weed control, recovery of native herbaceous vegetation, and sagebrush habitat restoration that are outlined in the *Idaho National Laboratory Site Natural Resources Wildland Fire Recovery Framework* (Forman, Kramer, et al. 2024).

- Soil Stabilization and Erosion Control
  - Dust control for wind erosion (applying water, tackifier, mulch, etc.)
  - Sediment control for soil deposition (installing snow fence, silt fence, straw wattles, etc.)
  - Recontour and revegetate disturbed soils (restoring containment lines and staging areas)
  - Limit traffic to designated roads (installing signs, barriers, or other deterrents).
- Cheatgrass and Noxious Weed Control
  - Chemical control, including aerial application (using approved herbicides consistent with label instructions)
  - Control by native competition (planting native herbaceous species)
  - Environmental control (using inoculants or nutrients to ameliorate soil conditions)
  - Noxious weed inventory (completing comprehensive surveys to document weed abundance and distribution)
  - Mechanical treatment (hand pulling, mowing, digging, and tilling to remove weeds of concern)
- Native Herbaceous Recovery
  - Resting grazing allotments (collaborating with the BLM to ensure implementation of deferral)
  - Planting native species (using locally sourced or locally adapted plant materials)
  - Broadcast seeding (apply seed to the soil surface with a broadcast spreader)
  - Hydroseeding (applying seed mixed with water and hydro mulch to the surface)
  - Drill seeding (planting seed with a rangeland drill)
  - Planting containerized stock (planting greenhouse grown seedlings)
  - Utilizing soil or growth medium amendments (fertilizer, organic material, mycorrhizae, etc.)
  - Applying surface protection (mulch in the form of straw, gravel, woodchips, bonded fiber matrix, etc.)
  - Supplementing water availability (irrigating with a temporary sprinkler system)

- Sagebrush Habitat Restoration
    - Plant locally appropriate sagebrush material (collecting local seed or acquiring locally collected seed from a vendor)
    - Seeding (applying sagebrush through aerial or ground-based broadcasting or drill seeding) with option for imprinting (using an implement to improve seed/soil contact)
    - Planting seedlings (installing nursery grown seedlings with hand tools)

The WLF recovery planning process is outlined in Section 1.1.1 of Appendix A.

2.1.1 Operational Controls

If DOE selects the proposed action, they will adopt the following operational controls as an integral part of the proposed action to help reduce the impacts of the action and lower the potential for significant impacts:

- Pesticide application, within mowed and burned areas, would follow existing and established practices as defined by the INL *Sitewide Noxious Weed Management Plan* (INL 2022), in accordance with local weed control program monitoring protocol and consistent with manufacture label instructions to reduce the potential for the long-term establishment of noxious weeds.
- The proposed activities would adhere to established plans and procedures for managing ecological resources within the INL Site. These plans and procedures include seasonal and spatial restrictions to limit direct impacts on ecological resources.
- Perform Site surveys in the proposed areas for mowing, road improvements, or recovery activities prior to performing construction or maintenance activities to ensure that the presence of nesting birds, species of concern, or other ecological resources are not present or can be avoided.
- A biological observer may be present, depending on location, to monitor activities and verify direct impacts to ecological resources are is avoided.
- Disturbed areas would be reseeded using a native species seed mix to restore native vegetation cover.
- Conservation measures and best management practices (BMPs) included in the *Candidate Conservation Agreement for Greater Sage-grouse (Centrocercus urophasianus) on the Idaho National Laboratory Site* (hereafter CCA) (DOE 2014)and Site Bat Protection Plan (BPP) (DOE 2018) would be followed while implementing the proposed activities throughout the life of the agreement. Conservation measures and BMPs outlined in the CCA include seasonal and daytime restrictions for certain activities, restricting activities within the Sage-grouse Conservation Area (SGCA), restricting activities within 1 km of active leks, and sagebrush compensatory mitigation. Sagebrush compensatory mitigation is carried out for the removal or disturbance of potential and existing sagebrush habitat (DOE 2014).
- Maintenance of graveled roads and roadside mowed areas would ideally be conducted during periods of low or moderate fire risk when soils are sufficiently dry to minimize soil compaction and disturbance, however, maintenance actives, including mowing, may be performed when fire danger is at higher levels when compensatory measures are in place and approved by the INL Fire Marshal.
- Conservation measures and BMPs included in the BPP would be followed while implementing the proposed activities. Conservation measures and BMPs outlined in the BPP include limiting activities and avoiding habitat modification within a certain proximity to hibernacula and important summer roosts (DOE 2018).

- Turn-around areas for equipment needed for road improvements and mowing would be located within the 100-foot mowed areas or at existing road intersections. Where turnarounds cannot be located within mowed areas or at existing road intersections, for example, on roads proposed for improvement but not for mowing, proposed turn-around areas would be identified prior to the commencement of road work, and cultural, ecological, and other required surveys (e.g., unexploded ordnance) would be required and other BMPs would be implemented to verify the impact to sensitive resources is reduced.
- A subset of historic properties identified within the project APE would be added to a map of sensitive areas that would be avoided during project implementation. "Sensitive areas" would include historic properties and areas of biological concern, ordnance areas, and other locations where off-road equipment use would threaten human safety or aspects of the human or physical environment.
- Individual historic properties may be excluded from the map of sensitive areas if road improvements and maintenance of mowed roadside strips are unlikely to diminish the integrity of the Site. Factors, such as distance from road, soil type, topographic position, and the character of surface cultural materials and features, would inform whether such exclusion is warranted.
- Boundaries of sensitive areas may be physically marked for avoidance with appropriate signage to alert equipment operators of the need for avoidance during road improvements or maintenance of mowed roadside strips. Appropriate signage for historic properties will be developed in consultation with representatives of the Shoshone-Bannock Heritage Tribal Office (HeTO).
- Maps of sensitive areas, those encouraged for avoidance whenever possible, would be provided to Facilities Sites and Services and incorporated into the processes within existing plans and procedures. The data could include hard copies, digital copies, and geospatial data. The distribution of such data would be limited, and all maps would be marked Official Use Only.
- In some locations where there is suspected or anticipated subsurface integrity of historic properties below the roadbed, geotextile barriers may be placed prior to gravel application.
- Monitoring by INL CRMO staff, and by HeTO staff when available, may also be implemented at individual historic properties during and post after project implementation pursuant to MCP-8008 Rev. 1 (*Section 106 Compliance*). The observations gathered during these monitoring events may also inform the necessity of future monitoring efforts at these locations.
- In the event of an inadvertent discovery, work would immediately halt, in keeping with INL's Stop Work Authority found in LWP-8000 (*Environmental Instructions for Facilities, Processes, Materials, and Equipment*). The discovery secured and flagged for avoidance, and the INL CRMO contacted to ensure that any potential disturbance is limited. CRMO will implement the *Post-Review Discoveries* procedure outlined in MCP-8013. In the event human remains are encountered, the same procedures discussed above would be followed, and CRMO would implement the [Native American Graves Protection and Repatriation Act] *NAGPRA Inadvertent Discoveries* procedure (MCP-8003).

2.2 No Action Alternative

The No Action Alternative serves as a baseline, enabling decision makers to compare the magnitude of environmental effects of the proposed action alternative to taking no action. No action does not necessarily mean doing nothing but involves maintaining or continuing the existing status or condition. In this document, no action means that WLF management options for pre-fire, fire suppression, and post-fire activities would continue in accordance with the 2003 WLF FONSI (DOE-ID 2003), and the proposed fire management and recovery actions described above would not be implemented.

3. AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.1 Regional Setting

INL is an 890-square-mile DOE facility located on the Eastern Snake River Plain (ESRP). It is primarily located within Butte County, Idaho, but portions of INL are also in Bingham, Jefferson, Bonneville, and Clark counties. All the land within the INL Site is controlled by DOE, and public access is restricted to highways, DOE-sponsored tours, special use permits (i.e., hunting and grazing), and the Experimental Breeder Reactor-I National Historic Landmark.

Public highways, U.S. 20 and 26 and Idaho 22, 28, and 33, pass through the INL Site, but off-highway travel within the INL Site and access to INL Site facilities are controlled. Currently, INL employs approximately 9,750 people (5,750 employees at BEA, 2,000 employees at Idaho Environmental Coalition, and 2,000 employees at the Naval Reactor Facility). No permanent Idaho resident resides within the INL Site boundary. Population centers in the region include large cities (more than 10,000 residents), such as Idaho Falls, Pocatello, and Blackfoot, which are located to the east and south of the INL Site, and several smaller cities (less than 10,000 residents), such as Arco, Howe, and Atomic City, which are located near the INL Site boundary (Figure 1).

Fire suppression activities have been evaluated in the 2003 WLF EA and are outside the scope of this analysis. The environmental impacts evaluated in this EA focus on the impacts from road improvements, mowing vegetation, and WLF recovery actions to protect natural resources.

Under the No Action Alternative, activities at the INL Site would continue under present-day operations and would be as analyzed in the 2003 WLF EA. The proposed road improvements, mowing, and WLF recovery options would not be implemented. The No Action Alternative would not result in impacts to resources at the INL Site beyond those captured in the discussion of the affected environment. The environmental impacts of future activities at the INL Site would be evaluated in project or program-specific analyses in compliance with NEPA. Therefore, impacts from the No Action Alternative are not discussed further in this EA.

3.2 Resource Areas Eliminated from Further Analysis

Scoping and preliminary analyses indicate the proposed capabilities would not likely impact the following resource areas; therefore, this EA does not analyze these areas further.

- **Land Use.** Land use is the term used to describe human development and use of land. It represents the economic and cultural activities (e.g., agriculture, residence, and industry) that are practiced at a given place. The proposed action would take place within the INL Site boundary and would be compatible with existing land uses. No changes in land use are expected. The proposed action would have no effect on land use.
- **Socioeconomics**. DOE would use contractor employees to implement the proposed action. The proposed action would not lead to an increase in employment. Potential impacts to local socioeconomics from the proposed activities would be indistinguishable from current INL Site operations. There would no socioeconomic impacts from implementing the proposed action.
- **Visual Resources**. It is anticipated that any WLF management activity would not be visually noticeable from any publicly accessible location on the INL Site. Post-fire recovery activities may be observed from any publicly accessible location because a fire may occur near it. However, there would be little-to-no substantial dominant visual change as observed from outside vantage points, no substantial change in visibility caused by predicted air pollutant emissions, no conflict with federal land management agency visual standards, and no long-term dominant visual interruption of existing or unique viewsheds.

- **Site Infrastructure**. INL Site infrastructure includes basic resources and services required to support the proposed activities and continued operations of existing facilities. For the purpose of this EA, infrastructure is defined as electricity, fuel (for equipment), water, and transportation infrastructure such as roads. The proposed activities would require fuel for equipment and water for recovery activities and dust suppression. The expected usage of these resources would be similar to existing demand at the INL Site. There would not be an increase in demand for these resources under the proposed action.
- **Waste Management**. Waste generated from the proposed activities would most likely be classified as construction or municipal waste. Construction waste would primarily be disposed of at the CFA Landfill Complex. Municipal waste is transported offsite to a commercial disposer. The CFA Landfill Complex is operated in accordance with State of Idaho regulations. The remaining capacity of the landfill is approximately 3.4 million cubic meters. The proposed action is not anticipated to generate waste in a quantity to noticeably affect the capacity of the CFA Landfill Complex. Nonhazardous solid waste items that cannot be disposed of at the landfill are sent off-Site to a commercial disposer. It is not anticipated that the proposed activities would generate radiological waste or other waste without an established disposition pathway.
- **Transportation**. The proposed action would not noticeably increase worker commuter traffic on the roadways that service INL beyond the current levels. Proposed activities would occur entirely on the INL Site and not affect publicly accessible roadways. Equipment or material delivery to the INL Site would be similar to shipments that currently are received on the INL Site and would follow existing plans and procedures. DOE estimates that the proposed action would require about 6,100 loads of fill material to be hauled from the T-28 and Monroe Borrow Sources to complete the proposed action. However, the majority of the transportation routes would occur on roads contained completely within the INL Site and on roads that only receive limited use. Traffic from the proposed action is not expected to cause a change in the existing level of service for on-Site roads.
- **Worker and Public Health and Safety.** Operations at the INL Site are required to comply with DOE requirements for worker health and safety. DOE environmental, safety, and health programs regulate the work environment and seek to minimize the likelihood of work-related exposures, illnesses, and injuries. These programs are controlled by the safety and health regulations for DOE contractor workers governed by 10 CFR 851, which establishes requirements for worker safety and health programs to ensure that DOE contractor workers have a safe work environment. Provisions are included to protect against occupational injuries and illnesses, accidents, and hazardous chemicals. Adherence to approved health and safety plans, use of personal protective equipment and engineered controls, and completion of appropriate hazards training would be expected to help prevent adverse acute or chronic health effects to workers. Activities planned under the proposed action would not be expected to have any adverse health effects on workers. The proposed action would not involve direct hazards to the public. The level of exposure to hazards, the regulatory requirements for managing those hazards, and existing exposures are not anticipated to change. Effects on human health would be negligible.

3.3 Air Quality and Greenhouse Gases

3.3.1 Affected Environment

The population over the region of influence (ROI) is exposed to air pollutants from a variety of sources, including agricultural and industrial activities, residential wood burning, wind-blown dust, and vehicle exhaust. Many of the activities at INL also emit air pollutants. Sources for criteria, toxic, greenhouse gases (GHGs), and both radiological and non-radiological Hazardous Air Pollutants (HAPs) at INL include fuel oil-fired boilers; diesel engines; emergency diesel generators (EDGs); miscellaneous small gasoline, diesel, and propane combustion sources; remediation; and research and development (R&D) activities. The boilers are used to generate steam for heating facilities and are the main source of non-radiological air emissions at INL. Diesel engines are used at the ATR Complex to generate electricity for reactor operations. EDGs are used at all INL facilities as emergency electrical power sources, and periodic testing contributes to criteria and toxic air pollutant emissions. The miscellaneous combustion sources include non-vehicle sources, such as small, portable generators, air compressors, and welders. Radiological emissions are primarily from the R&D activities as well as remediation.

Meteorology and Climatology

Meteorology and climatology at the INL Site, located along the western edge of ESRP, is characterized by a semi-arid steppe climate with low relative humidity, significant daily temperature variations, and variable annual precipitation due to its altitude, latitude, and inter-mountain setting. The area experiences intense solar heating during the day and rapid cooling at night, with most precipitation originating from Pacific Ocean air masses crossing the ESRP. Average midday relative humidity ranges from 18% in summer to 55% in winter, with extreme temperatures averaging 16.5°F in January and 69.0°F in July. The predominant wind flow is southwest-northeast, influenced by the ESRP's orientation and surrounding mountains, which channel west winds into a southwesterly pattern, promoting effective atmospheric dispersion during the day and limited dispersion at night. Average annual wind speeds are 7.5 miles per hour, with spring being the windiest season. Severe weather includes thunderstorms, strong winds, hail, tornadoes, snowstorms, and dust devils, with thunderstorms most commonly occurring from March to October and tornadoes being rare and typically weak. Dust devils are frequent in summer due to intense solar heating, creating localized dust clouds.

3.3.1.1 Air Quality Standards and Regulations

Federal and state agencies establish air quality regulations to protect public health and the environment from air pollution and prevent significant deterioration of air quality. These regulations set acceptable ambient pollution levels, limit radiation doses to the public, control emissions from vehicles and other human sources, and administer permits for stationary sources.

The Clean Air Act (CAA) and its amendments provide the framework to protect public health, particularly sensitive populations, and reduce pollution effects on visibility, animals, crops, vegetation, and buildings. The U.S. Environmental Protection Agency (EPA) delegates regulatory authority to the Idaho Department of Environmental Quality (IDEQ) through the State Implementation Plan, which enforces National Ambient Air Quality Standards (NAAQS) and other requirements.

Non-radiological emissions at INL are regulated under IDEQ's Air Permitting Program through a Site-wide permit with emission caps to stay below major source thresholds. Radionuclide emissions are regulated under EPA's National Emissions Standards for Hazardous Air Pollutants (NESHAP). INL ensures compliance by identifying pollutant sources, obtaining permits, controlling emissions, monitoring sources, operating within permit conditions, and obeying prohibitory rules.

NAAQS

The NAAQS are a critical component of the CAA designed to protect public health and the environment from the adverse effects of air pollution. The NAAQS set maximum allowable concentrations for six primary pollutants, known as criteria pollutants, which have been identified as posing significant risks to human health and the environment. These pollutants include sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter in two size ranges (PM10 and PM2.5), carbon monoxide (CO), lead (Pb), and ozone (O_3).

Each pollutant has specific standards that address both primary and secondary health and welfare concerns. Primary standards are intended to protect human health, particularly of sensitive groups such as children, the elderly, and individuals with respiratory illnesses. Secondary standards are designed to safeguard public welfare by preventing decreased visibility and damage to animals, crops, vegetation, and buildings.

For instance, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are regulated due to their potential to cause respiratory problems and contribute to acid rain, which can harm ecosystems. Particulate matter (PM10 and PM2.5) is monitored because fine particles can penetrate deep into the lungs and even enter the bloodstream, causing cardiovascular and respiratory issues. Carbon monoxide (CO) is a colorless, odorless gas that can impair oxygen delivery to the body's organs and tissues, leading to serious health problems. Lead (Pb) exposure can result in neurological impairments, particularly in children. Ozone (O_3), a secondary pollutant formed by the reaction of sunlight with precursors, such as nitrogen oxides (NOx) and volatile organic compounds (VOCs), can cause respiratory issues and other health problems.

Idaho has incorporated the NAAQS into its state regulations by referencing the federal standards outlined in 40 CFR Part 50. The state monitors air quality to ensure compliance with these standards and to determine allowable emissions of criteria pollutants for new or modified sources. Areas meeting the NAAQS are designated as attainment, while those that do not meet these standards are labeled as nonattainment. If sufficient data are not available to determine the status, an area may be designated as unclassifiable.

INL is currently designated as attainment, better than national standards, or unclassifiable/attainment for the criteria pollutants, meaning the air quality in these areas meets or exceeds the NAAQS. Therefore, the CAA General Conformity Requirements do not apply to INL. The closest nonattainment area for particulate matter is in Pocatello, Idaho, approximately 50 miles southeast of INL. Figure 5 illustrates Idaho's NAAQS designations.

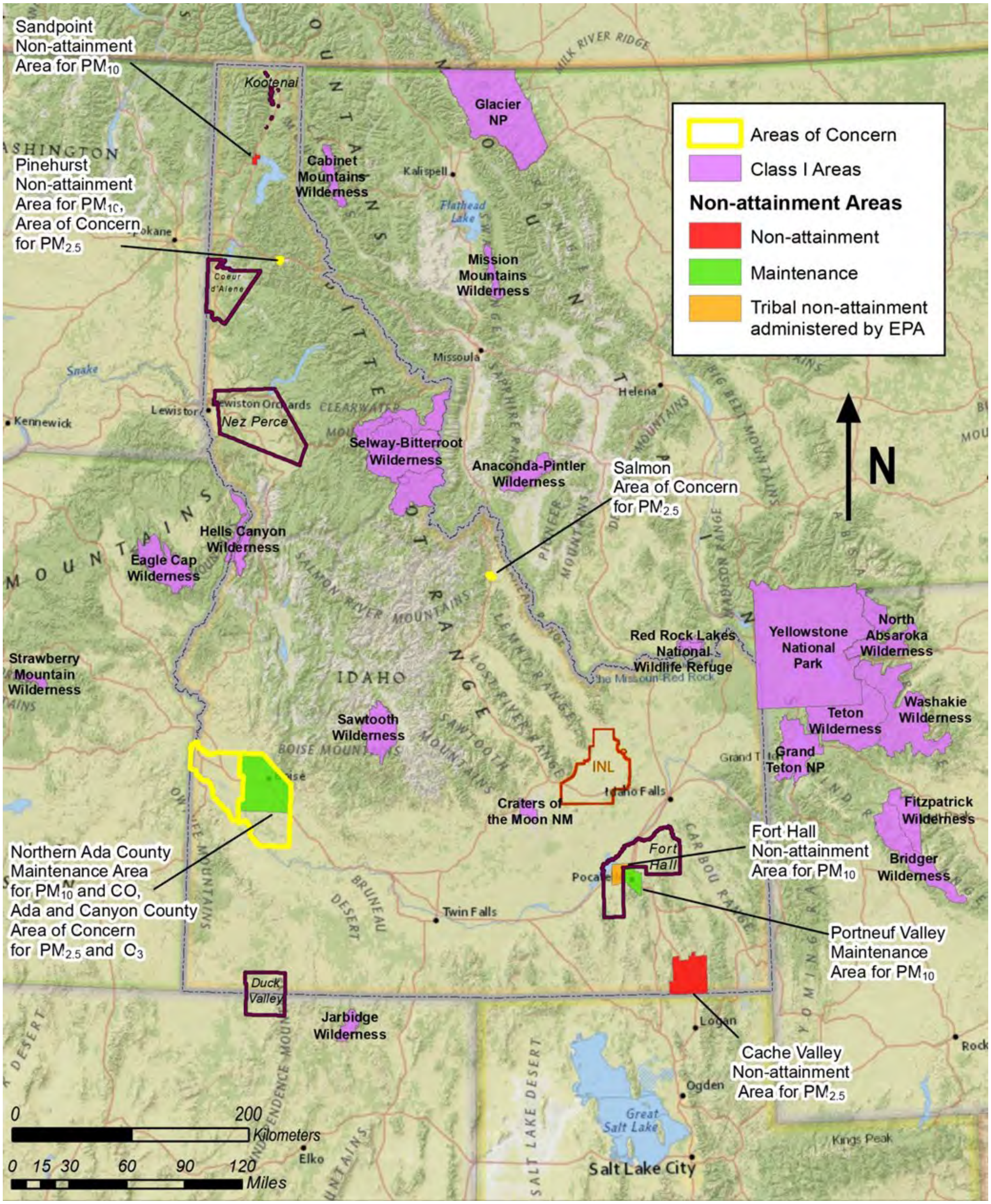

Figure 5. Idaho Prevention of Significant Deterioration and NAAQs classifications.

Prevention of Significant Deterioration

In areas with pollutant levels below the NAAQS, the Prevention of Significant Deterioration (PSD) Program (40 CFR § 52.21) places limits on the total allowable increases in ambient pollutant levels above the established baseline levels for SO_2, NO_2, and PM10. This prevents “polluting up to the standard.” Maximum allowable PSD pollutant concentration increases or increments are specified for the nation (designated as Federal Class II areas), and more stringent increment limits (as well as ceilings) are prescribed for national resources such as national forests, parks, and monuments (designated as Federal Class I areas). Federal Class I areas in Idaho are identified in Figure 5.

Limits on increases in specific air pollutants for PSD areas are based on an existing or baseline year. Maximum allowable ambient pollutant concentration increases or increments are specified for the nation (designated Class II areas), and more stringent increments (as well as ceilings) are prescribed for designated national resources such as national forests and parks (designated Class I areas). PSD increments for PM10, PM2.5, SO_2, and NO_2 have been established for Class I and II areas in the state of Idaho (Table 2). No Class III areas have been established in Idaho.

Table 2. Maximum allowable PSD increments.

PSD Class Area	Pollutant[1]	Averaging Time	Maximum Allowable Increment (micrograms per cubic meter)
Class I	PM10	Annual arithmetic mean	4
		24-hour maximum	8
	PM2.5	Annual arithmetic mean	1
		24-hour maximum	2
	SO_2	Annual arithmetic mean	2
		24-hour maximum	5
		3-hour maximum	25
	NO_2	Annual arithmetic mean	2.5
Class II	PM10	Annual arithmetic mean	17
		24-hour maximum	3
	PM2.5	Annual arithmetic mean	4
		24-hour maximum	9
	SO_2	Annual arithmetic mean	20
		24-hour maximum	91
		3-hour maximum	210
	NO_2	Annual arithmetic mean	25

PSD Class Area	Pollutant[1]	Averaging Time	Maximum Allowable Increment (micrograms per cubic meter)
Source: 40 CFR § 51.166(c)(1): Table for Class I, II, and III areas [1] PM10 = particulate matter ≤10 micrometers; PM2.5 = particulate matter ≤2.5 micrometers; SO_2 = sulfur dioxide; and NO_2 = nitrogen dioxide			

Construction or modification of any stationary source, facility, major facility, or major modification, as defined in Idaho Administrative Procedures Act (IDAPA) 58.01.01, requires an evaluation to determine the expected level of emissions of all pollutants (e.g., criteria, toxic, hazardous) and an evaluation of whether a PTC or Permit to Operate is required (IDAPA 58.01.01). Unless the source is specifically exempt from permitting requirements, a PTC and a Permit to Operate must be obtained prior to construction and operation. INL must comply with a Site-wide PTC with a Facility Emissions Cap (FEC), which contains specific emission limits and conditions for operation. This formal permitting process allows the State to determine that emissions will be adequately controlled, the source will comply with all emission standards and regulations, and public health and safety will be adequately protected.

If the expected level of emissions for a new source or modification is significant for any air pollutants, additional ambient air quality and PSD analyses are required. Levels of significance are tabulated below in Table 3 and vary depending on the pollutant. Emission limits, monitoring requirements, and reporting requirements for a proposed new or modified source that is not exemptible under IDAPA 58.01.01.220-222 are established and regulated through Idaho's PTC process and managed under an area source or major source permit.

Table 3. Significance levels for non-radiological pollutants.

Pollutant[1]		Significance Level	
		Kilograms per year[2]	Tons per year
CO		9.1×10^4	100
NO_2		3.6×10^4	40
O_3		3.6×10^4	40
Pb		5.4×10^2	0.6
SO_2		3.6×10^4	40
Total PM		2.3×10^4	25
PM10		1.4×10^4	15
PM2.5[3] as:	Direct PM2.5	9.1×10^3	10
	SO_2	3.6×10^4	40
	NO_2	3.6×10^4	40

Pollutant[1]	Significance Level	
	Kilograms per year[2]	Tons per year
Fluorides	2.7×10^3	3.0
Sulfuric acid mist	6.4×10^3	7.0
H_2S	9.1×10^3	10
Total reduced sulfur (including H_2S)	9.1×10^3	10
Reduced sulfur compounds (including H_2S)	9.1×10^3	10

Source: IDAPA 58.01.01

[1]CO=carbon monoxide; NO_2=nitrogen dioxide; O_3=ozone; Pb=lead; SO_2=sulfur dioxide; PM= particulate matter; PM10 = particulate matter ≤10 micrometers; PM2.5 = particulate matter ≤2.5 micrometers, and H_2S = hydrogen sulfide

[2] Significance levels from the regulations were converted from tons per year to kilograms per year and then rounded to two significant figures.

[3] SO_2 and NO_2 are precursors for the formation of $PM_{2.5}$.

IDEQ has established rules and methodologies to estimate and control the potential human health impacts of toxic air pollutants. Toxic air pollutants include cancer-causing agents, such as arsenic, benzene, carbon tetrachloride, and formaldehyde, as well as substances that pose non-cancerous health hazards such as fluorides, ammonia, and sulfuric acids (see IDAPA 58.01.01 for a list of toxic air pollutants). Rules and methodologies for the control of toxic air pollutant emissions are implemented through air quality permit programs (i.e., PTC and Permit to Operate). Threshold emission levels have been established for about 700 toxic air pollutants based on known or suspected toxicity of these substances. Acceptable ambient concentration levels have been defined for many toxic air pollutants by the state of Idaho. A project is eligible for a toxic air pollutant exemption if it can be shown that toxic air pollutant concentrations at the public receptor location most affected are less than the state threshold for those pollutants.

Greenhouse Gases

GHGs are a group of gases whose presences in the earth’s atmosphere trap heat, effectively warming the earth’s surface. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. The natural greenhouse effect is essential for maintaining temperatures conducive to life. However, human activities, such as burning fossil fuels, deforestation, and industrial processes, have significantly increased the concentrations of these gases, enhancing the greenhouse effect. This leads to additional heat being trapped, causing global temperatures to rise, a phenomenon known as global warming. The resulting climate change manifests in altered weather patterns, more frequent and severe extreme weather events, sea level rise, and disruptions to ecosystems and biodiversity. Mitigating GHG emissions is critical to addressing these adverse environmental and health impacts.

The EPA established PSD and Title V applicability permitting thresholds for GHG-emitting sources (40 CFR § 51.166). IDAPA 58.01.01 incorporated the federal rule by reference with a major and minor source permitting program. Sources are not required to obtain a permit based solely on GHG emissions. INL currently operates under a PTC, but there are no GHG reporting or reduction requirements in the permit. Additionally, statewide reduction targets for GHG emissions are not identified in IDAPA 58.01.01.

INL emits roughly 90,000 metric tons (MT) carbon dioxide equivalent (CO_2e) each year from Scope 1, 2, and 3 emission sources, according to the 2024 Site Sustainability Plan (DOE 2023). Scope 1 is direct emissions from production of electricity, heat, cooling, or steam; mobile combustion sources (e.g., automobiles, ships, and aircraft); fugitive emissions within an agency's organizational boundary; and process emissions from laboratory activities. Scope 2 emissions are indirect or shared emissions associated with the consumption of purchased or acquired electricity, steam, heating, or cooling. Scope 3 emissions include all other indirect emissions not included in Scope 2 (e.g., business air/ground travel, employee commuting, contracted solid waste disposal, contracted wastewater treatment, subcontractor emissions, and transmission and distribution losses associated with purchased electricity).

3.3.2 Environmental Consequences

The ROI of the proposed action consists of public roads and receptors as defined for INL by IDEQ (IDEQ 2011), and federal Class I areas (Craters of the Moon National Monument, Grand Teton National Park, and Yellowstone National Park).

The proposed action as well as fire recovery activities have the potential to generate fugitive emissions from mobile equipment, both from the combustion of fossil fuels and the mechanical disturbance of soil. Emissions from fire recovery are not defined due to their unpredictable and unbounding nature but are expected to be similar to current INL operations. Fire recovery emissions will be far less than the alternative emissions of leaving fire-affected land unamended. For these reasons, only the impacts associated with road improvements and mowing portion of the proposed action are addressed.

Road Improvements and Mowing

The proposed action would improve about 130 miles and place about 152,550 cubic yards of pit run gravel. It includes mowing roughly 80 miles, or 970 acres, of roadway shoulder. Mowing operations are expected to equate to a total of about 800 vehicle or mower miles traveled.

Using the AP-42 emission factors for heavy construction and unpaved roads, the proposed placing of soil and gravel, grading roadways, and mowing would result in combined emissions of fine particulate matter (PM2.5 and PM10) of 0.30 and 1.76 tons per year, respectively, which is below the PSD significant levels. These fugitive emissions will be emitted from locations across the INL Site over the course of the summer months. For conservative estimation purposes, assuming these emissions were to be emitted from a single location at the CFA area, impacts to the ambient emissions would be less than the PSD increments for Class II areas. Table 4 shows a comparison of estimated PM concentration from the proposed action compared to the PSD significance levels.

Table 4. Proposed action impacts to ambient air.

PSD Class Area			**PSD Significance Levels** (ug/m^3)	**Proposed Action Impact** (ug/m^3)
Class II	PM_{10}	Annual	17	0.08
		24-hr	3	2.54
	$PM_{2.5}$	Annual	4	0.01
		24-ha	9	0.43

Combustion emissions of the mobile vehicles used were estimated based on EPA's *Emission Factors for Greenhouse Gas Inventories* (EPA 2014). Table 5 shows the estimated emissions from the proposed action. CO_2 emissions are well below the GHG emissions reference point of 25,000 MT CO_2e per year for reporting under 40 CFR Part 98.

Table 5. Proposed action emissions from mobile source combustion.

Total Emissions	Nox	PM	THC	CO_2
lbs	5.9	0.2	1.0	11,956.2
tons	0.0	0.0	0.0	6.0

Emissions from the proposed action are well within acceptable ranges and are not considered significant. Additionally, DOE anticipates that the minor increase in emissions would result in a negligible contribution to cumulative impacts on air quality.

3.3.2.1 No Action Alternative

Under the No Action Alternative, activities at the INL Site would continue under present-day operations and as analyzed in the 2003 WLF EA. The proposed road improvements, mowing, and WLF recovery options would not be implemented. The No Action Alternative would not result in impacts to air resources at the INL Site beyond those captured in the discussion of the affected environment. The environmental impacts of future activities at the INL Site would be evaluated in project- or program-specific analyses in compliance with NEPA.

3.4 Water Resources

3.4.1 Affected Environment

The INL Site includes surface water from three primary streams—the Big Lost River, Birch Creek, and the Little Lost River—and from seasonal runoff from snowmelt. The Big Lost River is an intermittent ephemeral stream that begins in the pioneer mountains, dammed at Mackay Reservoir, and flows toward Arco into the INL Site. On the INL Site, the Big Lost River channel is either diverted to the south to the spreading areas or flows northward to a playa area or depression, known as the Big Lost Sinks or The Playas, where surface water infiltrates the Snake River Plain Aquifer (IDEQ 2004). Though periods of continuous flow above ground are infrequent on the INL Site, during high-water years, the river will run inside the INL Site boundary and be diverted toward the southern spreading area or to the Big Lost Sinks. The segment of the Big Lost River that traverses the INL Site is not identified as impaired waters in §303(d) under the Clean Water Act nor exceeds the Total Maximum Daily Load (TMDL) pollutant as this segment is usually a dry channel throughout the year (IDEQ 2004).

All three streams feed into the Snake River Plain Aquifer that underlies the INL Site (Figure 6). The Snake River Plain Aquifer is the major source of drinking water and crop irrigation for southeastern Idaho and has been designated a Sole Source Aquifer by the EPA. The U.S. Geological Survey estimates that the thickness of the active portion of the Snake River Plain Aquifer at the INL Site ranges from 250–820 feet. Depth to the water table ranges from about 200 feet below land surface in the northern part of the INL Site to about 1,000 feet in the southern part. The Snake River Plain Aquifer is the only source of water for INL facilities. The INL's Federal Reserved Water Right permits a maximum water consumption of 11.4 billion gallons per year from the Snake River Plain Aquifer. Each major facility is serviced by one or more production or potable water wells.

The U.S. Army Corp of Engineers has regulatory jurisdiction over waters of the United States, including those pursuant to Section 404 of the Clean Water Act, and has jurisdiction over Navigable Waters of the United States pursuant to Section 10 of the 1899 Rivers and Harbors Act. Any disturbance to vegetation or soils below the high-water mark of any surface water feature at INL may be considered a discharge of fill material that would require a permit from the Department of the Army pursuant to Section 404 of the Clean Water Act. Receipt of a Section 404 permit and adherence to the terms and conditions of the permit, including any associated compensatory mitigation and BMPs to reduce sedimentation and erosion control, would demonstrate compliance to the Clean Water Act.

INL has identified a storm water corridor where there is a reasonable potential to discharge storm water into waters of the United States (Figure 7). Projects that will disturb one or more acres and are located within the stormwater corridor, require coverage under an Idaho Pollutant Discharge Elimination System storm water construction general permit (CGP). A CGP requires BMPs to reduce the sediment and other pollutants discharged in stormwater. It also requires periodic inspection of construction projects by those who are knowledgeable about erosion, sediment control, and pollution prevention.

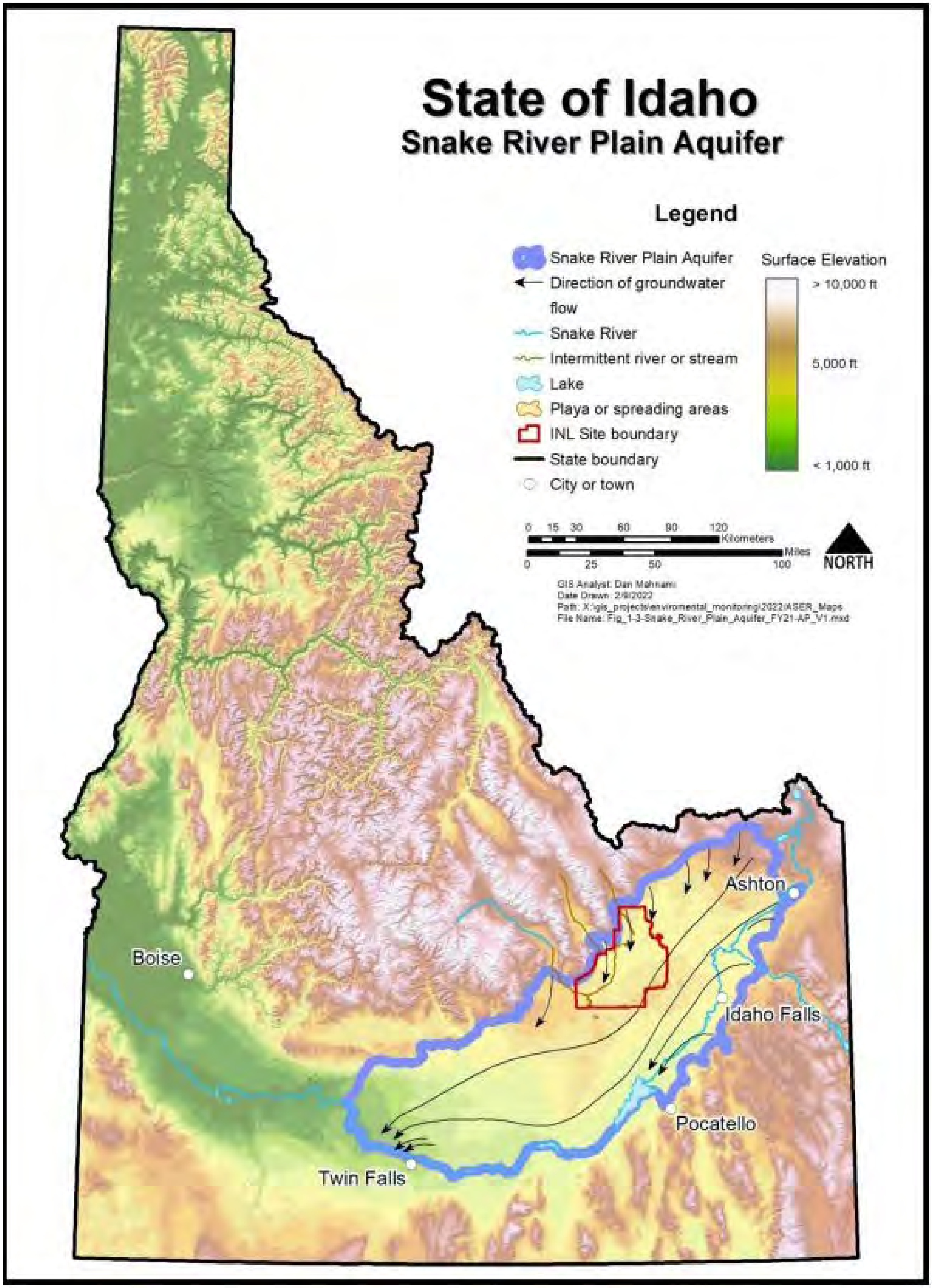

Figure 6. Snake River Plain Aquifer.

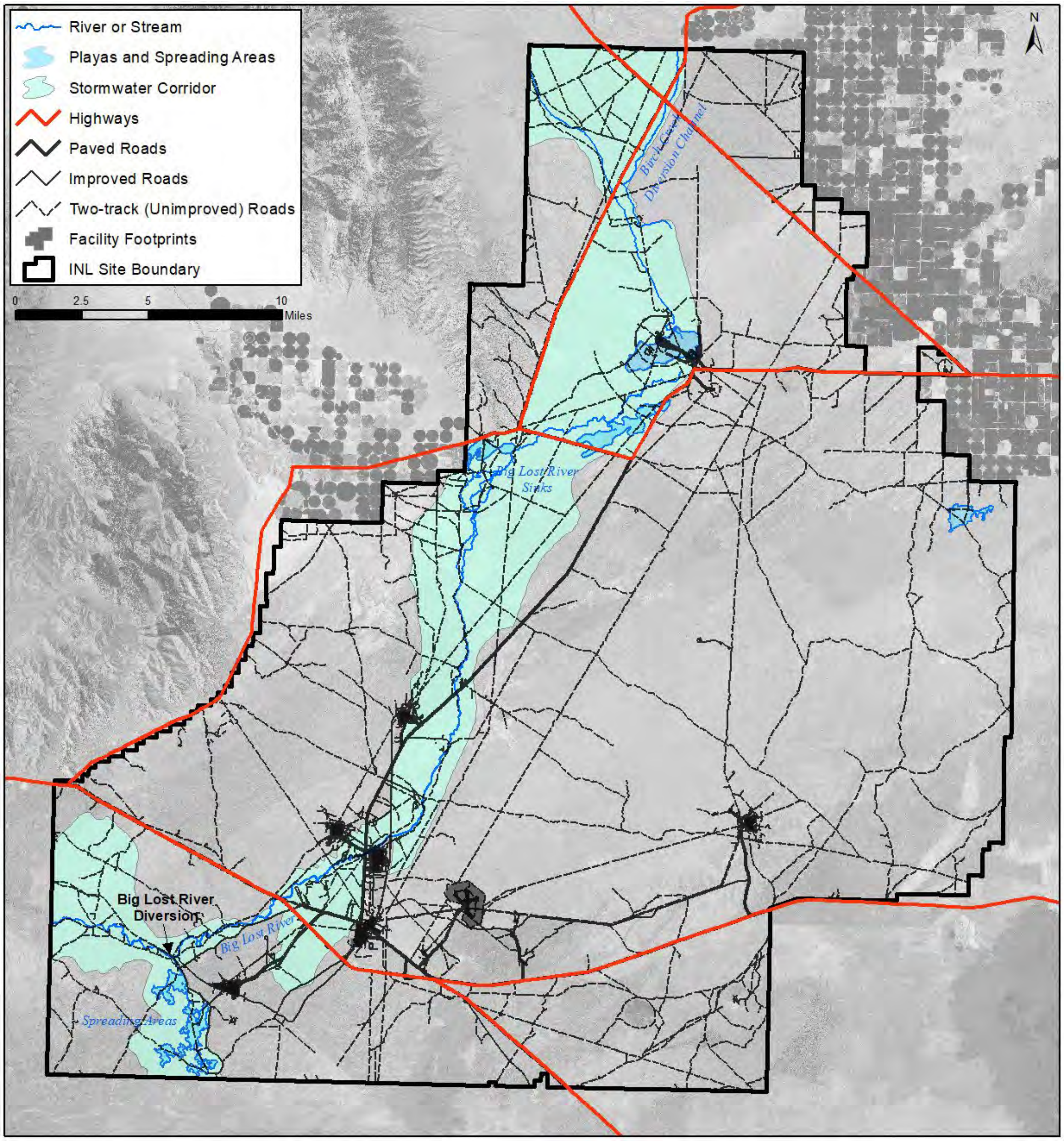

Figure 7. Surface water features at the INL Site.

3.4.2 Environmental Consequences

The proposed action would not require drilling wells, discharge into injection wells, or noticeable changes in groundwater consumption. Dust suppression activities associated with road improvements would use approximately 153,000 gallons of water. In 2023, total water use at the INL Site was 735 million gallons. The proposed action would increase INL water use by about 0.02%. This represents about 0.0013 percent of the INL Site's Federal Reserved Water right of 11.4 billion gallons per year. The proposed action would have a negligible increase on water use at the INL Site.

Mowing would reduce vegetation to 6-inches in height along about 130 miles of road but would not result in bare soil that would increase erosion and sediment to surface waters. Where roads would be improved and graded, soil compaction could affect infiltration and drainage. Roadway improvement and maintenance activities have the potential to alter local hydrology (e.g., removal/addition of material to roadway footprint), which may change the water flow along and adjacent to the roadways. However, most roads have already been compacted from vehicle travel, and impacts to infiltration and drainage would be negligible when compared to baseline conditions.

Any potential impact to surface water—direct, indirect, or cumulative impacts—is considered low because surface water sources are not prevalent on the INL Site. Most years, the three streams mentioned above do not appear above the surface on the INL Site. If surface water is present, then effort will be taken to avoid surface water features. The proposed action would not violate any water quality standard or degrade water quality, expose any undue risk to existing structures or personnel, or substantially alter existing drainage patterns. Efforts will be taken to ensure the work is performed outside of the stormwater corridor and BMPs are used for controlling storm water runoff. If improved roadways or mowing are needed within the stormwater corridor or surface waters, then permit requirements will be incorporated into work control documents to ensure compliance with the Clean Water Act.

Post-fire recovery activities would not likely impact surface water resources considering that the likelihood of resources being present is low. The proposed action also includes the use of BMPs, such as silt fencing and other measures, to reduce erosion and the movement of surface soils from recently burned areas. Silt fencing and similar BMPs would also reduce stormwater runoff from impacting surface water if present. The application of herbicides may contaminate surface waters, but the application would be per the manufacturer’s recommendations and avoid any standing surface water.

Any potential impacts to surface water from post-fire recovery activities would be considered low because surface water sources are not prevalent on the INL Site. If surface water is present, then efforts will be taken to avoid those features.

Cumulative impacts to water resources from the proposed action would be negligible.

3.4.2.1 No Action Alternative

Under the No Action Alternative, activities at the INL Site would continue under present-day operations and as analyzed in the 2003 WLF EA. The proposed road improvements, mowing, and WLF recovery options would not be implemented. The No Action Alternative would not result in impacts to water resources at the INL Site beyond those captured in the discussion of the affected environment. The environmental impacts of future activities at the INL Site would be evaluated in project- or program-specific analyses in compliance with NEPA.

3.5 Soil and Geological Resources

3.5.1 Affected Environment

INL is found on the ESRP, which is part of the broader Snake River Plain. This physiographic region is characterized by low-relief topography and is covered by basaltic lava flows and sediments. The Snake River Plain is about 56-miles wide and 348-miles long and extends as a broad arc across southern Idaho from the Yellowstone Plateau in Wyoming in the east to the Idaho and Oregon border on the west (Figure 8). Surface elevations gradually decrease from 6,562 feet near Yellowstone to 2,132 feet near the western edge of the plain.

The ESRP represents the track of buried and extinct volcanic centers associated with the passage of the North American plate over the relatively stationary “Yellowstone” hotspot (Pierce and Morgan 1992) (Pierce and Morgan 2009) (Smith, et al. 2009). From about 6.3 to 8.4 million years ago, the crust beneath the ESRP at and near the INL Site’s location was impacted by volcanism associated with the Yellowstone hotspot (McCurry, McLing, et al. 2016) (Anders, et al. 2014) (Schusler, et al. 2020). Volcanism within the last 2.1 million years associated with the Yellowstone hotspot is now beneath the Yellowstone Plateau (Christiansen, et al. 2007), 99–143 miles northeast of the INL Site. Since about 4 million to 2,100 years ago in the ESRP at and around the INL Site, basaltic magma has continued to periodically erupt producing volcanic vents and lava flows (Kunz, Skipp, et al. 1994) (Kunz, Anderson, et al. 2002) (Kuntz, et al. 2007). Surface basalt flows at the INL Site range in age from 13,000 to 1.2 million years ago (Kunz, Skipp, et al. 1994). During intervening eruptive periods, sediments have been deposited by wind and surface water. Along the southern INL Site border, basaltic magma stagnated in the crust and eventually evolved in composition to erupt from 300,000 years to 1.4 million years ago as rhyolitic domes, which formed five buttes with heights between 394 to 2,460 ft (McCurry, Hayden, et al. 2008).

Earthquakes occurring from 1850 to 2020 with magnitudes >2.0 compiled from INL’s and other nearby seismic networks (Payne and Montaldo Falero 2022) show a parabolic distribution of epicenters in the mountainous region outside of the ESRP.

Mineral resources within the INL desert Site are confined to several quarries. The INL Site features six active gravel/borrow quarries, known as borrow sources, and provide sand, gravel, pumice, silt, clay, and aggregate for road construction and maintenance, new facility construction, waste burial activities, and on-Site landscaping (DOE-ID, 2019). Beyond the INL Site and within about 100 miles of its boundary, mineral resources include sand, gravel, pumice, phosphate, and both base and precious metals (NRC, 2004).

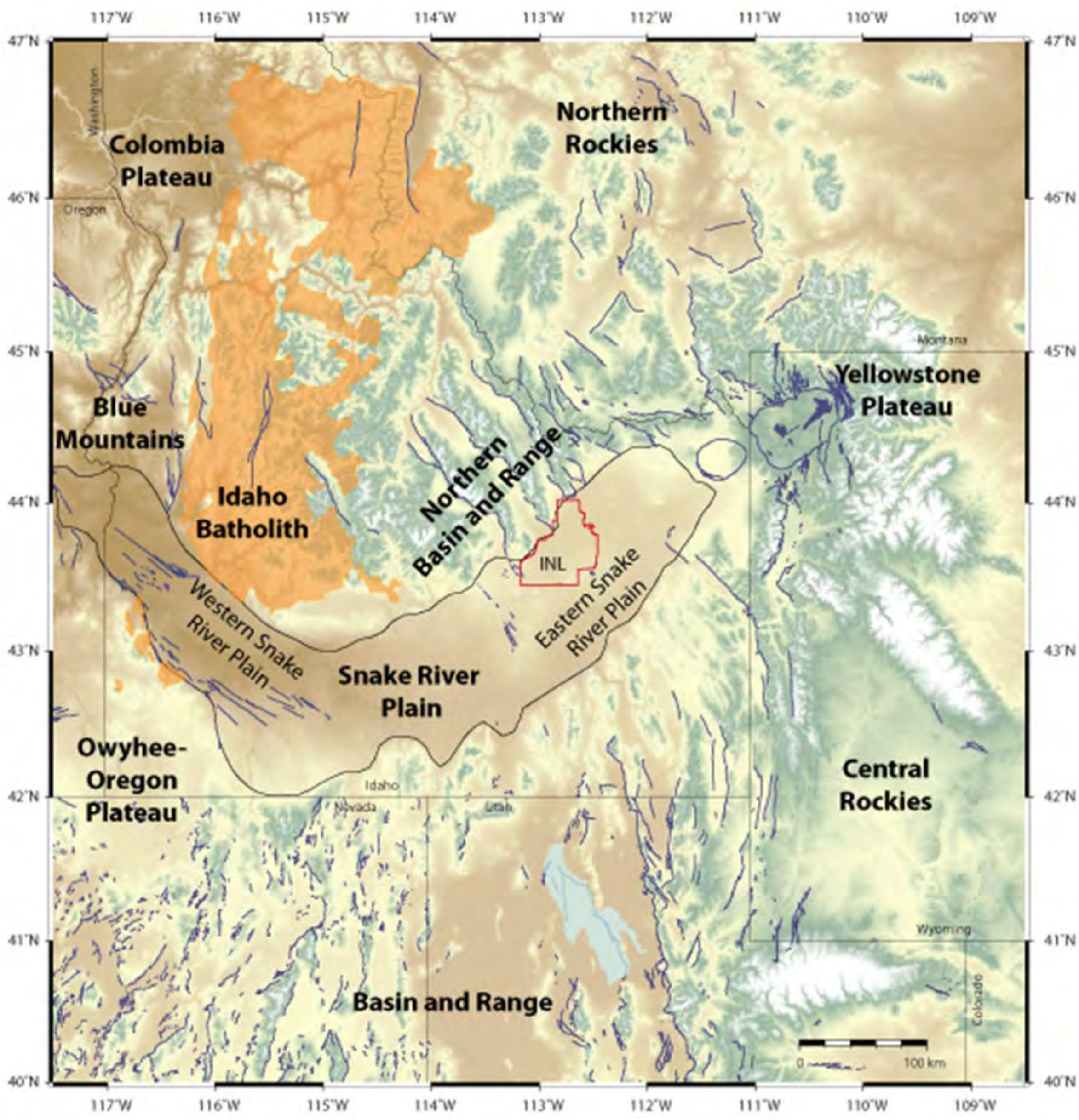

Figure 8. Location of the INL Site in relation to the Snake River Plain.

3.5.2 Environmental Consequences

The proposed action includes maintenance and soil disturbances of preexisting roads found on the INL desert Site, which would be associated with grading and shaping the preexisting roads. The proposed action would directly disturb 130 miles of previously disturbed roads. Although soil disturbed during the proposed work would be temporarily subject to wind and water erosion, adherence to standard BMPs for soil erosion and sediment control (e.g., use of silt fencing, staked hay bales, mulching and geotextile fabrics, and revegetation) during the proposed activity would serve to minimize soil erosion and loss.

The proposed action includes transitioning approximately 130 miles of non-graveled two-track roads to graveled roads and mowing 80 miles or 970 acres of roadway shoulder on the INL Site. Sources of materials would include gravel supplied by INL Site borrow sources (the Monroe and T-28 borrow sources). The proposed action would require about 152,550 cubic yards of fill material (about 6,100 loads at 25 cubic yards per load) from these INL Site borrow sources. However, this would not result in an expansion of the borrow pits. Therefore, the proposed action would have a small additional impact on geology and soils. In addition, the nature and location of the proposed work are not anticipated to have an impact as the result of potential future earthquakes. Additional discussion of soil impacts is included in Section 3.6.

3.5.2.1 No Action Alternative

Under the No Action Alternative, activities at the INL Site would continue under present-day operations and as analyzed in the 2003 WLF EA. The proposed road improvements, mowing, and WLF recovery options would not be implemented. The No Action Alternative would not result in impacts to geology and soil resources at the INL Site beyond those captured in the discussion of the affected environment and as further described in Section 3.6.2.1. The environmental impacts of future activities at the INL Site would be evaluated in project- or program-specific analyses in compliance with NEPA.

3.6 Ecological Resources

3.6.1 Affected Environment

General Ecological Description

The primary ecosystem of the INL Site is characterized as sagebrush steppe. Approximately 94% of the land on the INL Site is undeveloped (DOE 2014), with approximately 60% open to livestock grazing. Over the past two decades, WLF has affected ecological resources across a substantial portion of the INL Site. Since 2001, when individual fire size estimates were first available, several large WLFs have burned substantial portions of the INL Site. Of those that have occurred partially or entirely within the INL Site boundary, six fires have been over 2,741 acres. Vegetation maps of the INL Site prior to 1994 (McBride, et al. 1978) (Kramber, et al. 1992) indicate that plant communities across much of the landscape were dominated by big sagebrush (*Artemisia tridentata*). More recent vegetation maps reflect a transition to grassland and green rabbitbrush (*Chrysothamnus viscidiflorus*) dominated communities that are recovering from WLF (Shive, et al. 2019) (J. P. Shive 2024). Currently, approximately 43.1% of the INL Site remains as intact sagebrush plant communities, and 37.3% is recovering to a sagebrush climax.

Until the last few decades, vegetation across the INL Site was thought to be in generally good ecological condition (Anderson and Inouye 2001). Although ecological condition has declined in some plant communities on the INL Site over the past 10–20 years, native vegetation still dominates much of the area (Shive, et al. 2019). Studies of post-fire dynamics on the INL Site and across the region indicate that, except for sagebrush, post-fire species composition closely resembles pre-fire composition (Ratzlaff and Anderson 1995), (Blew and Forman 2010). Communities that were in good ecological condition prior to fire will generally recover to good-condition communities within a few years post-fire (Blew 2010). However, the recovery of sagebrush to pre-burn abundance can take more than a century (Forman 2024).

Wildlife

The INL Site is host to a variety of wildlife species, including large ungulates, (e.g., elk [*Cervus canadensis*] and pronghorn [*Antilocapra americana*]), 11 species of bats, sagebrush-obligates (e.g., sagebrush lizard [*Sceloprus graciosus*]), the greater sage-grouse (*Centrocercus urophasianus*), and the pygmy rabbit (*Brachylagus idahoensis*). Herpetofauna, such as the Great Basin rattlesnake (*Crotalus oreganus lutosus*) and the Great Basin spadefoot toad (*Spea intermontana*), use locally appropriate habitats, as do over 200 species of birds (e.g., raptor, waterfowl, passerine, and upland game species).

Vegetation

The vegetation of the INL Site consists predominantly of an overstory of shrubs and an understory of grasses and forbs. Nearly 500 vascular species have been documented occurring on and adjacent to the INL Site (Anderson, Ruppel, et al. 1996). Big sagebrush (*Artemisia tridentata*) and green rabbitbrush (*Chrysothamnus viscidiflorus*) are the most common shrubs (Forman, Blew and Hafla 2010). However, communities dominated or co-dominated by low sagebrush (*Artemisia arbuscula*), black sagebrush (*Artemisia nova*), and three-tip sagebrush (*Artemisia tripartita*) are frequently distributed around the periphery of the INL Site, and salt desert shrub communities are generally associated with playas and floodplains. Junipers (*Juniperus osteosperma*) are common at higher elevations associated with the buttes and foothills on the INL Site. Native grasslands may be dominated by rhizomatous species like streambank wheatgrass (*Elymus lanceolatus*) and western wheatgrass (*Pascopyrum smithii*) or by bunchgrasses like bluebunch wheatgrass (*Pseudoroegneria spicata*), needle and thread (*Hesperostipa comata*), or Indian ricegrass (*Achnatherum hymenoides*); they are most abundant in burned areas but are also understory components of most native shrublands.

Non-native species like crested wheatgrass (*Agropyron cristatum*), cheatgrass (*Bromus tectorum*), saltlover (*Halogeton glomeratus*), and annual mustards (*Sisymbrium* spp., *Descurainia* spp.) occasionally dominate INL Site plant communities, but typically occur as minor components of native communities. See Figure 9. INL vegetation community map for a map of the distribution of plant communities on the INL Site (Shive, et al. 2019). Noxious weed species that have been identified and treated on the INL Site include, but are not limited to, rush skeletonweed (*Chondrilla juncea*), scotch thistle (*Onopordum acanthium*), musk thistle (*Carduus nutans*), Russian knapweed (*Acroptilon repens*), spotted knapweed (*Centaurea stoebe*), black henbane (*Hyoscyamus niger*), leafy spurge (*Euphorbia esula*), houndstounge (*Cynnoglassum officinale*), sowthistle (*Sonchus arvensis*), and Canada thistle (*Cirsium arvense*).

Special Status Species and Communities

There are several plant and wildlife species designated as special status species and plant communities with elevated conservation rankings that occur within the INL Site boundary. Special status plant and wildlife species on the INL Site include species identified as threatened or endangered under the Endangered Species Act (16 USC 1531-1544), species protected by specific Federal Acts, Birds of Conservation Concern, sensitive species identified by the BLM, Idaho Department of Fish and Game (IDFG) sensitive species, and plant communities with elevated conservation rankings.

The United States Fish and Wildlife Service (USFWS) provides spatially explicit information regarding threatened and endangered wildlife and plant species, bald eagles (*Haliaeetus leucocephalus*) and golden eagles (A*quila chrysaetos*), and Birds of Conservation Concern. Based on the information provided by the USFWS, there is no critical habitat nor listed or proposed plant species identified within the INL Site boundary (USFWS 2025). The USFWS identifies the North American wolverine (*Gulo gulo luscus*; Threatened), the Suckley's Cuckoo Bumble Bee (*Bombus suckleyi*; Proposed Endangered), and the monarch butterfly (*Danaus plexippus;* Proposed Threatened) as potentially occurring within the INL Site. The USFWS also acknowledges the protection of bald and golden eagles under the Bald and Golden Eagle Protection Act of 1940 (16 USC 668-668d), both of which have been documented on the INL Site (DOE-ID 2024). There were 17 Birds of Conservation Concern identified by USFWS to have the potential to occur on the INL Site, of which 12 have been documented on the INL Site (Owens 2025).

Aside from the federally listed wildlife species identified by the USFWS, there are at least 35 wildlife species of conservation concern identified by the BLM as special status species (Type 2) that have been documented or are likely to occur on the INL Site (BLM 2022). Of these species, some of the most common on the INL Site include the greater sage-grouse (*Centrocercus urophasianus*), the sage thrasher (*Oreoscoptes montanus*), the sagebrush sparrow (*Artemisiospiza nevadensis*), the loggerhead shrike (*Lanius ludovicianus*), and the ferruginous hawk (*Buteo regalis*).

At least 61 wildlife species identified in the Statewide Wildlife Action Plan (IDFG 2024) by the IDFG as Species of Greatest Conservation Need (SGCN) or Species of Greatest Information Need have been documented to have occurred or are likely to occur on the INL Site. These include 11 species of bats, as well as commonly observed species, such as the greater sage-grouse, the burrowing owl (*Athene cunicularia*), the Brewer's sparrow (*Spizella breweri*), Hunt's bumble bee (*Bombus huntii*), pronghorn (*Antilocarpa americana*), and the short-eared owl (*Asio flammeus*).

Special status plant species on the INL Site are identified based on their designated conservation rank using NaureServe Explorer. On the INL Site, there are 48 wildflowers, 6 grasses, 3 shrubs, 1 cactus, 1 tree, 4 lichens, and 1 moss designated as special status plant species (NatureServe 2025). Included within these, there are 17 BLM-ranked plant species (BLM 2022) and 2 SGCN-ranked (IDFG 2024) plant species. Most of these species have very limited distribution and are restricted to areas with unique soils, topography, and associated plant communities. Many species that are recognized as likely to occur were identified as such due to nearby, documented occurrences or the presence of appropriate habitat on the INL Site.

The INL Site includes mapped plant communities with elevated conservation rankings (NatureServe 2025) (Shive, et al. 2019). There are 47 special status associations that either have been mapped or have the potential to occur on the INL Site. These associations include 20 grasslands, 22 shrublands, 2 meadows, 2 woodlands, and 1 prairie. The large-scale vegetation mapping and classification efforts prioritize characterizing representative plant communities across the INL Site, rather than focusing on unique species assemblages. This approach ensures efficient use of resources and avoids the unnecessary workload from fine-scale mapping. Consequently, highly localized and rare plant communities were not identified in these efforts.

Conservation Planning Areas

There are currently three conservation plans at INL that are related to the proposed actions. These conservation plans identify specific threats and tailor conservation measures to address threats. The operational controls listed in Section 2.1.1 identify specific mitigation measures, project-specific instructions, hold points, and BMPs that include seasonal time-of-day restrictions, buffers, altitude restrictions for aircraft, and pre-activity surveys. These measures are intended to minimize impacts to ecological resources and will be applied to the extent possible during and after the proposed actions.

The Candidate Conservation Agreement for the Greater Sage-grouse: The CCA identifies threats to greater sage-grouse and their habitat and defines conservation measures and objectives to avoid or minimize threats to the species. The CCA established the SGCA, which is designed to be deprioritized for future infrastructure development and employs additional conservation measures and BMPs to reduce human disturbance of breeding and nesting greater sage-grouse, including seasonal buffers and time-of-day restrictions (Figure 10). In conjunction with the CCA, PRD-407 requires sagebrush mitigation for any project in which related activities result in the loss of sagebrush habitat or recovering sagebrush habitat. Any activities taking place contrary to the conservation measures and BMPs listed in the CCA will require further consultation between DOE and USFWS (DOE 2014).

The INL Site Bat Protection Plan: Large undisturbed areas of shrub-steppe habitat, basalt outcrops, lava caves, juniper uplands, and ponds and landscape trees at industrial facilities provide complex and abundant foraging and roosting habitat for a variety of resident and transient bat species. The INL Site BPP (DOE 2018) provides a framework to reduce mission impacts on bat species, monitor the status of bat populations, and establish conservation measures and BMPs designed to reduce the threat to or destruction of bat habitat. To protect summer roosts and hibernacula from INL-related activities, the BPP established distances in which certain activities are limited, including vegetation removal, herbicide use, and noise.

The Sagebrush Steppe Ecosystem Reserve: On July 19, 2004, DOE signed a FONSI for an EA and Management Plan that outlined a framework to collaboratively manage the INEEL Sagebrush Steppe Ecosystem Reserve (SSER) with the BLM, USFWS, and IDFG. The SSER includes 74,000 acres of high desert land in the north central portion of the INL Site (Figure 10). Specific actions to guide the SSER management according to its mission and management goals were provided in the INEEL Sagebrush Steppe Ecosystem Reserve Final Management Plan (DOE-ID and BLM 2004). The primary actions included in the preferred alternative for managing the SSER were as follows: (1) established a Reserve Management Committee, (2) reduced road access and use, (3) implemented an integrated weed management plan, (4) limited restoration actions to locally collected plant materials, (5) no changes in livestock class or increase in stocking levels, (6) no construction of wells for livestock watering purposes, (7) minimized anthropogenic structures for raptor perching, and (8) responded to WLF suppression and post-fire restoration in a manner that is consistent with INL's WLF EA.

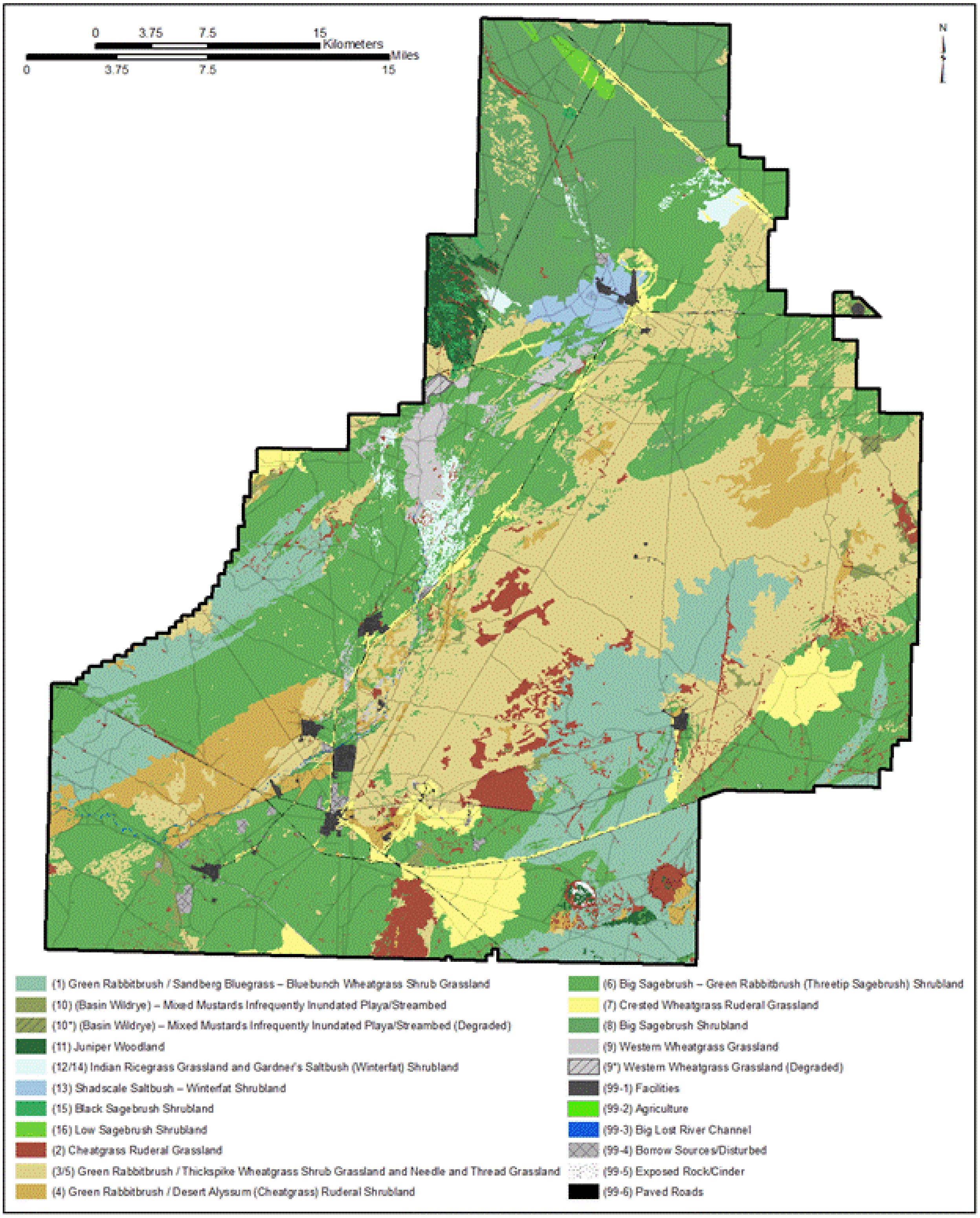

Figure 9. INL vegetation community map.

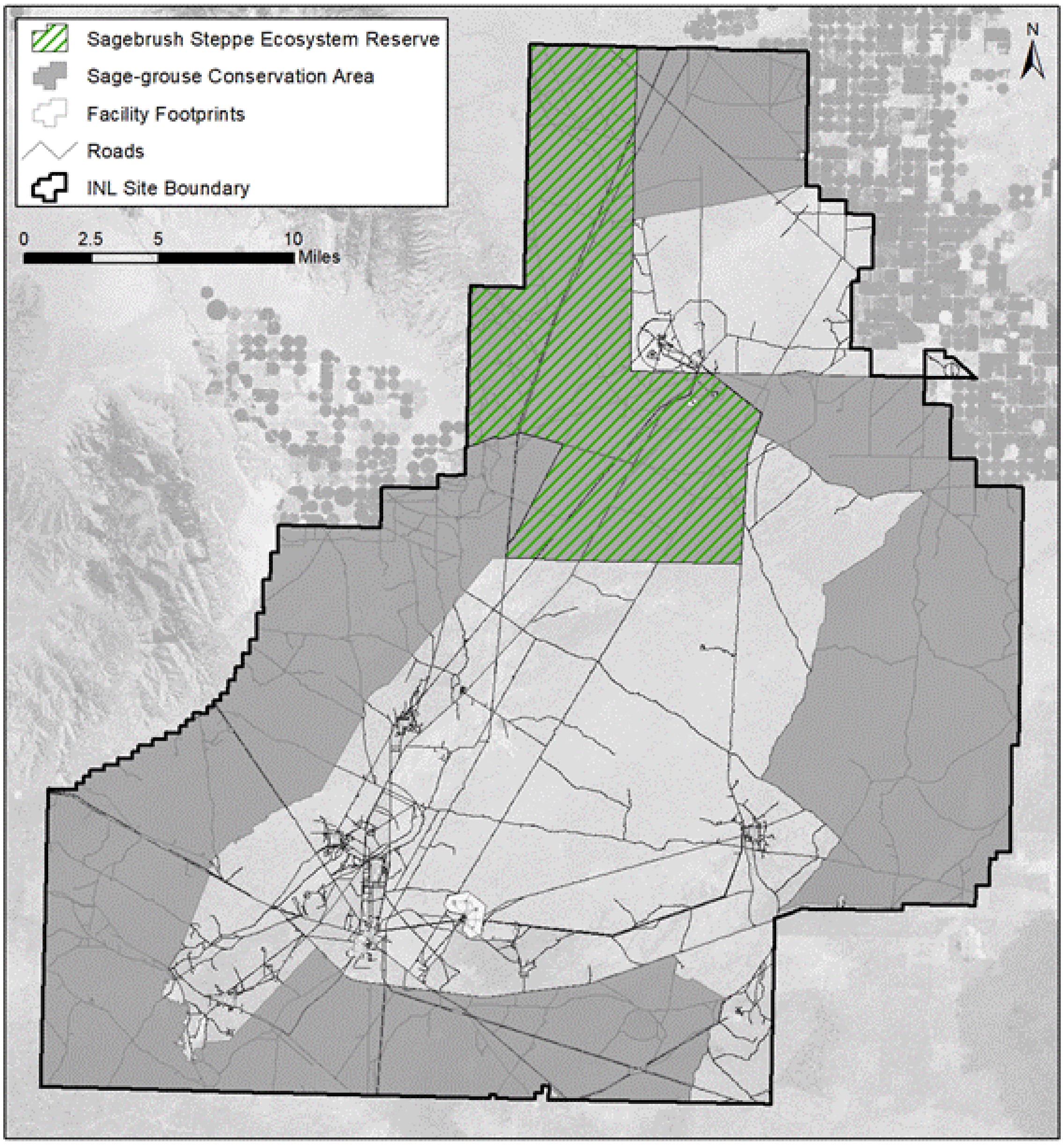

Figure 10. Sagebrush Steppe Ecosystem Reserve and SGCA on the INL Site.

3.6.2 Environmental Consequences

Wildland Fire Management Activities

Unlike fuels reduction treatments, which are intended to reduce the size and severity of WLF events and improve ecological resilience (Waltz, et al. 2014) (Chambers, et al. 2024), mowed roadside strips are linear strips that are treated to reduce hazardous fuels to provide safe, strategic anchor points for fire suppression activities (Moriarty, Okeson and Pellant 2015). Vegetation treatments for fuel breaks may include promoting plant growth that retains a high moisture content (green strips), mowing and applying herbicide to reduce the amount and structure of fuels, or removing all vegetation (brown strips). While this reduction in fuels may passively change fire behavior under the right weather, fire, and fuels conditions (Weise, et al. 2023), mowed roadside strips are intended to reduce the rate of spread and residence time of fires by disrupting fuel continuity and reducing flame lengths (Maestas, et al. 2016) (Ellsworth, et al. 2022) to support fire suppression efforts.

Mowed roadside strips are most effective when designed based on fuel loading, topography, local weather conditions, and predicted fire behavior (Syphard, Keeley and Brennan 2011) (Gannon, et al. 2023) and when used in conjunction with fire-fighting activities (Syphard, Keeley and Brennan 2011). Roads are often used as tools in the control and management of fires, providing efficient ingress and egress of firefighting personnel and equipment and may be enhanced by roadside vegetation treatments. However, while the areas adjacent to roads proposed for mowing and herbicide application actions within this EA may be used for a similar purpose, they were not explicitly selected based on fuel loads, topography, or weather conditions, but are intended to enhance firefighter safety and access to remote areas of the INL Site in the event of a WLF. Ecologically, potential consequences and benefits are similar to planned mowed roadside strips, but these proposed actions will be referred to as mowed roadside strips to indicate the difference in reasoning for site selection.

The primary purpose of road improvements is to reduce the response time to lightning ignitions of remote WLFs and to increase accessibility of backcountry locations to fight larger fires that exhibit extreme fire behavior. Over the past thirty years, about 25% of ignitions on the INL Site were caused by lightning, with the remaining ignitions resulting from roadside human behavior (summarized in (Forman, Kramer, et al. 2024). Although most fires that have burned on the INL Site did not exhibit extreme fire behavior, there have been six fires in the last three decades that quickly expanded to over 2,500 acres within the span of a few hours. The primary purpose of the mowed roadside strips is to enhance firefighter safety by reducing flame length. The INL FD has determined that 100-foot strips on either side of the road, mowed to a stubble height of 6 inches, with an annual frequency, will be sufficient to address safety requirements. Discussions of the environmental consequences of mowed roadside strips are based on these design specifications.

Vegetation

Road improvement and maintenance activities, including turnarounds, staging areas, and any other areas needed to support road work, will result in direct disturbance of vegetation and soil within and adjacent to current road footprints, which will increase the potential for the establishment of noxious weeds and undesirable annual grasses and forbs in those areas. If soils impacted by road improvements, including turnarounds and other support areas, are not sufficiently stabilized, they may increase the risk of the road becoming a vector for weed spread (Ferguson, Duncan and Snodgrass 2003) (Hansen and Clevenger 2005) (Lazaro-Lobo and Ervin 2019). Because road improvements often result in increased traffic volume (Hills 1996), the potential for weed establishment and movement along the vector corridor will increase proportionally to road use. Potential indirect impacts from roadway improvement and maintenance activities may include habitat degradation associated with alterations in hydrology (e.g., removal/addition of material to roadway footprint), which could change the flow of water along and adjacent to the roadways and into the surrounding native plant communities.

Under the proposed action, approximately 2,100 acres of established vegetation would be disturbed because of roadside mowing (Table 6). Sagebrush and other shrubs would be removed, and native perennial grasses and forbs would be damaged. Any populations of special status plant species that occur within the areas impacted by roadside mowing could be permanently lost. The removal of sagebrush and other native species through mechanical processes like mowing allows for encroachment of less desirable weedy species (Prevey, et al. 2010). Overall, mowing in sagebrush steppe has been shown to shift fuel composition, but does not result in long-term changes to fuel amount (Ellsworth, et al. 2022). Mowing in sagebrush steppe has also been shown to significantly increase cheatgrass abundance (Davies, Bates and Nafus, Mowing Wyoming Big Sagebrush Communities With Degraded Herbaceous Understories: Has a Threshold Been Crossed 2012) (Swanson, et al. 2016) even in stands that did not previously have degraded understories (Davies, Bates and Nafus, Comparing Burned and Mowed Treatments in Mountain Big Sagebrush Steppe 2012). Cheatgrass provides continuous fine fuels (Young, et al. 1987), and when cheatgrass monocultures occur along the roadside, they may increase the risk of fire spreading from a roadside into adjacent native vegetation (Harrison, et al. 2024). Because road improvements often result in increased traffic volume, any risk of human fire ignition and spread would increase proportionally with any increase in traffic. Additionally, fire ignitions may result from mowing activities due to equipment malfunctions, inattentive personnel, sparks created by mowing equipment contacting rocks or other surface features, etc.

Table 6. Estimated acreage disturbed during the establishment and maintenance of mowed roadside strips.

Proposed Areas of Disturbance	Total Disturbed Acres	Total Acres
All Roads Proposed for Mowing (100-ft buffer)	2,133.58	569,157
Sage-grouse Conservation Area	488.95	326,176
Sagebrush Steppe Ecosystem Reserve	98.69	74,171
Recovering Sagebrush Habitat	1,118.7	212,250
Existing Sagebrush Habitat	576.2	245,570

The increased risk of weed introduction, establishment, and spread due to road improvements and roadside mowing can be minimized through soil stabilization and by implementing a program-specific weed monitoring and treatment program. However, the potential impacts of herbicide treatment may potentially harm or destroy non-target vegetation, including special status species (BLM 2023). The effects of herbicides applied to treat vegetation vary by the type of chemical pathway employed (foliar vs. soil), the timing of application (growing season vs. dormant season), and plant community composition and soil types in the target area. Impacts of herbicide treatments may be minimized by using appropriate chemicals only under optimal conditions and applying the chemicals no more than necessary to address weed concerns.

The loss of sagebrush from mowing roadside strips can be mitigated as required under the CCA (DOE 2014). The CCA requires that the removal or loss of potential and existing greater sage-grouse habitat from the INL Site will be compensated or restored at another location (DOE 2014). Based on the projected sagebrush loss from the proposed action, it is anticipated that approximately 1,700 acres of sagebrush will need to be mitigated. Although many decades are required for mitigated areas to provide sagebrush habitat equivalent to those where sagebrush has been removed, if mitigation efforts are successful, they will eventually offset sagebrush losses from mowing roadside strips.

The impacts of road improvements and mowed roadside strips on local vegetation resources can be minimized to the extent possible by implementing project- and location-specific operational controls, as described in Section 2.1.1. These operational controls include hold points and project-specific instructions to ensure that BMPs for special status species and their associated conservation planning areas are effectively implemented.

If road improvements are effective in reducing response times and mowed roadside strips are effective in increasing safe access points for firefighters, then wildfire sizes may be reduced under certain conditions. For reference, when data about weather, fuels, topography, and ignition risk are analyzed and results are used to guide the placement of mowed roadside strips, then those strips can effectively function as fuel breaks. Based on data summarized over the past 30 years, mowed roadside strips are expected to be effective in the sagebrush biome about 58% of the time (Weise, et al. 2023). These estimates assume that the mowed roadside strips are used as anchor points for active suppression efforts. If those wildfires that are effectively managed would have otherwise burned an area that had not burned in the previous 30 years, then these proposed actions may be beneficial for preventing further sagebrush habitat loss. If the proposed actions prevent wildfire spread into areas that are recovering from previous wildfire, then any recovery from natural or assisted treatment actions would be preserved.

Wildlife

The construction and maintenance of roadway improvements and mowed roadside strips will have short-term direct effects on wildlife species. Wildlife occupying areas within proposed roadways and mowed strips will be disturbed by dust, noise, equipment, vehicles, and human presence. This can cause changes in behavior, including flight initiation, interruption of courtship and reproduction, non-optimal movement, and habitat avoidance. Wildlife with restricted mobility, such as small mammals, pollinators, reptiles, or ground-nesting birds, may be displaced, injured, or killed by the operation of mowers, vehicles, and heavy equipment. Some of these impacts can be minimized by following operation controls in Section 2.1.1 (e.g., seasonal and time-of-day restrictions, nesting bird surveys). The potential short-term effects to wildlife species from herbicide treatments implemented during the construction and maintenance of roadway improvements and mowed roadside strips to control noxious weeds and undesirable annual grasses and forbs includes direct spraying and ingestion of contaminated foliage (BLM 2023). These short-term effects will vary depending on the chemical, duration, and mechanism of exposure and can be minimized or eliminated by following the operational controls for herbicide application listed in Section 2.1.1.

Long-term direct effects of the construction and maintenance of roadway improvements and mowed roadside strips on wildlife species include soil compaction and altered hydrology, which may negatively impact burrows, nesting areas, and caves near project activities; habitat degradation or loss due to changes in vegetation amount and structure; edge effects that may increase the risk of predation by reducing available cover for prey species and lowering energy costs and detection time for some predators (Chalfoun, Thompson III and Ratnaswamy 2002) (DeGregorio, Weatherhead and Sperry 2014); and increased habitat fragmentation by creating visual barriers to movement (Edgel, et al. 2018) or by reducing habitat connectivity, particularly for less mobile species (Meinzen, Burkle and Debinski 2023). Another long-term direct effect of roadway improvements is a higher probability of vehicle-wildlife collisions due to increased driving speeds and roadbed usage by some wildlife species (e.g., snakes) (Jochimsen, et al. 2004). Additionally, indirect habitat loss may occur if species avoid high quality habitat due to adjacent human disturbance (Heinemeyer, et al. 2019) (Jones, et al. 2019).

Alteration or removal of sagebrush and recovering sagebrush habitat will have larger long-term impacts on pollinator, sagebrush-obligate, and sagebrush-associated species. Reduced shrub height from mowing will remove nesting habitat for sage thrashers, sagebrush sparrows, and loggerhead shrikes, which require sagebrush with structural complexity (Miller, et al. 2017) (Dinkins and Beck 2019) (Timmer, Aldridge and Fernandez-Gimenez 2019). Multiple studies have indicated that mechanical manipulation of sagebrush reduces nest and brood site selection for greater sage-grouse (Smith, et al. 2023) and does not increase the abundance or diversity of important nesting and brood-rearing habitat elements such as insects and forbs (Hess and Beck 2012), (Smith, et al. 2023). Pygmy rabbit habitat is characterized by areas of higher forb cover, shrub cover, and sagebrush density (Gabler, Heady and Laundre 2001), which will be reduced by the proposed action. Depending on the timing and blade height, mowing can reduce the availability of floral resources, increase habitat fragmentation, and limit population connectivity of pollinators (Meinzen, Burkle and Debinski 2023). Additionally, the potential for the spread of noxious weeds and invasive annual grasses from equipment and vehicles used for mowing and roadway improvements may reduce habitat quality for many of these species within the proposed action area.

Roadway improvements and mowed roadside strips will alter the habitat and produce noise disturbance for 26 greater sage-grouse leks within 0.62 miles of the proposed action area. Unoccupied leks have been associated with lower shrub heights compared to occupied leks (Smith, et al. 2006), and increasing variability in shrub height was found to be associated with lek abandonment (Hess and Beck 2012) at this distance. Chronic noise from road traffic and industrial machinery within 1,312 feet of a lek has been associated with lower lek attendance by both males and females (Blickley, Blackwood and Patricelli 2012). Conservation measures found in the CCA are designed to minimize disruptions to greater sage-grouse and are detailed in Section 2.1.1. These measures include restricting non-emergency activities from March 15 through May 15 between 6 p.m. to 9 a.m. within 0.62 miles of greater sage-grouse leks to avoid disrupting courtship behaviors. Additionally, disruptive non-emergency activities within the SGCA that may disturb nesting greater sage-grouse hens should be avoided between April 1 through June 30.

Habitat will be altered, and noise disturbance will impact nine known bat hibernacula and summer roost sites that are located within 1 mile of the proposed action area. Conservation measures found in the BPP are designed to minimize disruptions to bats and are detailed in Section 2.1.1. These measures include restricting activities generating continuous noise levels exceeding 75 decibels within 1 mile of a bat hibernacula or important summer roosts. Large-scale modification of native vegetation (>10 acres) in undisturbed areas within 1.5 miles of a hibernacula should be avoided. Prior to implementing activities involving pesticide application, fertilizer use, or mechanical vegetation removal within 150 feet of caves, a bat survey must be conducted to assess potential impacts.

Generalist predators, such as common ravens (*Corvus corax*) and coyotes (*Canis latrans*), will likely benefit from roadway improvements and mowed roadside strips as these species commonly use linear features and edge habitats (Crete and Lariviere 2003) (O'Neil, et al. 2018) to reduce energy costs and increase prey detection. If the proposed action decreases response times for initial attack and results in successful fire suppression, then it may reduce loss and fragmentation of native wildlife habitat on the INL Site from a WLF event.

Post-Fire Recovery Activities

The primary purpose of the proposed post-fire recovery activities is to rehabilitate and restore vegetation communities following a WLF. Active post-fire recovery treatments will be limited to areas where post-fire conditions may affect INL Site operations, where an area is at risk of poor natural recovery and where restoring habitat would yield high potential value for wildlife like seasonal-use areas or migration corridors. Treatments may also be prioritized in conservation areas like the SGCA or the SSER. When post-fire recovery activities are initiated in conservation areas, they will be conducted in accordance with the BMPs of that area. For example, locally collected seed will be used as directed by the SSER EA (DOE-ID and BLM 2004). The evaluation of effects of proposed post-fire recovery activities on the local ecosystem provided in this document includes the potential impacts and benefits associated with soil stabilization activities, noxious and invasive weed treatments, native herbaceous recovery activities, and sagebrush habitat restoration activities.

Vegetation

The goal of soil stabilization efforts on the INL Site are focused on (1) reducing erosion and weed vector potential of soils that were disturbed during fire suppression activities, (2) reducing human health impacts of blowing dust around facilities, and (3) minimizing damage to infrastructure from soil loss or deposition. Soil stabilization efforts, such as the installation of stormwater control features (e.g., silt or snow fencing, wattles), use of dust suppression techniques (e.g., water or chemical applications), and performance of recontouring or revegetating disturbed areas may impact existing vegetation not eliminated by the fire or fire-fighting activities. Physical structures may cause unintended soil redistribution. These activities may also temporarily increase fugitive dust or have the potential to introduce undesirable plant species where revegetation, and commercially procured plant materials, are used for stabilization. Weed seeds may also be spread via equipment used for stabilization activities.

The potential impacts of herbicide treatment implemented during WLF recovery activities to control noxious weeds and undesirable annual grasses and forbs include potentially harming or destroying non-target vegetation, including special status species (BLM 2023). The effects of herbicides applied to treat vegetation vary by the type of chemical pathway employed (foliar vs. soil), the timing of application (growing season vs. dormant season), and plant community composition and soil types in the target area. Additional potential risks of herbicide application include the spread of weed seed via equipment, destabilization of soils, and recurrence of weedy species where adequate native species are not available to recolonize after weeds have been removed (Monson 1994) (Elseroad and Rudd 2011). Herbicide application will only be considered when other means of weed control prove to be ineffective at controlling noxious and invasive species and when the overall impact of these effects would be low.

Herbaceous revegetation treatments are intended to increase the resilience and invasion resistance of plant communities and to decrease recovery time of important habitat. Revegetation efforts, including seedbed preparation, application of soil amendments, seedings, and seedling plantings could cause impacts to the soil and remaining vegetation (Forman, Kramer, et al. 2024). Mechanical seedbed preparation, application of soil amendments, and seed drilling would be more damaging to existing vegetation than hand planting because mechanical techniques have the potential to expose the soil surface to wind erosion and damage the root structures of surviving perennial species (Ratzlaff and Anderson 1995). Herbaceous revegetation treatments also have the potential to introduce undesirable genetic materials or weeds through seed contaminants and equipment.

Sagebrush restoration would be used to reduce recovery time for sagebrush habitats that are of high importance to obligate species. Post-fire recovery activities include sourcing appropriate plant materials, sagebrush seeding, and planting seedlings. Potential impacts of sagebrush planting include soil disturbance, creating weed vectors with equipment, introduction of genetic materials that impact local sagebrush populations, and introduction of sagebrush chemotypes that are not preferred forage for locally adapted wildlife populations (Rosentreter, Robb and Forbey 2021).

The impacts of the revegetation efforts on local ecological resources can be minimized to the extent possible by implementing project- and location-specific operational controls, as described in Section 2.1.1. Assuming the same level of efficacy as mechanical and hand-based revegetation efforts, any aerial seeding, soil amendments, or other activities completed using airplanes, helicopters, or drones would have no short-term impact on vegetation. Additional impacts may also be reduced using deferred livestock grazing or limiting access to recovering sites, in collaboration and accordance with BLM policies. This practice would protect restoration efforts until vegetation is established adequately to withstand regular use.

Restoration and revegetation in cold desert environments can be particularly challenging and any benefits from assisted recovery treatments would be proportional to the level of success achieved with those treatments. In the short-term, only weed control treatments will provide substantial benefit. If successful, longer term benefits to treatment would include enhanced site diversity and vigor of the restored vegetation communities. Anticipated long-term benefits from soil stabilization, weed control, and restoration also include (1) improving and restoring biodiversity of native vegetation, (2) restoring quality habitat for wildlife, (3) protecting habitat for species of concern, and (4) preventing extensive invasive annual grass dominance that could lead to an altered fire cycle. All these benefits would eventually translate to increases in available functional habitat for sagebrush-obligate species, improved ecosystem function, and increased ecological stability against stressors like shifts in precipitation amount and timing.

Wildlife

Near-term post-fire recovery actions, including creation of stormwater control features, dust suppression, recontouring, seedbed prep, mechanical seed drilling, weed control efforts, and associated human presence, will have short-term direct effects on wildlife species. Wildlife occupying areas within proposed post-fire recovery treatment areas will be disturbed by dust, noise, equipment, vehicles, and human presence. This can cause changes in behavior, including flight initiation, interruption of courtship and reproduction, non-optimal movement, and habitat avoidance. Wildlife with restricted mobility, such as small mammals, pollinators, reptiles, or ground-nesting birds, may be displaced, injured, or killed by the operation of vehicles and heavy equipment. Noise and visual disturbance from activities involving aerial operations may also induce short-term behavioral changes in some wildlife species. These disturbances can be minimized by following operation control listed in Section 2.1.1. Herbicide treatments may be used to control noxious weeds and undesirable annual grasses and forbs during WLF recovery activities. Short-term potential wildlife impacts from herbicide treatments include indirect contact with sprayed foliage and ingestion of contaminated food items (BLM 2023). These short-term effects will vary depending on the chemical, duration, and mechanism of exposure and can be minimized or eliminated by following the operational controls for herbicide application listed in Section 2.1.1.

Some wildlife species of conservation concern have exhibited positive responses to post-fire recovery actions. For example, pre-emergent herbicide application to reduce invasive annual grasses and aerial seeding of sagebrush, grasses, and forbs were associated with increased habitat use by greater sage-grouse in the first three years after the Soda Fire in Idaho and Oregon (Poessel, et al. 2022) (Germino, et al. 2023). However, longer term responses of greater sage-grouse to post-fire recovery actions are unknown. Sagebrush-associated species are negatively impacted by the conversion of sagebrush habitats to non-native grasslands (Rottler, et al. 2015), which can occur in low-resilience communities after a WLF event. Soil stabilization, application of pre-emergent herbicides, reseeding with native herbaceous species, and planting sagebrush can help reduce the establishment of non-native grasses and retain habitat elements for these species post-fire.

If WLF recovery efforts to stabilize soil and control the spread of noxious weeds and invasive annual grasses are successful, then wildlife species that are associated with early successional native plant communities will likely benefit in the near term. If suitable timing and duration of rainfall aids in the natural or assisted recovery of sagebrush, then use by sagebrush-obligate species will likely increase over the following decades.

3.6.2.1 No Action Alternative

Under the No Action Alternative, impacts on ecological resources from WLF, pre-fire suppression activities, and suppression activities will remain the same as they have been since the initial WLF EA was implemented in 2003. Risk of weed spread and the impacts of habitat loss and fragmentation associated with roads will remain unchanged. The tools available for post-WLF recovery will remain limited to those available under the current EA, and many proposed individual treatments will require environmental evaluation before they can be initiated. Treatment options related to the aerial application of herbicide to reduce cheatgrass dominance would not be feasible under the No Action Alternative. Cheatgrass-dominated plant communities currently occupy about 5% of the INL Site and have not increased in distribution substantially over the past 15 years (J. P. Shive 2024), so extreme shifts in fuels and fuels-related fire frequency are unlikely over the next decade under the No Action Alternative.

If road improvements and mowed roadside strips are effective in reducing response times and increasing access points for firefighting and increasing in capability results in smaller fire footprints, then the No Action Alternative may result in some loss of habitat that may not have occurred by adopting the proposed action. The amount of sagebrush habitat conserved by the proposed action would have to substantially offset the losses and fragmentation that will be incurred from the proposed action. Because nearly half of the INL Site has been impacted by wildfire over the past three decades, each new wildfire burns proportionally less sagebrush habitat than preceding fires, so the proposed action would need to be used to focus efforts on remaining sagebrush to yield effective protection for the remaining sagebrush habitat.

3.7 Noise

3.7.1 Affected Environment

The area surrounding the project site is characterized as being predominantly developed, surrounded by sagebrush steppe communities. Regionally, elevated noise levels mainly result from vehicular traffic on the highways. The closest manmade structures within the project area include numerous access roads and 25 INL facilities. Primary noise contributors at the INL Site are natural sounds (e.g., the wind and occasionally wildlife) and manmade sounds, including vehicular traffic and activities associated with INL operations. Within the INL Site boundary, the vegetation cover and regional topography quickly attenuate noise and vibrations with distance from the noise source.

3.7.2 Environmental Consequences

The proposed activities would occur within the INL Site boundary. The closest noise-sensitive receptors to INL are agricultural properties that surround the INL Site at certain locations. U.S. Highway 20 is typically considered the primary source of noise noticeable to the public on publicly accessible locations throughout the Site. It is expected that discernible sound would range from approximately 80–85 decibels (dBA). To give context, a whisper registers at approximately 30 dBA, normal conversation at approximately 50–60 dBA, a ringing phone at 80 dBA, and a power mower at 90 dBA (OSHA 2011). Any discernible noise from proposed activities would be from mechanical equipment used for mowing, broadcasting seeds or herbicides, or any aircraft that may be used. For reference, a typical tractor at idle speed produces about 85 decibels, while a tractor at work speed will produce up to 100 decibels. However, these noise levels would be consistent with other equipment used at the INL and, when in use, operators and nearby INL personnel are required to use appropriate PPE. The proposed action would not cause a change in the noise environment at the INL Site.

Given the distance to the nearest off-site receptors, cumulative noise from the proposed action within the INL Site would be indistinguishable from background, and therefore, the impacts would be negligible.

3.8 Cultural Resources

3.8.1 Affected Environment

Section 106 of the National Historic Preservation Act (NHPA) and implementing regulations, 36 CFR Part 800, require federal agencies to consider potential effects to historic properties from undertakings funded or permitted by the U.S. federal government. *Historic properties* are historic districts, buildings, structures, sites, or objects that are eligible for inclusion or listing on the National Register of Historic Places (NRHP). The proposed actions are subject to Section 106 review.

In 2022 and 2023, the INL Cultural Resources Management Office (CRMO) conducted background research and intensive cultural resource inventories necessary to identify and characterize cultural resources within the project area of potential effects (APE). An undertaking's APE is defined as "the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist." (36 CFR 800.16[d]). The APE for the proposed activities was designed to capture the geographic extent where road improvements and roadside mowing would take place. The APE includes the roads and their immediate margins for those roads proposed for improvements only, and includes 100 feet from each edge of the road, resulting in a total of 200 feet along the sections of road currently identified for road improvements and mowing." (Figure 4). The total APE equals 3,055.43 acres, encompasses over 140 linear miles of road, and crosses through three counties.

Activities proposed in the post-fire recovery portion of the EA are not included in the APE for the proposed action because the specific footprint of future WLF incidents cannot be anticipated. Current INL procedures establish a framework for Section 106 review of emergency incidents, including WLF methods for analyzing effects to historic properties during emergency response to wildfire and post-fire recovery efforts, are identified in Appendix F of the 2023 Programmatic Agreement (PA) between DOE, Idaho State Historic Preservation Office (SHPO), and the ACHP (DOE-ID 2023). Individual recovery plans will be reviewed by the INL CRMO on a case-by-case basis to evaluate effects on historic properties in accordance with the INL Section 106 Process for Emergency Actions (Management Control Procedure 8014).

The records review and Class III archaeological inventory of the APE identified 120 cultural resources within the APE (e.g., isolated finds, linear resources, and archaeological sites). Of these, 44 are historic properties (eligible or listed in the NRHP). The remaining cultural resources in the APE are recommended as not eligible for listing on the NRHP.

3.8.2 Environmental Consequences

Assumptions

- This analysis provides a broad overview of cultural resource types and potential effects based on the available information used to determine the APE. Additional consultation would be performed before the implementation of proposed activities to avoid, minimize, or mitigate adverse effects to historic properties, as defined by Section 106 of the NHPA.
- The avoidance of cultural resources during proposed activities may compromise the effectiveness or the intention of the activity, and it may be necessary to minimize effects to such sites through using manual treatments, cultural resource awareness training, or other appropriate measures.
- The effectiveness of the proposed activities would have long-term benefits on cultural resources by decreasing the acres burned and promoting fire resiliency of the landscape through soil stabilization and vegetation restoration.

Wildland Fire Management Activities

Road improvements have the potential to cause direct, indirect, and cumulative effects to historic properties. Spot grading, applications of gravel, and incidental widening of routes resulting from these actions may damage or displace artifacts and features at archaeological sites adjacent to, and bisected by, roads. However, the proposed improvements will be limited to the existing envelope of disturbance associated with these roads, which may alter characteristics that qualify the historic property for the NRHP (e.g., artifacts, features, subsurface deposits) but not to the degree to diminish integrity. In certain locations, geotextile fabric can be placed and sites and site features can be avoided to further reduce impact to NRHP characteristics of historic properties. Road improvements along NRHP-eligible linear resources of historic roads, railways, and trails may affect route design but would not alter or diminish the other aspects of the Site integrity (e.g., location, feeling, setting, and association).

The action of roadside mowing may affect archaeological historic properties within the APE. Mechanical thinning and mowing may also affect some archaeological historic properties, such historic homesteads, where high-relief features and artifact scatters are susceptible to damage or displacement by mowing equipment. Effects to precontact archaeological historic properties, like lithic scatters and other sites where artifacts are well below the target fuel height of six inches, are less likely. Offroad use of heavy equipment during periods of high soil moisture or in areas with loose, sandy soils could result in disturbance to archaeological historic properties through soil disturbance, compaction, and erosion. Roadside mowing along NRHP-eligible historic roads, railways, and trails may affect aspects of integrity such as feeling and setting. Combined with potential effects to the integrity of design that would result from proposed road improvements, mowing may compromise the integrity of some route segments.

While the proposed road improvements have the potential to result in a disturbance to historic properties within the APE, they would also stabilize roadbeds, reduce erosion, discourage overland travel, and improve access during emergency events. If road improvements are effective in reducing response times and mowed roadside strips are effective in increasing safe access points for firefighters, then wildfire sizes may be reduced under certain conditions and more timely response to WLFs has the potential to facilitate more rapid containment. If successful, the proposed road improvements would reduce the impacts of WLF to archaeological historic properties in areas susceptible to post-fire soil loss due to wind erosion processes. Improved containment and suppression may also reduce the effects to historic properties from fire suppression efforts (i.e., containment lines and overland travel) and to post-fire erosion and deflation. Potential impacts to historic properties that would result from the proposed action could also be prevented through implementation of avoidance and minimization strategies described in Section 2.1.1.

In conjunction with the operational controls in Section 2.1.1, cultural resource awareness training and an annual environmental training refresher are provided for DOE contractor staff who conduct work at the INL Site. These trainings enrich the knowledge of cultural resources and how and why they are protected. Although Section 106 has been initiated, project-specific consultation has not been completed as of June 2025. Through consultation with the Idaho SHPO and the Shoshone-Bannock Tribes, DOE will establish the specifics of the avoidance and minimization recommendations necessary for each historic property and decide on the effect under Section 106. At this time, with the project controls in place (see Section 2.1.1), DOE anticipates there would be no adverse effects to historic properties as a result of the proposed action under Section 106, and there would be moderate impacts given the context and intensity under NEPA.

Post-Fire Recovery Activities

Proposed post-fire actions would expedite the development and implementation of recovery plans for individual WLF incidents. This would reduce the indirect effects of fire to historic properties by streamlining habitat recovery and restoration. Efforts to facilitate the timely recovery of native vegetation and combat the spread of invasive species are essential to stabilize soils and prevent further degradation of cultural resources impacted by fire. Timely restoration (i.e., before the next growing season) of disturbance caused by fire suppression activities (e.g., recontouring and reseeding of containment lines) would reduce the potential for repeated disturbance incurred due to delays in post-fire restoration efforts.

Post-fire recovery actions will likely vary depending on the fire suppression actions. The proposed activities would be tailored to the restoration needs that arise following a given incident or fire season. The scope of actions described in such plans will remain subject to Section 106 review on an individual basis under established INL plans and procedures.

3.8.2.1 No Action Alternative

Under the No Action Alternative, no road improvements or additional mowing beyond that which was already analyzed as part of the 2003 WLF EA would occur. Section 106 reviews would continue to be performed on a case-by-case basis for actions that occur under the 2003 EA. Additionally, consideration of impacts to cultural resources during emergency fire suppression methods and post-fire recovery are facilitated through the Wildland Fire Management Committee and Appendix F of the 2023 PA (DOE-ID 2023).

Routine maintenance of roadways has little potential to directly affect historic properties on the INL Site as actions for maintenance are limited to spot filling ruts with no grading. Current conditions on unimproved roads may have indirect or cumulative effects to historic properties by incentivizing offroad vehicle use in rough conditions and emergency events. Slow travel over unimproved routes encourages WLF equipment operators to travel overland (authorized during emergencies) to reduce response times, and results in soil disturbance in areas that would otherwise be unaffected by vehicular travel. Slower emergency response times allow fires to grow larger, resulting in a potential need for more containment lines and greater degrees of vegetation loss in larger burn areas, which ultimately impacts cultural resources through damage and displacement of artifacts and features through dozer grading and erosion susceptibility.

Mowed roadside strips along U.S. Highways 20, 26, 20/26 and State Highways 22, 28, and 33 are established within right-of-way areas maintained by the Idaho Transportation Department. These actions performed by the Idaho Transportation Department are subject to Section 106 review. Mowed roadside strips along improved roads between INL facilities have been maintained by INL since the WLF EA was issued in 2003. Areas within existing mowed roadside strips are affected by continual ground disturbance from initial road construction and maintenance, utility corridors, and drainage infrastructure. Continued maintenance of these mowed roadside strips through mowing, mechanical thinning, and herbicides is unlikely to further affect the integrity of historic properties located adjacent to, and bisected by, roads.

Following WLF events, DOE would continue to develop stand-alone recovery plans outlining measures needed to facilitate habitat recovery and address disturbances resulting from emergency response. In the absence of a formal WLF recovery guide, development of such plans would continue to require considerable time and negotiation among stakeholders, slowing or impeding implementation of recovery measures. Failure to facilitate the timely recovery of native vegetation prior to the following growing season and combat the spread of invasive species can irreversibly compromise the biotic integrity and soil stability of burn areas, with consequences for cultural resources impacted by removal of vegetation through fire. Failure to address disturbance resulting from fire suppression efforts (such as recontouring and reseeding of containment lines) prior to the next growing season may further contribute to the spread of invasive species, such as cheatgrass, increasing susceptibility to repeated fire and exacerbating vegetation and soil loss in areas containing cultural resources. As a result of the No Action Alternative, impacts to cultural resources would be moderate to high.

3.9 Accidents and Emergency Planning

DOE Order 151.D, "Comprehensive Emergency Management System," describes detailed requirements for emergency management that DOE must implement (2016). Each DOE site, facility, and activity, including the INL Site, establishes and maintains a documented emergency management program that implements the requirements of applicable federal, state, and local laws, regulations, and ordinances for fundamental worker safety programs (e.g., fire, safety, and security). In addition, each DOE site, facility, and activity containing hazardous materials (e.g., radioactive materials or certain chemicals that do not fall under the purview of fundamental worker safety programs) establishes and maintains an Emergency Management Hazardous Material program.

The emergency management system at INL includes emergency response facilities and equipment, trained staff, and effective interface and integration with off-site emergency response authorities and organizations. INL maintains the necessary apparatus, equipment, and state-of-the-art Emergency Operations Center in Idaho Falls, Idaho, to respond to emergencies not only at INL but throughout the local communities.

The purpose of the proposed action is to reduce the risks WLF poses at the INL Site and recover after a WLF occurs. Risk reduction efforts, such as improving existing roadways and creating mowed roadside strips, reduces the possibility that a large WLF would impact an INL worker, a member of the public, or INL facility. Furthermore, in efforts to restore sagebrush habitat following a WLF, the existing landscape would become more robust and resilient to the effects of a WLF.

If a WLF was to occur, the Emergency Operations Center is activated and WLF response efforts are coordinated from that office. In preparation of an event, INL workers and support personnel are prepared through training and readiness assessments.

3.10 Intentional Destructive Acts

INL routinely uses a variety of measures to mitigate the likelihood and consequences of intentional destructive acts. DOE maintains a highly trained and equipped Protective Force intended to prevent attacks against and entry into facilities and to mitigate the potential for an act of sabotage to occur on-Site.

Whether an intentional destructive act were to occur—including its exact nature, location, and consequential magnitude—is inherently uncertain. However, an intentional destructive act would be highly unlikely related to the proposed action as described in this document. INL is a protected area and under a high level of security as compared to the surrounding lands managed by other entities. If an intentional destructive act occurred on the INL Site that started a human-caused WLF, it would be managed as appropriate, regardless of the actions implemented under the proposed action.

3.11 Conclusion

Table 7 reflects the discussion of potential impacts of the proposed action and the No Action Alternative outlined in this report.

Table 7. Summary of potential impacts.

Resource Area	Potential Impact Proposed Action	Potential Impact No Action Alternative
Air Quality and Greenhouse Gases	The proposed action is expected to generate some fugitive emissions from road improvements and mowing activities. However, these emissions, including fine particulate matter (PM2.5 and PM10), will be below the significant levels set by regulations. For instance, PM2.5 emissions are estimated at 0.30 tons per year, which is well within acceptable limits. Overall, the increase in emissions is considered minor and will not significantly impact air quality.	Under the No Action Alternative, current activities at the INL Site will continue without the proposed road improvements or mowing. This means that there will be no new measures to control emissions, and air quality will likely remain the same as it currently is. Future activities will still be evaluated for their environmental impacts, but without improvements, the potential for increased emissions from uncontrolled wildfires remains.
Water Resources	The proposed action will not require drilling new wells or discharging into injection wells, and it will not cause noticeable changes in groundwater use. Dust suppression activities will use approximately 153,000 gallons of water, which is only about 0.02% of the total water used at INL in 2023. This means the increase in water use is negligible compared to the INL Site's annual water right of 11.4 billion gallons. The actions taken will not violate water quality standards or significantly alter existing drainage patterns. Potential impacts to surface water are also considered low, as these sources are not prevalent on the INL Site.	Under the No Action Alternative, current operations will continue as they are, with no new measures for managing water resources. This means there will be no additional water use or improvements to mitigate impacts. Water resources will remain managed under existing conditions, and future activities will still be evaluated. However, without the proposed enhancements, the risk of degradation from uncontrolled events may persist.

Resource Area	Potential Impact Proposed Action	Potential Impact No Action Alternative
Soil and Geology Resources	The proposed action will involve maintenance and soil disturbances along approximately 130 miles of existing roads. This will temporarily disturb soil and may expose it to wind and water erosion. However, the use of BMPs, such as silt fencing, hay bales, and revegetation efforts, will help minimize soil erosion and protect soil integrity. The transition of non-graveled roads to graveled surfaces will not expand existing borrow pits, resulting in only a small additional impact on geological resources. Furthermore, the proposed activities are not expected to be negatively impacted by potential future earthquakes.	Under the No Action Alternative, soil and geological conditions will remain unchanged, as current operations will continue without the proposed road improvements or mowing. This means no new protective measures will be implemented, leaving the area susceptible to ongoing risks of erosion from natural events. The existing conditions will persist, but without the potential benefits offered by the proposed action.
Ecological Resources	The proposed action aims to enhance fire management through the mowing of approximately 130 miles of roadside strips and the improvement of existing roads. These activities are designed to improve firefighter safety and increase access and egress to and from remote areas during wildfires. These activities may disturb approximately 2,100 acres of established vegetation. This disturbance is expected to include the removal of sagebrush and damage to native perennial grasses and forbs, which are critical components of the sagebrush steppe ecosystem. These activities may increase the potential for the establishment of noxious weeds and undesirable annual grasses, which could outcompete native species and alter habitat quality.	Under the No Action Alternative, ecological impacts will remain unchanged, and the current risk of habitat loss and fragmentation will continue without any new interventions. The tools available for post-WLF recovery will remain limited, and there will be no aerial application of herbicides to control invasive cheatgrass. Cheatgrass currently occupies about 5% of the INL Site, and without active management, the potential for further spread and associated changes in fire frequency remains. The absence of new fire management strategies may exacerbate ecological risks, particularly in the context of uncontrolled wildfires.

Resource Area	Potential Impact Proposed Action	Potential Impact No Action Alternative
	Additionally, road improvements may lead to changes in local hydrology, affecting water flow along and adjacent to roadways, which could impact surrounding native plant communities and wildlife. The proposed action includes roughly 1,700 acres of sagebrush mitigation measures as part of existing agreements that require replacing displaced sagebrush, which is essential for maintaining the ecological integrity of the area. Should BMPs and mitigation measures be diligently followed, any potential impacts are expected to be minimized, and potential benefits, maximized thereby helping to stabilize the ecosystem and support the recovery of impacted native vegetation and wildlife over time.	
Noise	The proposed action will generate noise from mechanical equipment used for mowing and other activities within the INL Site boundary, with sound levels expected to range from 80–100 decibels (dBA). This noise is consistent with existing levels from operations, such as traffic on U.S. Highway 20, and is not anticipated to significantly alter the overall noise environment. Operators will use appropriate personal protective equipment (PPE) to mitigate any impacts. Given the distance to the nearest offsite receptors, cumulative noise from the proposed action is expected to be negligible.	Under the No Action Alternative, noise impacts will remain unchanged, as current operations will continue without new measures. Existing noise levels from traffic and INL activities will persist, and no significant alterations to noise disturbances for nearby agricultural properties are expected.

Resource Area	Potential Impact Proposed Action	Potential Impact No Action Alternative
Cultural Resources	The proposed action includes road improvements and mowing activities that will impact cultural resources within the APE. These activities could potentially disturb archaeological sites and historic properties, possibly damaging or displacing artifacts. However, measures will be taken to avoid significant impacts, such as using geotextile fabric to protect sensitive areas and conducting cultural resource awareness training for staff. The aim is to stabilize roadbeds and improve access for emergency response, which can ultimately reduce the risk of wildfires damaging cultural sites. If implemented effectively, these actions will lead to long-term benefits by preserving the integrity of cultural resources and facilitating quicker recovery efforts after a wildfire.	Under the No Action Alternative, current practices will continue without new road improvements or mowing. This means that cultural resources will remain at risk without enhanced protections. Although Section 106 reviews will still be performed on a case-by-case basis, the lack of proactive measures will lead to ongoing degradation of historic properties. Additionally, the existing conditions may encourage offroad vehicle use during emergencies, causing unintended damage to cultural sites. The cumulative effects of this approach could result in moderate-to-high impacts on cultural resources, particularly if wildfires occur and are not managed effectively.

4. COORDINATION AND CONSULTATION

4.1 Shoshone-Bannock Tribes

DOE briefed the Shoshone-Bannock Tribes Tribal staff on [INSERT DATE] and the Fort Hall Business Council on [INSERT DATE] on the proposed capabilities.

4.2 State of Idaho

DOE briefed the Idaho Governor's Office on the proposed capabilities on [INSERT DATE].

4.3 Congressional

DOE briefed staff members of Senator Risch, Senator Crapo, and Congressman Simpson on the proposed capabilities on [INSERT DATE].

4.4 Idaho Department of Environmental Quality

DOE briefed staff from the IDEQ on the proposed capabilities operations on [INSERT DATE].

4.5 Buearu of Land Management

DOE briefed staff from the the Upper Snake Field Office of the BLM on the proposed capabilities on [INSERT DATE].

4.6 United State Fish and Wildlife Service

DOE briefed staff from the USFWS on the proposed capabilities on [INSERT DATE].

5. REFERENCES

Anders, M. H., D. W. Rodgers, S. R. Hemming, J. Saltzman, V. J. Divenere, J. T. Hagstrum, G. F. Embree, and R. C. Walter. 2014. "A Fixed Sublithospheric Source for the Late Neogene Track of the Yellowstone Hot Spot: Implications of the Heise and Picabo Volcanic Fields." *Journal of Geophysical Research: Solid Earth, V. 119.* doe:10.1002/2013JB0483.

Anderson, J. E., and R. S. Inouye. 2001. "Landscape-Scale Changes in Plant Species Abundance and Biodiversity of a Sagebrush Steppe over 45 Years." Ecological Society of America.

Anderson, J. E., K. T. Ruppel, J. M. Glennon, K. E. Holte, and R. C. Rope. 1996. "Plant Communities, Ethnoecology, and Flora of the Idaho National Engineering Laboratory." Environmental Science and Research Foundation, June.

Blew, R. D. 2010. "Jefferson Fire Recovery: Options and Recommendations for Stabilizing the Burned Area and Addressing Habitat Conservation." S.M. Stoller Corporation, August 30.

Blew, R. D., and A. D. Forman. 2010. "Tin Cup Fire Recovery Report." S.M. Stoller Corporation, December.

Blickley, J. L., D. Blackwood, and G. L. Patricelli. 2012. "Experimental Evidence for the Effects of Chronic Anthropogenic Noise on Abundance of Greater Sage-Grouse at Leks." Conservation Biology.

BLM. 2022. *BLM - Idaho Special Status Species Animal List.* March 24. Accessed May 21, 2025. https://www.blm.gov/sites/blm.gov/files/docs/2022-04/Programs_FishandWildlife_BLMIdaho_Special_Status_Species_Animals_2022.pdf.

—. 2022. *Idaho Rare Plants.* Accessed March 15, 2025. https://www.blm.gov/programs/natural-resources/native-plant-communities/rare-and-cultural-plant-conservation/idaho.

—. 2023. "Programmatic Environmental Impact Statement Addressing Vegetation Treatments Using Herbicides." Bureau of Land Management, December.

Chalfoun, A. D., F. R. Thompson III, and M. J. Ratnaswamy. 2002. "Nest Predators and Fragmentation: a Review and Meta-Analysis." Conservation Biology, April.

Chambers, J. C., E. K. Strand, L. M. Ellsworth, C. M. Tortorelli, A. K. Urza, M. R. Crist, R. F. Miller, M. C. Reeves, K. C. Short, and C. L. Williams. 2024. "Review of fuel treatments effects on fuels, fire behavior and ecological reslilience in sagebrush (Artemisia spp.) ecosystems in the Western U.S." Association for Fire Ecology, March.

Christiansen, R. L., J. B. Lowenstern, R. B. Smith, H. Heasler, L. A. Morgan, M. Nathenson, L. G. Mastin, P. Muffler, and J. E. Robinson. 2007. "Preliminary Assessmentof Volcanic and Hydrothermal Hazards in Yellowstone National Park and Vicinity." *U.S. Geological Survey Open-file Report 2007-1071.*

Crete, M., and S. Lariviere. 2003. "Estimating the costs of locomotion in snow for coyotes." Jornal of Zoology.

Davies, K. W., J. D. Bates, and A. M. Nafus. 2012. "Comparing Burned and Mowed Treatments in Mountain Big Sagebrush Steppe." Environmental Management, June.

—. 2012. "Mowing Wyoming Big Sagebrush Communities With Degraded Herbaceous Understories: Has a Threshold Been Crossed." Rangeland Ecology and Management, September.

DeGregorio, B. A., P. J. Weatherhead, and J. H. Sperry. 2014. "Power lines, roads, and avian nest survival: Effects on predator identity and predation intensity." Ecology and Evolution, March.

Dinkins, J. B., and J. L. Beck. 2019. "Comparison of conservation policy benefits for an umbrella and related sagebrush-obligate species." Human-Wildlife Interactions, December.

DOE. 2014. "Candidate Conservation Agreement for Greater Sage-grouse (Centrocercus urophasianus) onthe Idaho National Laboratory Site." *DOE/ID-11514.* U.S. Department of Energy and U.S. Fish and Wildlife Service, September.

—. 2023. "FY 224 Idaho National Laboratory Site Sustainability Plan." *DOE/ID-11383.* Idaho Falls: U.S. Department of Energy Idaho Operations Office, December.

—. 2018. "Idaho National Laboratory Site Bat Protection Plan." *DOE/ID-12002.* Idaho Falls, ID: U.S. Department of Energy Idaho Operations Office, September.

DOE-ID. 2024. "2023 Idaho National Laboratory Annual Site Environmental Report." *DOE/ID-12082(23).* Department of Energy Idaho Operations Office, September.

DOE-ID and BLM. 2004. "Final Management Plan Finding of No Significant Impact: INEEL Sagebrush Steppe Ecosystem Reserve." *EA ID-074-02-067.* Department of Energy - Idaho Operations , May.

DOE-ID. 2003. "Idaho National Engineering and Environmental Laboratory Environmental Assessment and Finding of No Significant Impact." *DOE/EA-1372.* Idaho Falls : U.S. Department of Energy Idaho Operations Office, April.

—. 2023. "Programmatic Agreement Among the Department of Energy, Idaho Operations Office, the Idaho State Historic Preservation Office, and the Advisory Council on Historic Preservation." *NE700154.* Idaho Falls, ID: U.S. Department of Energy Idaho Operations Office.

Edgel, R. J., R. T. Larsen, J. C. Whiting, and B. R. McMillan. 2018. "Space Use, Movements, and Survival of Pygmy Rabbits in Response to Construction of a large Pipeline." Wildlife Society Bulletin, September.

Ellsworth, L. M., B. A. Newingham, S. E. Shaff, C. L. Williams, E. K. Strand, M. Reeves, D. A. Pyke, E. W. Schupp, and J. C. Chambers. 2022. "Fuel reduction treatments reduce modeled fire intensity in the sagebrush steppe." Ecosphere, January.

Elseroad, A. C., and N. T. Rudd. 2011. "Can Imazapic Increase Native Species Abundance in Cheatgrass (Bromus tectorum) Invaded Native Plant Communities." Rangeland Ecology and Management, November.

EPA. 2014. "Emission Factors for Greenhouse Gas Inventories." April 4. Accessed May 22, 2025. https://www.epa.gov/sites/default/files/2015-07/documents/emission-factors_2014.pdf.

Ferguson, L., C. L. Duncan, and K. Snodgrass. 2003. "Backcountry Road Maintenance and Weed Management." USDA - Forest Service, July.

Forman, A. D. 2024. "The Idaho National Laboratory Site Long-Term Vegetation Transects: Updates Through 2022." *INL/RPT-24-80913.* Idaho National Laboratory, September.

Forman, A. D., C. J. Kramer, J. P. Shive, S. R. Williams, K. N. Kaser, and B. F. Bybee. 2024. "Idaho National Laboratory Site Natural Resources Wildland Fire Recovery Framework ." *INL/RPT-24-76050.* Idaho Falls, ID: Idaho National Laboratory, Natural Resources Group.

Forman, A. D., R. D. Blew, and J. R. Hafla. 2010. "The Idaho National Laboratory Site Long-term Vegetation Transects: A Comprehensive Review." S.M. Stoller Corporation, April.

Gabler, K. I., L. T. Heady, and J. W. Laundre. 2001. "A Habitat Suitability Model for Pygmy Rabbits (Brachylagus idahoensis) in Southeastern Idaho." Western North American Naturalist.

Gannon, B., Y. Wie, E. Belval, J. Young, M. Thompson, C. O'Connor, D. Calkin, and C. Dunn. 2023. "A Quantitative Analysis of Fuel Break Effectiveness Drivers in Souther California National Forests." Fire, March.

Germino, M. J., C. R. Anthony, C. R. Kluender, E. Ellsworth, A. M. Moser, C. Applestein, and M. R. Fisk. 2023. "Relationship of greater sage-grouse to natural and assisted recovery of key vegetation types following wildfire: insights from scat." Restoration Ecology, March.

Hansen, M. J., and A. P. Clevenger. 2005. "The influence of disturbance and habitat on the presence of non-native plant species along transport corridors." Biological Conservation, March.

Harrison, G. R., L. C. Jones, L. M. Ellsworth, E. K. Strand, and T. S. Prather. 2024. "Cheatgrass alters flammability of native perennial grasses in laboratory combustion experiments." Fire Ecology, November.

Heinemeyer, K. , J. Squires, M. Hebblewhite, J. J. O'Keefe, J. D. Holbrook, and J. Copeland. 2019. "Wolverines in winter: indirect habitat loss and functional responses to backcountry recreation." Ecosphere, Feburary.

Hess, J. E., and J. L. Beck. 2012. "Disturbance Factors Influencing Greater Sage-Grouse Lek Abandonment in North-Central Wyoming." Journal of Wildlife Management, July .

Hills, P. J. 1996. "What is Induced Traffic." Transportation.

IDEQ. 2004. "Big Lost River Watershed Subbasin Assessment and TMDL." Idaho Falls, ID: Idaho Department of Environmental Quality, May 6.

—. 2011. "Memorandum: Default Ambient Air Receptors for Idaho National Laboratory." Idaho Department of Environmental Quality, May 23.

IDFG. 2024. "Idaho State Wildlife Action Plan 2023." Idaho Department of Fish and Game, January.

INL. 2024. "2023 Idaho National Laboratory Annual Site Environmental Report." *DOE/ID-12082 (23).* Idaho Falls: Idaho National Laboratory, September.

—. 2022. "Sitewide Noxious Weed Management." *PLN-611.* Idaho Falls: Idaho National Laboratory, June 29.

Jochimsen, D. M., C. R. Peterson, K. M. Andrews, and J. W. Gibbons. 2004. "A Literature Review of the Effects of Roads on Amphibians and Reptiles and the Measures Used to Minimize Those Effects." Idaho State University, November.

Jones, P. F., A. F. Jakes, A. C. Telander, H. Sawyer, B. H. Martin, and M. Hebblewhite. 2019. "Fences reduce habitat for a partially migratory ungulate in the Northern Sagebrush Steppe." Ecosphere, July.

Kramber, W. J., R. C. Rope, J. Anderson, J. Glennon, and A. Morse. 1992. "Producing a Vegetation Map of the Idaho National Engineering Lab Using Landsat Thematic Mapper Data." Idaho National Engineering Laboratory.

Kuntz, M. A., B. Skipp, D. E. Champion, P. B. Gans, and D. P. Van Sistine. 2007. "Geologic Map of the Craters of the Moon 30' x 60' Quadrangle, Idaho." *U.S. Geological Survey Scientific Investigations Map.*

Kunz, M. A., B. Skipp, M. A. Lanphere, W. E. Scott, K. L. Pierce, G. B. Dalrymple, D. E. Champion, et al. 1994. "Geologic Map of the Idaho National Engineering Laboratory and Adjoining Areas, Eastern Idaho." *U.S. Geological Survey Miscellaneous Investigation Map, I-2330, 1:100,000 scale.*

Kunz, M. A., S. R. Anderson, D. E. Champion, M. A. Lanphere, and D. J. Grunwald. 2002. "Tension Cracks, Eruptive fissures, Dike, and Faults Related to Late Pleistocene-Holocene Basaltic Volcanism and Implications for the Distribution of Hydraulic Conductivity in the Eastern Snake River Plain, Idaho." *Geology, Hydrogeology, and Environmental Remediation: Idaho National Engineering and Environmental Laboratory, Eastern Snake River Plain, Idaho.* Geological Society of America Special Paper, 353.

Lazaro-Lobo, A., and G. N. Ervin. 2019. "A global examination on the differential impacts of roadsides on native vs. exotic and weedy plant species." Global Ecology and Conservation, Feburary.

Maestas, J., M. Pellant, L. Okeson, D. Tilley, D. Havlina, T. Cracroft, B. Brazee, M. Williams, and D. Messmer. 2016. "Fuel Breaks to Reduce Large Wildfire Impacts in Sagebrush Ecosystems." USDA - Natural Resources Conservation Service, March.

McBride, R., N. R. French, A. H. Dahl, and J. E. Detmer. 1978. "Vegetation Types and Surface Soils of the Idaho National Engineering Laboratory Site." *IDO-12084.* U.S. Department of Energy Idaho Operations Office, April.

McCurry, M., K. P. Hayden, L. H. Morse, and S. Mertzman. 2008. "Genesis of Post-Hot Spot, Atype Rhyolite of the Eastern Snake River Plain Volcanic Filed by Extreme Fractional Crystallization of Olivine Tholeiite." *Bulletin of Volcanology, V. 70.*

McCurry, M., T. McLing, R. P. Smith, W. R. Hackett, R. Goldby, W. Lochridge, R. Podgorney, et al. 2016. "Geologic Setting of the Idaho National Laboratory Geothermal Resource Research Area." *Proceedings, 41st Workshop on Geothermal Reservoir Engineering.* Stanford, California: Stanford University, February 22-24.

Meinzen, T. C., L. A. Burkle, and D. M. Debinski. 2023. "Roadside habitat: Boon or bane for pollinating insects." BioScience, November.

Miller, R. A., L. Bond, P. N. Migas, J. D. Carlisle, and G. S. Kaltenecker. 2017. "Contrasting Habitat Assocaitions of Sagebrush-Steppe Songbirds in the Intermountatin West." Western Birds, March.

Monson, S. B. 1994. "he competitive influences of cheatgrass (Bromus tectorum) on site restoration. In Proceedings-ecology and management of annual rangelands." US Forest Service, Intermountain Research Station.

Moriarty, K., L. Okeson, and M. Pellant. 2015. "Fuel Breaks that Work." Great Basin Factshee Series .

NatureServe. 2025. *NatureServe Explorer.* Accessed March 15, 2025. https://explorer.natureserve.org/.

O'Neil, S. T., P. S. Coates, B. E. Brussee, P. J. Jackson, K. B. Howe, A. M. Moser, L. J. Foster, and D. J. Delehanty. 2018. "Broad-scale occurrence of a subsidized avian predator: Reducing impacts of ravens on sage-grouse and other sensative prey." Journal of Applied Ecology, May.

Owens, T. M. 2025. "2024 Breeding Bird Surveys on the Idaho National Laboratory Site." *INL/RPT-25-83402.* Idaho National Laboratory , March.

Payne, S. J., and V. Montaldo Falero. 2022. "1850-2022 regional earthquake catalog compiled for the INL SSHAC Level 3 probabilitist seismic hazard analysis; Battelle Energy Alliance report." *INL/RPT-22-66235.* Idaho National Laboratory, March.

Pierce, K. L., and L. A. Morgan . 1992. "The Track of the Yellowstone Hot Spot: Volcanism, Faulting, and Uplift." *Regional Geology of Eastern Idaho and Western Wyoming: Geological Society of America Memoir.*

Pierce, K. L., and L. A. Morgan. 2009. "Is the Track of the Yellowstone Hot Spot Driven by a Deep Mantle Plume? - Review of Volcanism, Faulting, and Uplift in Light of New Data." *Journal of Volcanology and Geothermal Research, V. 188.*

—. 2009. "Is the Track of the Yellowstone Hot Spot Driven by a Deep Mantle Plume? -Review of Volcanism, Faulting, and Uplift in Light of New Data." *Journal of Volcanology and Geothermal Research, V. 88.*

—. 1992. "The Track of the Yellowstone Hot Spot: Volcanism, Faulting, and Uplift." *Regional Geology of Eastern Idaho and Western Wyoming: Geological Society of America Memoir 179.*

Poessel, S. A., D. M. Barnard, C. Applestein, M. J. Germino, E. A. Ellsworth, D. Major, A. Moser, and T. E. Katzner. 2022. "Greater sage-grouse respond positively to intensive post-fire restoration treatments." Ecology and Evolution, Feburary.

Prevey, J. S., M. J. Germino, N. J. Huntly, and R. S. Inouye. 2010. "Exotic plants increase and native plants decrease with loss of foundation species in sagebrush steppe." Plant Ecology, August.

Ratzlaff, T. D., and J. E. Anderson. 1995. "Vegetal recovery following wildfire in seeded and unseeded sagebrush steppe." Journal of Range Management, September .

Rosentreter, R., B. C. Robb, and J. S. Forbey. 2021. "Using an ultraviolet light test to improve sagebrush identification and predict forage quality for wildlife." Western North American Naturalist.

Rottler, C. M., C. E. Noseworthy, B. Fowers, and J. L. Beck. 2015. "Effects of Consersion From Sagebrush to Non-Native Grasslands on Sagebrush-Associated Species." Rangelands, Feburary.

Schusler, K. L., D. M. Pearson, M. McCurry, R. C. Bartholomay, and M. H. Anders. 2020. "Regionally Continuous Miocene Rhyolites Beneath the Eastern Snake River Plain Reveal Localized Flexure at its Western Margin: Idaho National Laboratory and Vicinity." *Rocky Mountain Geologist, V. 57.*

Shive, J. P., A. D. Forman, A. Bayless-Edwards, K. Aho, K. N. Kaser, J. R. Hafla, and K. T. Edwards. 2019. "Vegetation Community Classification and Mapping of the Idaho National Laboratory Site 2019." Veolia Nuclear Solutions - Federal Services, June.

Shive, Jeremy P. 2024. "Idaho National Laboratory Site Vegetation Map Update 2024 ." *INL/RPT-24-80957.* Idaho National Laboratory , September.

Smith, J. T., L. D. Flake, K. F. Higgins, and G. D. Kobriger. 2006. "Microhabitat Characteristics Relative To Lek Abandonment by Greater Sage Grouse in the Dakotas." Intermountain Journal of Sciences.

Smith, K. T., J. R. Levan, A. D. Chalfoun, T. J. Christiansen, S. R. Harter, S. Oberlie, and J. L. Beck. 2023. "Response of greater sage-grouse to sagebrush reduction treatments in Wyoming big sagebrush." Wildlife Monographs, March.

Smith, R. B., M. Jordan, B. Steinberger, C. M. Puskas, J. Farrell, G. P. Waite, S. Husen, W. L. Chang, and R. O'Connell. 2009. "Geodynamics of the Yellowstone Hot Spot and Mantle Plume: Seismic and GPS Imaging, Kinematics, Mantle Flow." *Journal of Volcanology and Geothermal Research, V. 88.*

Swanson, S. R., J. C. Swanson, P. J. Murphy, J. K. McAdoo, and B. Schultz. 2016. "Mowing Wyoming Big Sagebrush (Artemisia tridentata ssp. wyomingensis) Cover Effects Across Northern and Central Nevada." Rangland Ecology and Management, April.

Syphard, A. D., J. E. Keeley, and T. J. Brennan. 2011. "Comparing the role of fuel breaks across southern California national forests." Forest Ecology and Management, Feburary.

Timmer, J. M., C. L. Aldridge, and M. E. Fernandez-Gimenez. 2019. "Managing for Multiple Species: Greater Sage-Grouse and Sagebrush Songbirds." The Journal of Wildlife Management.

USFWS. 2025. *IPaC Information for Planning and Consultation.* May. Accessed May 21, 2025. https://ipac.ecosphere.fws.gov/.

Waltz, A. E.M., M. T. Stoddard, E. L. Kalies, J. D. Springer, D. W. Huffman, and A. S. Meador. 2014. "Effectiveness of fuel reduction treatments: Assessing metrics of forest resiliency and wildfire severity after the Wallow Fire, AZ." Forest Ecology and Management, September.

Weise, C. L., B. E. Brussee, P. S. Coates, D. J. Shinneman, M. R. Crist, C. L. Aldridge, J. A. Heinrichs, and M. A. Ricca. 2023. "A retrospective assessment of fuel break effectiveness for containing rangeland wildfires in the sagebrush biome." Journal of Environmental Management, April.

Young, J. A., R. A. Evans, R. E. Eckert, and B. L. Kay. 1987. "Cheatgrass." Society for Range Management, December.

Appendix A

Idaho National Laboratory Site Natural Resources Wildland Fire Recovery Framework

INL/RPT-24-76050
Revision 0

Idaho National Laboratory Site Natural Resources Wildland Fire Recovery Framework

March 2024

Amy D. Forman
Colby J. Kramer
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Samuel R. Williams
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Idaho National Laboratory

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

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EXECUTIVE SUMMARY

Introduction

As pressures from invasive species, climate change, and anthropogenic impacts increase across the landscape in the western U.S., managing wildland fire recovery to promote healthy sagebrush steppe becomes an increasingly important stewardship responsibility. The Idaho National Laboratory (INL) has developed and implemented wildland fire recovery plans to hasten desirable vegetation re-establishment on several individual fires, but lacks an overarching wildland fire recovery strategy, or framework. The intent of this document is to develop the technical approach and scientific basis for wildland fire recovery at the INL Site and to evaluate the tools available to support it in a comprehensive and broadly applicable format. This wildland fire recovery framework will outline the process of assessing the potential impacts of wildland fire on natural resources, present a range of post-fire recovery options, outline an approach for post-fire monitoring, and provide a template for post-fire recovery plans designed to addresses the specific conditions of each wildland fire.

There are numerous benefits to developing a wildland fire recovery framework for the INL Site. The first is streamlining the development of post-fire recovery plans for individual fires. A second benefit is more closely aligning INL's post-fire planning processes with those of other federal agencies. The development of an INL Site fire recovery framework will also allow resource professionals to consider a broader set of recovery tools than they have before because all proposed tools included in the framework were vetted through the process of scoping and stakeholder review. Finally, this framework is a publicly available document that can be used as a basis for communicating and discussing post-fire natural resource recovery objectives with agency collaborators, conservation partners, and other stakeholders. Through the proactive land stewardship principles outlined in this framework, current INL sustainability initiatives can be enhanced, and future INL mission flexibility will be maintained.

Background

Wildland fire was historically a dynamic component of sagebrush steppe ecosystems, though it was likely an infrequent occurrence during pre-European settlement. Fire rotation intervals for Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) have been estimated to range up to 350 years and sagebrush is not particularly well-adapted to fire, as evidenced by its lack of fire resistance, its inability to resprout, and its poor long-distance seed dispersal capability. As a foundation species, sagebrush modulates the local ecosystem and the loss of sagebrush from a plant community disproportionality affects co-occurring species and overall ecosystem function. When large regions of the sagebrush steppe shift from sagebrush-dominated shrublands to grasslands or communities dominated by resprouting shrubs, substantial changes in habitat availability and ecosystem function are expected. Because sagebrush has been lost from nearly 100,000 ha (247,105 ac) of the INL Site over the past 30 years, much of the landscape is already undergoing extensive ecological changes.

The loss of sagebrush habitats, from wildland fire or fuels management and suppression activities, can have an acute impact on wildlife. There are hundreds of birds, mammals, reptiles, and amphibians that depend on sagebrush as well as many unique insects, spiders, plants, and lichens that are closely associated with the sagebrush community and utilize it in a variety of ways during various seasons. Species such as sage-grouse (*Centrocercus urophasianus*) and pygmy rabbit (*Brachylagus idahoensis*) depend on relatively large expanses of sagebrush-dominated shrub steppe and are entirely dependent on sagebrush habitats for successful reproduction and winter survival. Songbirds rely on it for nesting and escape cover, and various small mammals use it as shelter and travel corridors.

Post-Fire Ecological Resource Assessments

Before post-fire treatment options can be evaluated for a specific wildland fire, the potential impacts to natural resources from the wildland fire and associated fire suppression activities must be characterized. For previous INL Site fire recovery plans, potential impacts to natural resources were characterized using an ecological resource assessment, and this approach was useful for identifying areas that should be prioritized for treatment. To allow for timely planning and execution of proposed treatments, an ecological resource assessment and a fire-specific natural resource recovery plan should be completed as quickly as possible. The ecological resource assessment process can be expedited by completing analyses at a high level, using existing natural resource monitoring data. This approach necessitates an understanding that ground-based evaluations are often required prior to initiating a treatment to ensure current on-the-ground conditions are as expected and treatment criteria are met. Potential treatment areas may then be prioritized based on minimizing the risk of poor ecological recovery, accelerating the recovery of important or high-use habitats, and limiting overall loss of ecosystem function. In many cases, results of an ecological resource assessment can be synthesized to focus restoration efforts within the context of the landscape, so that areas with maximum benefit in terms of restoring habitat connectivity or limiting vectors for weed spread can be targeted.

Natural Resource Recovery Tools

The overarching goals that guided the development of this framework focus on maintaining a healthy, functional ecosystem at the INL Site through a proactive land stewardship approach to wildland fire recovery. To address these goals, fire recovery treatment options are organized into four objectives based on the types of ecological risks they address. The INL's wildland fire recovery objectives are:

1. To stabilize soils and minimize erosion,
2. To limit cheatgrass dominance and control the spread of noxious weeds,
3. To facilitate the recovery of a resilient native herbaceous layer, and
4. To speed the recovery of functional sagebrush habitat.

The natural resource recovery objectives presented in this framework reflect those addressed in the two most recent wildland fire recovery plans developed for the INL Site. The structure and organization of both documents and the process for prioritizing treatment actions presented therein were useful to the INL's Wildland Fire Management Committee, so the fire recovery objectives and plan structure will continue to be used throughout this framework and in future individual fire recovery plans.

Soil stabilization is often the first natural resource recovery objective to be addressed post-fire. Soils are disturbed during firefighting activities like containment line construction, and soils are also left exposed when wildland fire removes vegetation structure across the surface of the entire burned area. Erosion, primarily from wind, can move large volumes of soil in a relatively short post-fire timeframe. Natural recovery will sufficiently stabilize soils after the first post-fire growing season across much of the affected footprint. However, the hazards associated with wind erosion following wildland fire, like fugitive dust and blowing sand may cause potential impacts downwind of disturbed areas. Therefore, the options for improving post-fire recovery of exposed soils that will be included in post-fire natural resource recovery plans are generally limited to mitigating the impacts to INL operations from fugitive dust, stabilizing soils impacted by firefighting activities, and restoring areas impacted during emergency infrastructure repair following a wildland fire.

The risk of reduced ecosystem function due to non-native species encroachment is a critical post-fire concern and reducing that risk is an important natural resource recovery objective. There are several non-native species of concern that are widely distributed across the INL Site. These species do not dominate large extents of the INL Site, but they can form localized, degraded stands that are characterized by low biodiversity, limited habitat value, and poor ecological condition. Cheatgrass is the only non-native species, widely considered to be an invasive annual grass, that has been documented on the INL Site, and though it does not currently dominate enough of the native habitat to influence fire regime or impact overall habitat condition, the risk of post-fire transition to more cheatgrass dominated plant communities is high and should be addressed accordingly. Likewise, noxious weeds, as defined by the State of Idaho, are one of the largest disruptors of ecosystem function and the longer the presence of noxious species is overlooked, the harder and more expensive it is to control them. Tools for limiting post-fire weed spread are organized by those treatments that are specific to cheatgrass and those that are specific to noxious weeds. Each functional group is addressed individually because their biology, the mechanism on which treatments act, and their invasion patterns are different. Within each functional group, chemical options are available, and they will often be the most feasible and cost-effective option for large treatment areas, but other options, like mechanical or environmental controls may be more situationally appropriate and should be considered where suitable within each natural resources post-fire recovery plan.

Improving recovery of native herbaceous vegetation post-fire was identified as a natural resource recovery objective for several reasons. A healthy and diverse herbaceous layer can impart resilience to a plant community, which can improve natural recovery after a disturbance like wildland fire or in response to an abiotic stressor like drought. Resistance to weed invasions and infestations is generally much higher in vegetation with an abundant native perennial component, and habitat for taxa ranging from plants and invertebrates to birds and mammals is improved by a healthy herbaceous stratum. Options for improving post-fire ecological condition where herbaceous recovery is expected to be poor include working with BLM to reduce grazing pressure and planting native herbaceous species. There are two primary reasons for reducing grazing pressure; to decrease stress on naturally resprouting and reseeding species and to allow seedlings from active treatments to become established. In addition, reducing grazing pressure directly limits the spread of weed seed into fire-affected areas. The restoration tools associated with planting are organized into three topical areas and include selecting appropriate plant materials, applying effective growing and planting techniques, and adding supplemental treatments that can be used to improve restoration success.

Sagebrush is a foundation species of the ecosystem occupied by the INL Site, and healthy sagebrush stands are crucial for the structure and function of the natural landscape. Sagebrush shrublands are the primary food source for many wildlife species, especially through the winter months, and they provide much of the vertical structure for concealment and protection from exposure year-round. Additionally, deep rooted sagebrush shrubs effectively return soil moisture to the atmosphere and maintain the heterogeneous distribution of soil nutrients characteristic of natural arid systems. For these reasons, facilitating the recovery of functional sagebrush habitat was included as one of four post-fire recovery objectives. The approach for reducing sagebrush habitat recovery time after wildland fire includes identifying and prioritizing areas where sagebrush restoration can provide the greatest benefit and planting sagebrush seeds or seedlings to augment natural recovery. This framework presents options for plant materials acquisition; growing, if seedlings will be used; and planting for both seed and seedlings.

Post-Fire Natural Resource Monitoring

Monitoring should be considered a fundamental component of natural post-fire recovery, post-fire treatment, and other management actions because it provides timely insight regarding the success of implemented actions or the necessity of implementing actions where conditions are deteriorating. Effective monitoring plans are those that establish a process to collect, analyze, and use data to track the status of the natural resources of interest and the effectiveness of any implemented actions. This two-pronged approach will allow us to answer two fundamental questions:

1. Are natural resource recovery objectives being met through natural recovery processes, and

2. If actions are taken to assist the natural recovery processes, are those actions effective?

Post-fire ecological monitoring will ultimately be used to inform an adaptive management approach to post-fire recovery. Ecological communities are complex, and natural resource professionals often face uncertainties about which strategies will best contribute to achieving recovery goals following a large disruptive event such as wildfire. An adaptive management framework is a common, practical methodology that can be applied to post-fire recovery to determine if a restoration action is necessary to meet natural resource recovery goals. Adaptive management is rooted in the idea that proposed treatments or management actions should not simply be trial and error over time, but rather purposeful, strategic actions that build upon lessons learned. Management goals or actions are generally defined, implemented, monitored, and lastly modified based on what was learned following the initial implementation.

A post-fire monitoring plan will be developed to support each natural resource wildland fire recovery plan. The monitoring plan will cover the duration of the post-fire recovery plan and will be accompanied by annual reports to summarize monitoring results and identify suitable adaptive management responses when appropriate. The primary components and considerations of a monitoring plan include identifying monitoring needs, establishing benchmarks against which to evaluate progress, selecting appropriate monitoring techniques, defining the approach to data summary and analysis, and evaluating natural recovery or additional treatment options that should be considered.

Natural Resources Wildland Fire Recovery Plan Template

The final section of this document provides a general template for a natural resource wildland fire recovery plan. Each subsection presents a summary of anticipated content that should be included in each plan. At a minimum, each natural resource wildland fire recovery plan will include a brief background summarizing our natural resource recovery goals and objectives as described in this framework; a description of the wildland fire; results of the ecological resource assessment, organized by soils, vegetation, and wildlife; a list of recommended postfire restoration actions and associated treatment options, organized by recovery objectives; and an overview of the post-fire natural resources monitoring plan.

ACKNOWLEDGEMENTS

We would like to thank the members of the DOE/INL internal stakeholder group who participated in a series of meetings to develop the scope and post-fire treatment options presented in this framework. Members of this diverse team included individuals from DOE-ID, the INL Fire Department, Facilities and Site Services, the Office of Campus Planning and Space Management, the NEPA team, and the Cultural Resources Management Office. Several external stakeholders provided valuable insight, feedback, and reference materials, both for this framework and for preceding fire recovery plans that informed this effort; they include professionals from the BLM, USFWS, USGS, and IDFG. We would also like to acknowledge Dakotah Smith for providing a literature review of several sections and Sarah Baccus for a thorough editorial review of the document. Brande Hendricks adeptly handled document management and formatting.

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CONTENTS

FIGURES

TABLES

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ACRONYMS

BBS	Breeding Bird Survey
BLM	Bureau of Land Management
BMP	Best Management Practice
BPP	Bat Protection Plan
CCA	Candidate Conservation Agreement
CRMO	Cultural Resource Management Office
DOE	Department of Energy
DOE-ID	Department of Energy-Idaho Operations Office
EA	Environmental Assessment
EPA	Environmental Protection Agency
IDFG	Idaho Department of Fish & Game
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
F&SS	Facilities and Site Services
GIS	Geographic Information System
ICP	Idaho Cleanup Project
INL	Idaho National Laboratory
MOU	Memorandum of Understanding
NERP	National Environmental Research Park
NRG	Natural Resources Group
SSP	Special Status Plant
U.S.	United States
USFWS	United State Fish and Wildlife Service
USGS	United States Geological Survey
UTV	Utility Terrain Vehicle
WFMC	Wildland Fire Management Committee

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1. BACKGROUND

The Idaho National Laboratory (INL) Site occupies approximately 2,305 km^2 (890 mi^2) of the Upper Snake River Plain in Southeast Idaho (Figure 1-1). It was established as the National Reactor Testing Station in 1950 and continues to be used to "discover, demonstrate and secure innovative nuclear solutions, other clean energy options and critical infrastructure." The ecosystem of the INL Site is characterized by cold desert sagebrush steppe and wildland fire has been a dynamic component of the ecosystem for millennia. As pressures from invasive species, climate change, and anthropogenic impacts increase across the landscape in the western U.S., managing wildland fire recovery to promote healthy sagebrush steppe becomes an increasingly important stewardship responsibility. The INL has developed and implemented wildland fire recovery plans to hasten desirable vegetation re-establishment on several individual fires (e.g., Forman et al. 2020, Blew et al. 2010), but lacks an overarching wildland fire recovery strategy, or framework.

A wildland fire recovery framework will outline the process of assessing the potential impacts of wildland fire on natural resources, present a range of post-fire recovery options, provide a template for post-fire recovery plans designed to addresses the specific conditions of each wildland fire, and outline an approach for post-fire monitoring. This framework document will evaluate the potential restoration tools available for post-fire recovery, identify the conditions under which each tool should be considered, summarize the efficacy of each tool, and discuss the risks associated with each tool. The intent of this document is to develop the technical approach and scientific basis for wildland fire recovery at the INL Site and to evaluate the tools available to support it in a comprehensive and broadly applicable format. This document will also include a template that can be used to summarize the natural resource assessment and recommended post-fire recovery actions for each individual fire. Because this framework will contain all the supporting material needed for plan development, each individual fire recovery plan can remain brief and straightforward, with minimal technical justification.

There are numerous benefits to developing a wildland fire recovery framework for the INL Site. The first is streamlining the development of post-fire recovery plans for individual fires. As described above, individual fire recovery plans will be more concise, and therefore, they will require less time and effort to draft than they have previously. A second benefit is more closely aligning INL's post-fire planning processes with those of other local agencies. The Upper Snake Field Office of the Bureau of Land Management (BLM), for example, has been using a similar framework effectively for many years (e.g., BLM USRD-E 2004). The development of an INL Site fire recovery framework will also allow resource professionals to consider a broader set of recovery tools than they have before because all proposed tools included in the framework were vetted through the process of scoping and stakeholder review. Finally, this framework is a publicly available document that can be used as a basis for communicating and discussing post-fire natural resource recovery objectives with agency collaborators, other stakeholders, and conservation partners.

Figure 1-1. Location of the Idaho National Laboratory Site within Southeast Idaho.

2

1.1 Purpose and Scope

The purpose of this wildland fire recovery framework is to provide a comprehensive strategy for wildland fire recovery on the INL Site along with an evaluation of the tools available to facilitate natural resource recovery and minimize the risk of unfavorable outcomes, like weed invasions or loss of ecosystem function. The recovery strategy presented in this framework is applicable to all land within the INL Site boundary (Figure 1-1). It is the responsibility of the Wildland Fire Management Committee (WFMC; INL 2012) to meet after any wildland fire larger than 40 ha (100 ac) or any wildland fire where containment lines have been used (INL 2023a) to determine the need for a wildland fire natural resources recovery plan. Generally, a plan should be developed after any wildland fire larger than 40 ha (100 ac), to address soil disturbance resulting from containment line construction for wildland fires of any size, or after smaller wildland fires that have the potential to substantially affect sensitive natural resources (e.g., bat hibernacula or sage-grouse nesting habitat). Multiple fires occurring within one season may be included within a single annual plan. When a plan is requested by the WFMC, it will include an assessment of the natural resources impacted by the wildland fire or associated firefighting activities, the potential risk of poor recovery to natural resources, recovery treatment options that may be considered to reduce those risks, and an adaptive management based monitoring plan to prioritize treatment areas and evaluate the efficacy of treatments. Each post-fire natural resources recovery plan and monitoring plan will be implemented over a five-year time-period immediately post-fire. The period of five years generally aligns with similar processes used by other agencies and has been successfully implemented previously at the INL.

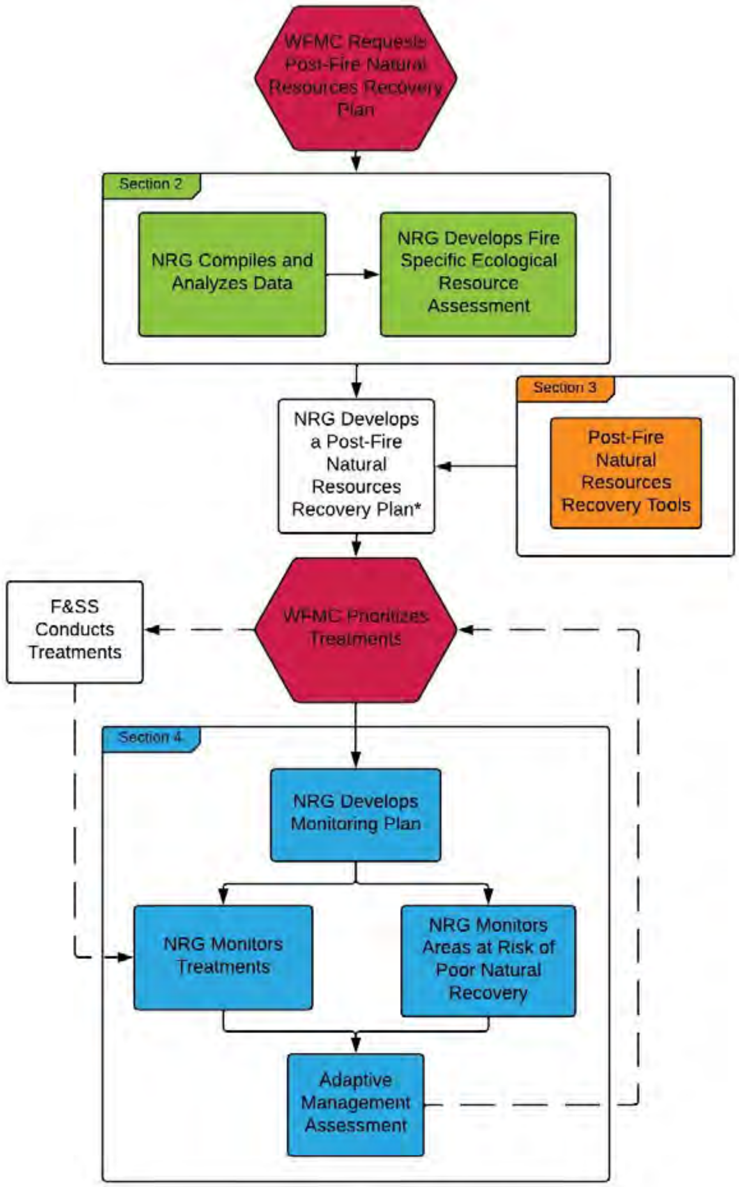
To help define INL's post-fire stewardship approach, there are four overarching goals that guided the development of this framework. Successful implementation of this framework will help achieve the following goals:

1. Reduce the risk of noxious and invasive species spread to the extent possible.
2. Maintain the diversity and resilience of the INL Site vegetation and wildlife communities.
3. Ensure the local ecosystem can continue to provide ecosystem services by maintaining functional processes like water balance, nutrient cycling, and carbon storage.
4. Mitigate potential changes to the historical fire disturbance regime with respect to fire frequency and the annual grass feedback cycle.

Through the proactive land stewardship principles outlined in this framework, current INL sustainability initiatives can be enhanced, and future INL mission flexibility will be maintained.

1.1.1 Fire Recovery Planning Process

Once the WFMC requests a natural resources wildland fire recovery plan, the Natural Resources Group (NRG) will compile and analyze available data to complete a post-fire ecological resources assessment. Results of the assessment will be used to identify and prioritize treatments in areas at risk of slow or poor natural recovery, and this framework will be used to develop a list of recovery tools appropriate to address the risks associated with each wildland fire. Each natural resources wildland fire recovery plan will include results of the post-fire ecological resources assessment, potential treatment areas and recommended treatment tools, and an outline of the post-fire monitoring plan (Figure 1-1). Enough information will be provided in each plan so that the WFMC can effectively evaluate and prioritize treatment options. All treatment options will be evaluated through the Environmental Review Process prior to initiation to ensure that all environmental concerns, including cultural resources, have been addressed. Each plan will also contain enough information about treatment options so that Facilities and Site Services (F&SS) can proceed with work planning once treatment options have been prioritized. Once treatments are prioritized by the WFMC, NRG will finalize a monitoring plan to evaluate the



*NRG will consult with agency stakeholders as needed.

Figure 1-2. Post-fire ecological resource assessment, post-fire natural resource recovery plan development, and post-fire monitoring process.

effectiveness of the treatments as well as the recovery status of areas at risk of poor recovery. After monitoring has occurred for the treatments and for areas at risk of poor recovery, results will be evaluated against success criteria. Additional adaptive management actions will be recommended to the WFMC as needed.

Effects to cultural resources, in particular historic properties, will be evaluated following wildland fire events pursuant to Appendix F of the 2023 Programmatic Agreement among DOE-ID, the Idaho State Historic Preservation Office, and the Advisory Council on Historic Preservation. Early involvement of the INL Cultural Resource Management Office (CRMO) during development of post-fire recovery plans will help to avoid or minimize effects to historic properties. Beneficial actions, such as additional soil stabilization efforts, for preservation and protection of historic properties may also be considered when developing post-fire recovery plans. Avoidance measures will be developed on a case-by-case basis and may include but are not limited to flagging, temporary fencing, monitoring, or any combination of tools available at the time of review. In areas identified for restoration that lack cultural resource surveys, additional surveys may be necessary to identify historic properties if the treatments proposed in post-fire recovery plans have the potential to affect historic properties.

Government agencies and academic research institutions are continuously developing strategies, guidance documents, and tools to facilitate post-fire resource assessment and to improve the efficacy of post-fire treatments. Many of these resources are relevant to the post-fire planning and recovery process at the INL Site. These resources have not been referenced individually as they will continue to change and improve, and new resources will become available throughout the lifespan of this framework. This does not preclude the use of these resources, and NRG will evaluate and apply these resources, as appropriate, throughout the post-fire planning and recovery process. Furthermore, wildland fire science is advancing quickly and because INL land use priorities change and evolve, this framework should be periodically reevaluated to ensure it remains useful and relevant.

1.1.2 Applicable Ecological or Natural Resource Regulations

The land currently occupied by the INL Site is under federal ownership. Some of the land is owned by the Department of Energy (DOE), but much of it is Department of the Interior land that was withdrawn from the public and would otherwise be managed by the BLM (see Section 1.2 for additional information). The BLM currently manages grazing allotments across a large portion of the INL Site and the responsibilities of remaining land management activities are outlined in a Memorandum of Understanding (MOU) between Department of Energy-Idaho Operations Office (DOE-ID) and BLM Idaho Falls District, Upper Snake Field Office. Because of its status as withdrawn BLM land, the regulations that govern land management activities on BLM land should also be considered as appropriate land stewardship actions on the INL Site. In addition, there are several DOE plans and Executive Orders that should be addressed in land management decision-making. Some of the guiding legislation most pertinent to INL's wildland fire recovery framework is outlined below.

The INL Site has also been designated a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or superfund, site. As such, there are requirements and engineering controls in place with respect to vegetation cover on specific environmental cleanup project sites and wildland fire may impact vegetation cover on those project sites. The Idaho Cleanup Project (ICP) manages most activities related to CERCLA on the INL Site. Though it is outside of the scope of this framework to detail all the regulatory documents pertaining to environmental cleanup activities and institutional controls pertaining to CERLCA, INL will work closely with ICP to ensure that CERCLA requirements are considered when developing recovery strategies.

1.1.2.1 Memorandum of Understanding Between DOE-ID & BLM

Memorandum of Understanding Between Department of Energy, Idaho Operations Office and Bureau of Land Management (MOU NO. ID11451)

This MOU is between the Department of Interior, BLM Idaho Falls District, Upper Snake Field Office (BLM-USRD) and the DOE, acting through its Idaho Operations Office. It provides for the cooperative management of certain land within the INL Site. The BLM is granted authority to enter into this cooperative agreement under the Federal Land Policy and Management Act of 1976 and DOE-ID is granted authority to enter this cooperative agreement under the Atomic Energy Act (MOU No, ID11451). This MOU outlines the responsibilities of each agency with respect to grazing, predator control, range improvements, noxious weeds or insect infestations, Upper Snake River ecosystem stewardship, rights-of-way, mineral exploration and mineral material disposal, fire suppression/management and other emergencies, collaborative resource management, and general agreement on third party use of land within the INL. In the context of this framework, this MOU will provide direction on which activities associated with wildland fire recovery requires collaboration with BLM.

1.1.2.2 Applicable Regulations

Federal Insecticide Fungicide Rodenticide Act (7 U.S.C. §136 et seq. (1996))

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provides for federal regulation of pesticide distribution, sale, and use. All pesticides distributed or sold in the U.S. must be registered (licensed) by the Environmental Protection Agency (EPA). Before the EPA may register a pesticide under FIFRA, the applicant must show, among other things, that using the pesticide according to specifications "will not generally cause unreasonable adverse effects on the environment." FIFRA defines the term "unreasonable adverse effects on the environment" to mean: "(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide, or (2) a human dietary risk from residues that result from a use of a pesticide in or on any food inconsistent with the standard under Section 408 of the Federal Food, Drug, and Cosmetic Act." All safety information and approved uses of each registered pesticide can be found on the product's label. Pesticide labels and instructions are required to be followed under federal law and any deviation from use as described on the label shall be considered a federal offense. Throughout this framework the use of pesticides may be recommended for certain treatments such as discouraging the establishment and spread of invasive plant species. Any pesticide treatment recommendation described in this framework will be implemented in accordance with the specific pesticide label and FIFRA.

Plant Protection Act of 2000 ((7 U.S.C. § 7701 et seq. (2000))

The Plant Protection Act of 2000 as amended discusses the importance of detection, control, eradication, suppression, prevention, or retardation of the spread of plant pests or noxious weeds. This Act also establishes the responsibility of federal agencies to facilitate exports and imports of agricultural products in a manner that prevents the spread of invasive or noxious weeds. This Act defines noxious weeds as any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the U.S., the public health, or the environment. Requirements described in this act associated with the prevention of further spread of invasive species are in alignment with requirements in IDAPA 02.06.09 (see discussion below). All post-fire treatment recommendations that require plant materials to be acquired or propagated outside of INL Site boundaries will comply with the requirements of this act.

Executive Order 13751, Safeguarding the Nation from the Impacts of Invasive Species

Executive Order (EO) 13751, Safeguarding the Nation from the Impacts of Invasive Species, defines and outlines the responsibilities of agencies to, "prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established."

Further explaining that, "Invasive species pose threats to prosperity, security, and quality of life. They have negative impacts on the environment and natural resources, agriculture and food production systems, water resources, human, animal, and plant health, infrastructure, the economy, energy, cultural resources, and military readiness." Additionally, EO 13751 amends existing EO 13112, Invasive Species. These amendments include an updated list of Federal Agency duties relating to actions that may affect the introduction, establishment, or spread of invasive species. Included in these duties is for each federal agency to, "assess and strengthen, as appropriate, policy and regulatory frameworks pertaining to the prevention, eradication, and control of invasive species and address regulatory gaps, inconsistencies and conflicts." Because wildland fire inherently increases the risk of establishment and spread of invasive species, this framework will address compliance with EO 13751.

Executive Order 14008, Tackling the Climate Crisis at Home and Abroad

Executive Order 14008, Tackling the Climate Crisis at Home and Abroad establishes the need for the U.S. to increase the speed and scale of necessary actions to mitigate the effects of the climate crisis. Additionally, this EO states, "The United States will also move quickly to build resilience, both at home and abroad, against the impacts of climate change that are already manifest and will continue to intensify according to current trajectories." To address this objective, EO 14008 requires that federal agencies identify strategies that will encourage broad participation in the goal of conserving 30 percent of the Nation's lands and waters by 2030. As a response to this requirement, DOE developed a Climate Adaptation and Resilience Plan. The Climate Adaptation and Resilience Plan states, "DOE manages over two million acres of land, over half of which is comprised of vegetated or forested land. In these areas, DOE will continue to advance its ecological and land use management practices as a tool to enhance resilience (e.g., reduce impacts from wildfires) and to mitigate greenhouse gas emissions (e.g., provide additional carbon storage benefits)." These commitments will be considered while carrying out recommendations made using this framework.

DOE Order 436.1A, Departmental Sustainability

The purpose of DOE O 436.1A is to establish an integrated approach to implementing sustainability in DOE operations as DOE carries out its missions, including addressing challenges to national energy security, advancing reliable energy for the future, conserving natural resources, and ensuring DOE achieves sustainability goals outlined in applicable laws, regulations and EOs. Aspects of DOE O 436.1A that pertain to the natural resources wildland fire recovery framework are direction to 1. Manage land to protect natural resources, utilize nature-based solutions, and preserve ecosystem services, 2. Use site-specific ecological research to inform conservation planning and land use decisions, and 3. Engage with Tribal authorities regarding resources of Tribal significance and applying applicable Indigenous Knowledge. Successful implementation of this recovery framework will enhance ecosystem resilience, provide nature-based solutions for carbon storage, preserve ecosystem services, and minimize the potential for regulatory restrictions through proactive habitat management. All aspects of DOE O 436.1A pertinent to each wildland fire will be considered as individual fire recovery plans are drafted.

IDAPA 02.06.09 Rules Governing Invasive Species and Noxious Weeds

The State of Idaho rule, IDAPA 02.06.09, "Rules Governing Invasive Species and Noxious Weeds," governs the designation of invasive species, inspection, permitting, decontamination, recordkeeping, and enforcement and apply to the possession, importation, shipping, transportation, eradication, and control of invasive species within the State of Idaho, in alignment with the Plant Protection Act of 2000. This rule identifies those plants that have been officially designated as noxious weeds in the State of Idaho, designates articles capable of disseminating noxious weeds, requires treatment of articles to prevent dissemination of noxious weeds, and provides authority to designate cooperative weed management areas for management of noxious weeds (ISDA 2022). Furthermore, this rule establishes a system for designating noxious weeds within the State of Idaho as Statewide Early Detection/Rapid Response species, Statewide Control Species, or Statewide Containment Species. Any Statewide Early

Detection/Rapid Response species found within Idaho must be reported to Idaho Department of Agriculture within ten days following positive identification and shall be eradicated during the same growing season. Weeds listed as the Statewide Control Species are known to exist throughout the state, and populations of these weeds are distributed such that control or eradication, or both, may be possible. Weeds listed as Statewide Containment Species are known to exist throughout the state and populations are widespread enough that control efforts are directed at reducing or eliminating new or expanding weed populations and managing known and established populations to prevent further spread. Idaho Administrative Code 02.06.09, "Rules Governing Invasive Species and Noxious weeds" provides a current list of species designated as Noxious Weeds (ISDA 2022). Additionally, this rule governs the inspection, certification, and marking of noxious weed free forage and straw to allow for the transportation and use of forage and straw in Idaho and states where regulations and restrictions are placed on such commodities. This rule should be used as the basis for identifying and determining which species are considered noxious and should be treated as such, as well as for determining restrictions on plant materials used for restoration.

1.1.2.3 Federal Policies, Standards, and National Strategies

Federal Wildland Fire Management Policy (NIFC 2001)

In 2001 a multi-agency working group that included DOE released a review and update of the 1995 Federal Wildland Fire Management Policy (Douglas et al. 2001). The findings of this review and update of the 1995 Policy were reflected in the 2001 Federal Wildland Fire Management Policy (Douglas et al. 2001). The 2001 Federal Wildland Fire Management Policy and its implementation are founded on several guiding principles, which all participating agencies are expected to adhere and adopt. These guiding principles address topics ranging from firefighter/public safety and implementing sound risk management strategies to understanding the role of fire as an essential ecological process and building fire management plans upon the best available science. The INL can use these guiding principles to align wildland fire management decision making with surrounding agencies to the greatest extent possible.

Fire Protection, DOE Standard 1066 (2023)

This standard was developed to support the implementation of DOE Order 420.1C Chg. 3, Facility Safety. Specifically, it provides criteria and guidance for developing site-specific fire protection programs for DOE facilities. This standard was considered during the development of this recovery framework because it provides some interpretation of, and DOE guidance related to federal policy for rehabilitation and restoration post-fire. To address federal wildland fire policy, DOE provides the following guidance for post-fire activities, 1. An assessment of watershed conditions should be conducted immediately post-fire, 2. The need for emergency rehabilitation efforts should be identified where necessary to minimize damage to soil resources and restore watershed function, 3. Rehabilitation efforts should be used to stabilize biotic communities, address safety concerns, and prevent further degradation of resources, and 4. Treatments should be monitored for efficacy. Because the topography of the INL Site is not conducive to a watershed management approach, some guidance related to restoring watershed function is not directly applicable to the INL Site. However, the general post-fire rehabilitation and restoration guidance presented in DOE Standard 1066 are addressed by the ecosystem function, biodiversity, and biotic community resilience goals that guided the development of this framework, as discussed above.

National Strategy to Promote the Health of Honeybees and Other Pollinators 2015

The National Strategy to Promote the Health of Honeybees and Other Pollinators was created in 2015 by the Pollinator Health Task Force, which included a DOE representative, to increase the national awareness of the importance of pollinator conservation and is addressed in agency plans for public outreach and education. The DOE Pollinator Protection Plan is included as Appendix E of the National Strategy, and it describes how DOE can adopt best management practices (BMP)s consistent with a site's mission, including how to improve DOE policies and increase the amount of land supporting pollinator health. Although the INL was not identified in DOE's Pollinator Protection Plan as having time sensitive actions required under this strategy, there are opportunities to include BMPs from this strategy in INL policies such as this framework. Adopting these BMPs, where possible, while carrying out wildland fire recovery actions increases benefits to pollinators and the overall ecological health of the INL Site.

1.1.3 Applicable INL Ecological Resource Guidance Documents

There are several INL-specific interagency agreements, guidance documents, and charters that provide direction about how ecological resources should be managed and prioritized on the INL Site. The most relevant of those documents, as they pertain to this wildland fire recovery framework, are briefly discussed below. Many of these documents are updated periodically and the most current versions of these documents will be used for the development of individual post-fire recovery plans. Updates to this framework will include updating this section to reference the most current versions of these plans.

2003 Wildland Fire Management Environmental Assessment

The first document to guide post-fire natural resource recovery at the INL Site was the 2003 Idaho National Engineering and Environmental Laboratory Wildland Fire Management Environmental Assessment (EA). The Wildland Fire Management EA was prepared in response to a DOE complex-wide review of fire safety programs and related emergency management capabilities in 2000 (DOE 2003). DOE considered four alternative wildland fire management strategies in the EA and selected a modified Alternative 2, Balanced Fire Protection Approach. DOE approved the EA and prepared a Finding of No Significant Impact in 2003. Although a new EA will be required to evaluate the potential impacts of alternatives associated with implementing this wildland fire recovery framework, the values guiding the first EA remain relevant and will be included as appropriate in the natural resources fire recovery framework.

The 2003 Wildland Fire Management EA recognized that protecting human life and public safety are top priorities of INL's fire management strategy. The protection of physical assets and infrastructure are also among the most important of the listed fire management goals. Additional goals identified in the EA include complying with air and water resource regulations, minimizing and documenting impacts to cultural resources, and protecting or mitigating impacts to ecological resources. The EA discussed the importance of sagebrush steppe habitat at the INL Site and made several recommendations for minimizing impacts to sagebrush steppe for pre-fire activities (e.g., establishing defensible space), during fire suppression activities (e.g., blading containment lines), and for post-fire activities (e.g., soil stabilization and site restoration). Restoration recommendations that pertain to this framework include post-fire stabilization activities like seeding containment lines and habitat improvement activities like controlling noxious weeds and reestablishing native vegetation to reduce recovery timelines (DOE 2003).

Candidate Conservation Agreement for Greater Sage-Grouse

Due to concerns over the steady decline in Greater Sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations and the potential for listing under the Endangered Species Act (U.S. 1983), DOE-ID and the United States Fish and Wildlife Service (USFWS) have entered into a Candidate Conservation Agreement (CCA; DOE-ID and USFWS 2014). The primary purpose of this agreement is to conserve sage-grouse populations and their habitats and to establish a monitoring program to facilitate ongoing data collection on the INL Site that could be used to support a Biological Opinion so that should a listing be considered in the future, potential impacts to the INL Site mission and operations could be minimized.

As part of the CCA, population and habitat "triggers" were identified, which if tripped would initiate an automatic response by USFWS and DOE. The CCA established the Sage-grouse Conservation Area that limits infrastructure development and human disturbance in approximately 68% of remaining sagebrush-dominated communities. Leks protected by the Sage-grouse Conservation Area support an estimated 74% of the known active leks on the INL Site. The CCA also identifies potential threats to sage-grouse survival and establishes conservation measures that can be used to mitigate threats. The loss of sagebrush cover resulting from wildland fire is considered a major threat to the persistence of sage-grouse (Connelly et al. 2011). Therefore, the CCA identifies several conservation measures that can be implemented to reduce impacts to sage-grouse habitat from wildfire or hasten sagebrush reestablishment in burned areas. These conservation measures should be considered when choosing specific treatment options from this framework.

Bat Protection Plan

Over the past decade, the emergence of newly identified threats to bat populations (e.g., white-nose syndrome and large-scale commercial wind energy development) has caused widespread multiple mortality events in bats and resulted in precipitous declines of numerous common bat species and elevated conservation concern for bats across the U. S. (O'Shea et al. 2016). Currently, no bat species listed under the federal Endangered Species Act are found on the INL Site. Six species found on the INL Site are considered Species of Greatest Conservation Need by the State of Idaho (IDFG 2023). All bats are considered protected non-game wildlife and afforded protection. DOE-ID has recognized the importance of INL Site habitats for protected and sensitive bat resources for over thirty years and has funded numerous bat research and monitoring projects over that time.

In 2018, DOE-ID, in collaboration with the Naval Reactors Laboratory Field Office/Idaho Branch Office, finalized an INL Site Bat Protection Plan (BPP; DOE-ID 2018). The BPP provides guidance for addressing conservation needs, tracking monitoring results, and making adaptive modifications, as data or regulatory changes warrant. Additionally, the BPP identifies threats and recommended conservation measures to mitigate the impacts of those threats. Some threats include conversion or destruction of vegetation (i.e., impacts from wildland fire) and environmental contaminants (e.g., pesticide application). Implementation and maintenance of the BPP is conducted chiefly by INL's NRG in coordination with DOE-ID. Any recommended conservation measures listed in the BPP should be considered when performing actions relating to this framework.

Revegetation Guidance, GDE-8525

Revegetation at the INL Site is completed in accordance with GDE-8525, "INL Revegetation Guide" (INL 2012). The purpose of the Guide is to provide revegetation strategies for hastening the establishment of desired plant communities, to minimize erosion of disturbed soils, and to prevent weed invasions. The use of native species is strongly encouraged, as is the use of a species mix containing adequate diversity of growth forms and root profiles to facilitate successful establishment. The Guide also provides recommendations for seed bed preparation, soil amendments, planting strategies, weed control, optimal planting timeframes, and post-planting techniques for improving establishment. Recommendations from the Guide are generally tailored to each project, depending on the site's condition and the goal of the revegetation effort. Any revegetation recommendations made to improve post-fire vegetation recovery should be consistent with the INL Revegetation Guide.

Sitewide Noxious Weed Management Plan, PLN-611

Federal agencies are required to develop management programs for controlling undesirable plants, typically invasive or noxious weeds, on federal lands. The INL's PLN-611, "Sitewide Noxious Weed Management Plan" (INL 2013) focuses on noxious weed control to the extent practical and within administration budgetary limits. The Plan recognizes that preventing encroachment and revegetation with native species in degraded areas are the best long-term strategies for noxious weed control. There is also discussion regarding tactics to minimize noxious weed spread, methods for inventory and mapping, techniques for controlling noxious weeds, and monitoring for treatment effectiveness. Because weed management is also a post-fire concern, the Sitewide Noxious Weed Management Plan will be used to guide weed control efforts where appropriate.

National Environmental Research Park

The National Environmental Research Park (NERP) program was established in response to recommendations from citizens, scientists, and members of congress to set aside land for ecosystem preservation and study. The INL Site was designated as a NERP in 1975 and the objectives of the Idaho NERP are to: 1) Preserve the area as a representative example of a cool-temperate desert scrub biome, 2) Develop a regional reference data archive of the sagebrush steppe ecosystem, 3) Provide training and education opportunities for environmental scientists and students, and 4) Develop ecosystem models which can predict the effect of proposed activities (Blew et al. 2010). Since its establishment, the Idaho NERP has facilitated research for numerous scientists across a broad range of topics from wildlife movement to ecosystem function. Any post-fire recovery treatments recommended through this framework should not impact the use of the INL Site as a NERP.

1.2 Overview of INL Site Land Use

Approximately 75% of lands surrounding the INL are managed by the federal government. The BLM currently administers eight grazing allotments that partially overlap about 60% of the INL Site. The allotment boundaries encompass the outer perimeter of the INL Site and permits include grazing for both sheep and cattle; permits outline livestock class, stocking rate, and season of use within each allotment. The Idaho Department of Fish & Game (IDFG) also oversees public hunting access for pronghorn (*Antilocapra americana*) and elk (*Cervus canadensis*) in limited areas across the northern INL Site boundary.

Less than 1% of the INL Site is occupied by permanent or temporary facilities interspersed within vast regions of primarily native grasslands and shrublands. Other INL Site infrastructure comprises a transportation network that includes U.S. Highways, State Highways, non-public paved roads, and unpaved two-track roads. In addition, the INL Site contains several railways or spurs, utility corridors for power transmission and distribution, and several landfills and borrow source pits.

The Idaho National Laboratory Comprehensive Land Use and Environmental Stewardship Report (INL 2020a) summarizes strategic planning decisions about future land use and infrastructure development. This document, however, may not include more recent projects and programs, such as Wireless Test Bed and the National Security Test Range, that utilize areas of the INL Site outside the existing long-term facility footprints. In 2019, the INL was designated as the National Reactor Innovation Center to support the growth and development of next-generation reactors from the private sector. With additional micro-reactor programs anticipated to start within the next 10 years, land use and associated mission activities will likely expand into more remote areas, increasing the infrastructure footprint across the landscape.

1.3 INL Site Landscape

The INL Site is located in a large basin averaging 1,500 m (4,921 ft) elevation and is generally bordered on the west by the Lemhi and Lost River mountains and on the north by the Beaverhead and Centennial mountains. The climate of the INL Site is greatly affected by its altitude, latitude, and intermountain setting. Air masses that reach the Eastern Snake River Plain cross a mountain barrier where much of the moisture is lost to precipitation, leaving it arid or semi-arid. Annual average precipitation is 213 mm (8.38 in), and precipitation type is dependent on season (Clawson et al. 2018). Although winter precipitation typically occurs as snow, monthly precipitation totals usually peak in May and June and occur as rain showers. Mean daily temperature ranges from -9 °C (16 °F) in January to 21 °C (69 °F) in July and diurnal temperature fluctuation extremes also occur during those same months, ranging from -9

°C ± 13 °C (16 ± 23°F) to 21 ± 21°C (69±38°F). Wind patterns are well characterized on the INL Site and are best described as cyclic, where direction and speed fluctuate both diurnally and seasonally. See Clawson et al (2018) for additional detail on INL Site climate.

There are three major drainages that enter or approach the INL Site: Big Lost River, Little Lost River, and Birch Creek. Although formerly perennial, the Big Lost River and Little Lost River flow onto the INL Site only in wet years and much of the water infiltrates into the streambed. Birch Creek has been diverted from its original channel before reaching the INL Site for agricultural use and power production, and it no longer flows in its original streambed on the INL Site. During the non-irrigation season, water from the power plant enters a diversion canal that brings the water through the northern boundary of the INL. To provide flood control for some facilities, during high flow, some of the Big Lost River is diverted along an earthen dike into low-lying basins called the Spreading Areas southwest of the Radioactive Waste Management Complex.

Much of the landscape is influenced by volcanic activity as evidenced by three prominent buttes that mark the southern boundary of the INL Site. Two of these are on the INL Site and the third, and largest of the three buttes, is immediately south of the boundary. They range from about 300,000 to 600,000 years in age and the summit elevation of these buttes ranges from 1,948 m (6,391 ft) for Middle Butte to 2,301 m (7,550 ft) for Big Southern. These three buttes together with many small volcanic cones are part of a volcanic axial ridge that extends from near Craters of the Moon National Monument and Preserve toward the northeast and separates the Lost River drainages from the Snake River. Additionally, numerous basalt flows are located throughout the INL Site, contributing to unique subsurface features like lava tubes, and characterizing near-surface conditions like soil depth and discontinuities in topography that are associated with pressure ridges.

Wind erosion and deposition play a large role in shaping the INL landscape as sediments are moved by wind, especially following disturbances that remove vegetation (e.g., wildland fire). Loess is one of the primary sediment types on the INL Site and it is up to several meters thick on the oldest basalts. Alluvial soils are the result of water deposition and are most common on the west side of the INL Site where alluvial fans form at the base of the bordering mountain foothills extending onto the INL Site, and in the northern region of the INL Site at the Big Lost River and Birch Creek floodplains. Fluvial soils are also commonly associated with historical rivers and streams. Colluvial soils, derived from sediment originating in adjacent mountains, are most commonly found on the western side of the INL Site at the base of foothills as well areas around East and Middle Buttes.

1.4 Fire History of the INL Site

Prior to 1994, recordkeeping for INL Site wildland fires was much less consistent than it has been in the period since, making it difficult to reconstruct an accurate fire history. However, we can extrapolate some general trends from old reports, and early records indicate large wildland fires were relatively infrequent on the INL Site (Anderson et al. 1996). A review of reported historical fires suggested that wildland fires over approximately 1,000 ha (2,471 ac) likely occurred only a few times in the century prior to the 1994 Butte City Fire (Colket 2003). Since 2001, when individual fire size estimates were first available, several large wildland fires have burned substantial portions of the INL Site (Forman and Hafla 2018) and of those that have occurred partially or entirely within the INL Site boundary, six have been over 1,000 ha (2,741 ac; Figure 1-3). Vegetation maps of the INL Site prior to 1994 (McBride et al. 1978, Kramber et al. 1992) indicate that plant communities across much of the landscape were dominated by big sagebrush (*Artemisia tridentata*). More recent vegetation maps reflect a transition to the grasslands and green rabbitbrush (*Chrysothamnus viscidiflorus*) dominated communities that result from sagebrush lost to wildland fire (Shive et al. 2011, Shive et al. 2019). Because sagebrush can take more than a century to recover to pre-burn cover levels, the relatively recent shift in the distribution of dominant vegetation types across the landscape also points to an increase in wildland fire frequency when the period encompassing the past 30 years is compared to the prior century. It should be noted, however, that within the past 30 years, records do not indicate a marked increase in fire frequency (Figure 1-4).

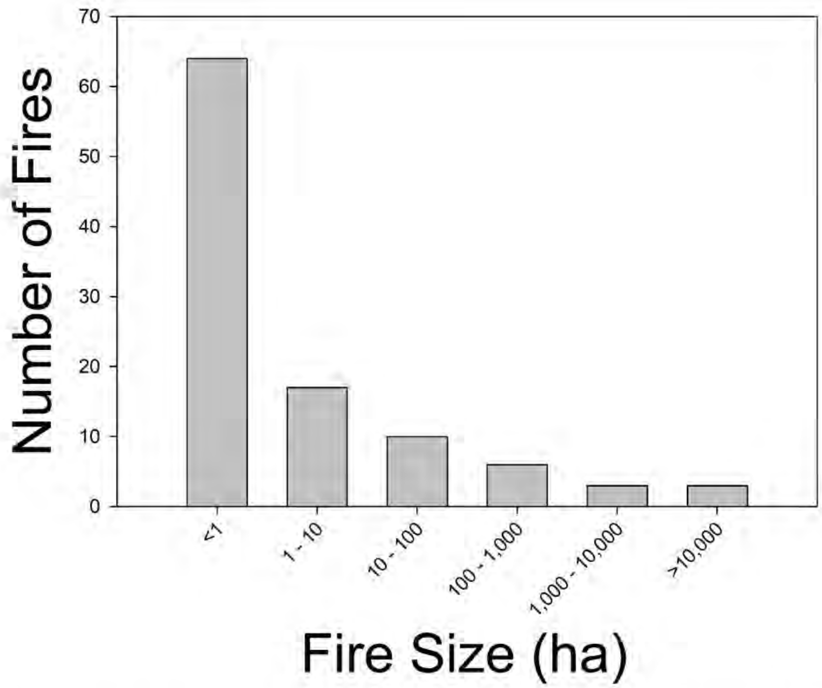


Figure 1-3. Fire size for all wildland fires that burned on the Idaho National Laboratory Site between 2001 and 2023. For fires that crossed the Idaho National Laboratory Site boundary, only the area burned within the Idaho National Laboratory Site was included.

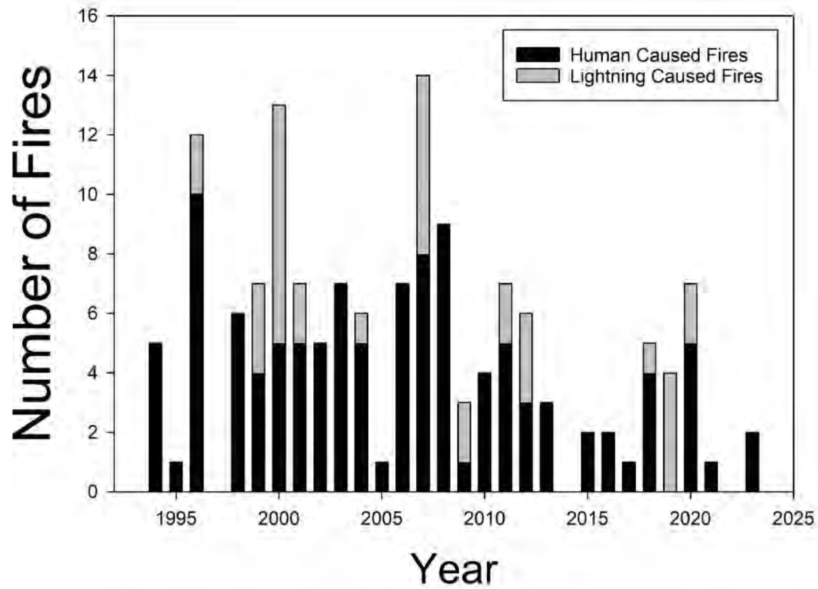


Figure 1-4. Number of fires by ignition source type for all wildland fires that burned on the Idaho National Laboratory Site between 1994 and 2023.

Between 1994 and 2021, the INL Fire Department has reported a total of 147 wildland fires on the INL Site. Of those fires, 36 were caused by lightning and 111 were human caused; most of the human caused wildland fires were ignited along public highways. Based on initial fire perimeter mapping, often using containment lines, a total burned area of 167,027 ha (412,733 ac) was impacted by wildland fire since 1994. The fire footprint for many fires since 2010 were re-mapped to remove unburned islands and areas where vegetation did not burn up to the containment line, resulting in a revised burned area of 154,528 ha (381,846 ac). Because more recent wildland fires have burned over portions of older burned areas, the actual area impacted is less than the total amount of area that has burned. The total area of the INL Site that has been impacted by wildland fire between 1994 and 2021 is estimated to be 97,620 ha (241,225 ac; Figure 1-5). Methodologies used for initial mapping have not been consistent throughout the period, so fires that are either larger or more recent are generally mapped with greater accuracy and all summary numbers provided here are estimates.

The cause for the increase in large fires (> 1,000 ha; 2,471 ac) after 1994 may be due to several factors including, but not limited to changes in weather conditions and shifts in fuel type and/or fuel moisture. Nearly all the fires that burned more than 1,000 ha (2,471 ac) and many of the fires that burned more than 100 ha (247 ac) occurred during periods where weather conditions were conducive to extreme fire behavior. High air temperature, low relative humidity, and high wind speed are examples of conditions that contribute to extreme fire behavior. Regionally, increases in the length of the season during which these conditions prevail are likely already occurring and seasonality of extreme fire weather will continue to expand over the next century (Creutzburg et al. 2015). The weather conditions that lead to extreme fire behavior also contribute to higher risk fuel conditions like lower fuel moisture earlier in the growing season. Though cheatgrass (*Bromus tectorum*) is not yet dominant enough to lead to an altered fire cycle

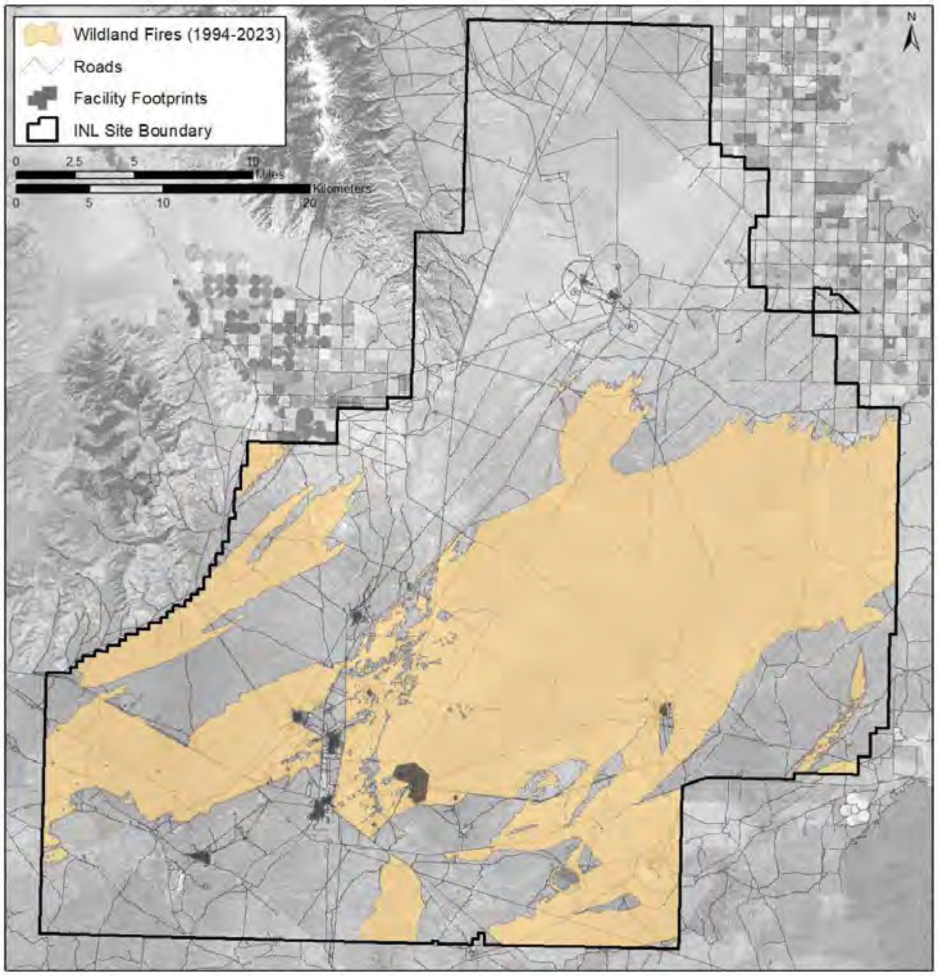


Figure 1-5. Areas on the Idaho National Laboratory Site impacted by wildland fire between 1994 and 2023.

across the INL Site (Shive et al. 2019), it is abundant enough in some locations to affect fine fuel continuity, and consequently fire behavior. Climate trends and their impacts on fuel and fire risk at the INL Site reflect trends across Western U. S. and the challenges associated with wildland fire recovery are shared across many local, state, and federal agencies.

1.4.1 Potential Ecological Impacts from a Wildland Fire

Wildland fire was historically a dynamic component of sagebrush steppe ecosystems, though it was likely an infrequent occurrence during pre-European settlement. Fire rotation intervals for Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) have been estimated to range up to 350 years (Baker

2006). Sagebrush is not particularly well-adapted to fire, as evidenced by its lack of fire resistance, its inability to resprout, and its poor long-distance seed dispersal capability. In local sagebrush stands, fire is not required for stand regeneration (Forman et al. 2013), which further underscores the role of fire as an occasional disturbance that is not obligatory for ecosystem maintenance. As such, the distribution of pre-settlement wildland fire footprints, especially in eastern Idaho, likely resulted in plant communities typified by large swaths of contiguous sagebrush with occasional patches of grassland and lower-density sagebrush shrubland. The distribution of these plant communities represented a coarse mosaic of recovering vegetation within a much larger matrix of moderate to dense sagebrush (Bukowski and Baker 2013).

As a foundation species, sagebrush modulates the local ecosystem and the loss of sagebrush from a plant community disproportionality affects co-occurring species and overall ecosystem function (Prevey et al. 2010). Therefore, the mosaic of sagebrush distribution in recovering burns of varying ages reflects the habitat available to other plants and wildlife species and the ability of the ecosystem to carry out processes like soil stabilization, water balance, and nutrient cycling. When large regions of the sagebrush steppe shift from sagebrush-dominated shrublands to grasslands or communities dominated by resprouting shrubs, substantial changes in habitat availability and ecosystem function are expected. Because sagebrush has been lost from nearly 100,000 ha (247,105 ac) of the INL Site over the past 30 years, much of the landscape is already undergoing extensive ecological changes.

1.4.1.1 Changes in Soil Distribution and Erosion

Following a wildland fire there are multiple factors related to soil that can be affected. One of the largest impacts across a fire footprint is the removal of vegetative cover from the soil surface which exposes soil for the remainder of the growing season, over the following winter, and into the beginning of the next growing season. This creates an increased risk for soil erosion. Wind erosion is the most prevalent form of erosion on the INL Site following wildland fire and can cause decreased visibility and air quality in the surrounding areas. Water erosion is a less likely form of erosion because conditions leading to water erosion are dependent on specific topography that are not widespread across the INL Site, so the effects of water erosion are generally localized. Areas impacted by erosion following a wildland fire typically take about a year to stabilize through reestablishment of resprouting grasses and shrubs.

Other impacts related to direct soil disturbance include but are not limited to, the creation of roads, containment lines, and staging areas during fire suppression activities. The impacts from fire suppression activities have the potential to result in more severe disturbance than from the wildfire itself because vegetative structures such as roots may also be removed furthering the instability of the soils, decreasing soil nutrients, and prolonging natural recovery. Decreased soil nutrients and stability also have the potential to create a vector in which invasive species better adapted to degraded conditions may become established and spread. Areas impacted by soil disturbance associated with suppression activities generally take longer to recover because the below ground biomass has been damaged or removed so recovering species must reestablish from seed.

1.4.1.2 Changes in Vegetation Structure and Function

Wildland fire on the INL Site typically results in the removal of nearly all aboveground biomass. During the first growing season after the wildland fire, resprouting grasses and shrubs emerge, but total vegetative cover from these species remains lower than average for several years post-fire and sagebrush can take more than a century to return to pre-burn cover levels (Blew and Forman 2010). The result is a loss of vertical structure and associated productivity that can persist for many decades. Diversity of sagebrush steppe plant communities can also be negatively impacted by wildland fire, especially in areas that have burned multiple times (Mahood and Balch 2019). Intact sagebrush shrublands exhibit a unique patchy vertical and horizontal distribution of soil nutrients that may be homogenized somewhat after wildland fire (Sankey et al. 2012). With respect to water use, individual sagebrush shrubs can redistribute water through the soil profile (Richards and Caldwell 1987), influencing the conditions experienced by nearby plants, and at the stand level, sagebrush loss can result in less overall available soil moisture. In addition to changes in subsurface moisture conditions, reduction in the above-ground structure associated with sagebrush can result in higher wind and solar exposure, which at the INL Site may contribute to lower sagebrush recruitment rates in burned areas and longer recovery timeframes (Forman et al. 2013). Finally, carbon stored in above ground plant structures is released during a wildland fire and the ability of the plant community to effectively store carbon at pre-burn capacity is directly related to the time required to recover to vegetation abundance and species composition to pre-burn levels (Maxwell and Germino 2022).

Sagebrush steppe that is in good ecological condition is resilient in response to environmental stressors and is resistant to invasion by non-natives (Chambers et al. 2014). Good condition sagebrush steppe plant communities are characterized by a diversity of native species, are not highly impacted by introduced grasses and forbs, and they tend to be more stable in terms of total vegetative cover (Anderson and Inouye 2001). Plant communities that have burned on the INL Site generally exhibit greater annual variability in cover of native, perennial herbaceous species and in non-native annuals when compared to intact sagebrush shrublands (INL 2023b). Vegetative cover from non-native annuals also tends to be much higher on average in areas that are recovering from wildland fire, which results in an overall decrease in condition and reflects a loss of invasion resistance and reduced resilience to other stressors like drought. Compared to other regions (Bradley et al. 2018), annual grasses do not yet dominate large portions of the INL Site. However, reduced post-fire ecosystem resistance and resilience coupled with increasing pressure from non-natives across the region poses a substantial risk of native plant communities transitioning to non-native annual grasslands. Once landscapes are dominated by annual grasses, they are susceptible to a feedback cycle which results in a changed fire regime that ultimately reinforces non-native grass dominance (Balch et al. 2013). Ecosystem function in plant communities that have experienced this type of transition are highly impacted and tend to remain so in the absence of intensive restoration efforts.

1.4.1.3 Changes in Habitat Availability and Wildlife Use

Like surrounding arid regions, food, cover, and water resources are distributed unequally across the sagebrush steppe ecosystem. Animal species were required to adapt to this mosaic patchwork of natural resources inherent to such an expansive landscape to meet their seasonal and annual resource needs. When the loss or degradation of sagebrush habitats occurs, from wildland fire or fuels management and fire suppression activities, many sagebrush obligates can be acutely impacted. There are hundreds of birds, mammals, reptiles, and amphibians that depend on sagebrush as well as many unique insects, spiders, plants and lichens that are closely associated with the sagebrush community and utilize it in a variety of ways during various seasons. Species such as sage-grouse and pygmy rabbit (*Brachylagus idahoensis*) depend on relatively large expanses of sagebrush-dominated shrub steppe and are entirely dependent on sagebrush habitats to survive (Connelly et al. 2004). Many songbirds rely on it for nesting and escape cover; some exclusively like the sage thrasher (*Oreoscoptes montanus*) and various small mammals use it as shelter and travel corridors.

Wildland fire can affect bats both positively and negatively, and the extent of the effects can vary by species, time of the year, and fire intensity (Perry 2012). Heat, smoke, and carbon monoxide from fire may directly impact bats survival (Dickinson et al 2009, Perry 2012, Gaetani et al 2010). Indirectly, fire affects bats by modifying the habitat and what food is available (Dickinson et al 2009, Perry 2012, Gaetani et al 2010). For tree/shrub roosting bats, fire may create and destroy roosting habitat, thus being both beneficial and harmful (Gaetini et al 2010, Boyles and Aubrey 2006, Dickinson et al. 2009). Fire can also temporarily affect how many insects are available, but the number of insects may increase above pre-fire levels as the plants begin to reestablish (Gaetini 2010, Dickinson et al. 2009). Cave roosting bats tend to be more negatively affected by the smoke entering the caves (Gaetini 2010, Dickinson et al. 2009) which may be of particular concern to hibernacula located on the INL site.

The INL Site is a critical breeding bird area, primarily due to the large amounts of intact sagebrush communities (National Audubon Society 2024). The INL Site has long been known as a vital area for several sagebrush obligate species such as the sage-grouse, sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher, and Brewer's sparrow (*Spizella breweri*). Big sagebrush is the most important species for functional sagebrush plant communities on the INL Site and is recognized as the major component of sagebrush habitat for greater sage-grouse described in the CCA (DOE-ID and USFWS 2014).

Habitat fragmentation, as discussed by Franklin et. al. (2002), refers to not only the end state of habitat alteration, but it also refers to the process in which these changes occur. Incorporating previous works (Lord and Norton 1990, Hall et al. 1997), Franklin et. al. proposed that habitat fragmentation be defined as "the discontinuity, resulting from a given set of mechanisms, in the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, or survival in a particular species". When sagebrush steppe habitats are altered by wildland fire, road creation, infrastructure, agriculture or other factors, populations of sagebrush obligate species decline due to the reduction/fragmentation of sagebrush habitat or the increase of edge habitat favorable to generalist wildlife species (Noson et al. 2006, Pierce et al. 2011, Mutter et al. 2015, Knight et al. 2016). For some species (e.g. pygmy rabbits), habitat fragmentation isolates or separates populations as they refuse or are unable to cross barriers such as wildland fire footprints, roads, or containment lines (Lawes et al. 2012, Edgel et al. 2018). Maintaining large, contiguous sagebrush habitat is critically important for these obligate species and is a primary reason sagebrush habitat restoration is becoming an important post-fire consideration across the West and on the INL Site.

1.4.2 Potential Ecological Impacts from Fire Suppression Activities

Active fire suppression has been and continues to be a critically important response to wildland fire on the INL Site. Not only is it necessary to protect the INL workforce and its infrastructure, but it also helps stem the ongoing loss of high-quality sagebrush shrublands. Blading containment lines, digging hand lines, establishing temporary access roads, and clearing temporary equipment and personnel staging areas are all examples of soil disturbances associated with wildland fire suppression activities that are commonly used at the INL Site.

The ecological effects of fire suppression activities differ from those associated with wildland fire alone. In a historical wildland fire, the primary form of soil disturbance was post-fire wind erosion, which results in the loss of some of the uppermost soil horizon. Alternately, soil disturbance from modern fire suppression activities often results in damage to below ground vegetation structures (e.g., roots, rhizomes, bulbs, and corms), disruption of soil nutrient patterning, loss of soil structure, and soil compaction. Though limited in areal extent when compared to a wildland fire footprint, these types of soil disturbances have unique ecological risks which may include creating vectors for weed spread, contributing to habitat fragmentation, and ongoing erosion concerns. Because the effects of soil disturbance from suppression activities differ from those associated with wildland fire, they often require different post-fire recovery strategies.

1.5 Post-Fire Ecological Resource Recovery

Over the course of a century, burned areas on land that is now occupied by the INL Site historically progressed through secondary succession, eventually returning to sagebrush shrublands. Immediately after a wildland fire, nearly all the above ground biomass had been removed, resulting in a landscape of bare soil, burnt shrub stumps, and grass culms. Occasional islands or fingers of unburned vegetation were typical after wildland fire in this region. In the first few post-fire years perennial grasses, forbs, and shrubs with the ability to do so, resprouted. After the first decade, the cover of resprouting species had returned to or exceeded pre-burn abundance levels. Eventually sagebrush and its associated vertical structure reestablished from unburned edges or islands, and throughout the process, native annuals seasonally responded to precipitation to fill niche space as available. As vegetation composition progressed through these changes, available habitat for wildlife and wildlife population dynamics responded accordingly. More recently, changes in abiotic stressors like drought and biological pressures like invasive species are altering the historical fire recovery trajectory, which can result in an alternate stable state for the plant community (Bagchi et al. 2013) and severely impact wildlife habitat.

1.5.1 Vegetation Recovery

There are both natural and assisted recovery options available for post-fire sagebrush shrublands. It is logistically and financially unrealistic to pursue assisted recovery across the entirety of a large burn, and there are often areas within a burned footprint that retain the capacity to recover naturally. In some cases, assisted recovery efforts can do more harm than good, especially when the area has sufficient remnant natives available for natural recovery and active treatments have the potential to introduce soil disturbance and associated risks (Ratzlaff and Anderson 1995). Therefore, prioritizing assisted recovery in areas of greatest need is often a necessity and it can be an effective way to target areas that are unlikely to recover well naturally and to target areas where there are more immediate habitat needs and wildlife species will be severely impacted over the timeframe necessary for natural recovery.

1.5.1.1 Natural Recovery

Until the last few decades, vegetation across the INL Site was thought to be in generally good ecological condition (Anderson and Inouye 2001). Although ecological condition has declined in some plant communities on the INL Site over the past ten to twenty years, native vegetation still dominates much of the area (Shive et al. 2019). For example, roughly 80% of the area burned by the Sheep Fire was mapped as plant communities dominated by native species prior to the fire (Forman et al. 2020). Studies of post-fire dynamics on the INL Site and across the region indicate that except for sagebrush, post-fire species composition closely resembles pre-fire composition (Ratzlaff and Anderson 1995, Blew and Forman 2010) and communities that were in good ecological condition prior to fire will generally recover to good condition communities within a few years post-fire (Blew et al. 2010). For this reason, areas dominated by native species before wildland fire are good candidates for natural recovery after a wildland fire.

Because of increasing pressures from ecosystem stressors, even good condition post-fire communities are at higher risk for non-native species invasion and overall poor recovery than they were historically. Therefore, post-fire monitoring is an important aspect of any effective post-fire recovery strategy. Depending on results from ongoing vegetation condition monitoring, areas that were allowed to recover naturally could be reconsidered for assisted recovery to address unanticipated declines in post-fire ecological condition or could be deprioritized for additional action if they are recovering well.

1.5.1.2 Assisted Recovery

Assisted recovery strategies may include any number of treatments that can be used to reduce recovery times, improve ecological conditions, or address other post-fire environmental concerns. Post-fire recovery treatments are often targeted to areas at risk of poor recovery and to areas where excessive habitat loss has occurred, which could reduce the likelihood of wildlife populations persisting until habitat has recovered naturally. In sagebrush steppe ecosystems, post-fire recovery treatments are often used to address soil stabilization, control the spread of non-native species, and facilitate the return of native species diversity and ecosystem function. Some of the most common treatments include recontouring disturbed soils, weed spraying, and planting species desirable for soil stabilization and habitat improvement.

Restoration of native plant communities, particularly in the sagebrush steppe, can be difficult under even ideal conditions, but the harsh climate of the arid high desert in the Intermountain West poses additional challenges. Sagebrush communities are particularly low in available moisture, have numerous invasive species that exploit local conditions, may be difficult to access, have low/poor soil nutrition, and may be subject to several additional conditions that vary spatially and temporally (i.e., grazing, wind, etc.). These challenges are important considerations when weighing assisted recovery treatment options and they are important to factor into the criteria used to assess treatment success as part of an adaptive management monitoring strategy.

1.5.2 Wildlife Population Recovery

Recovery of wildlife populations after wildfire events is species specific with varied responses dependent upon the amount and type of habitat altered, and time since wildfire occurrence. As an example, songbird species, specifically those with ground or shrub nesting strategies, have shown dissimilar responses to wildfire in sagebrush shrublands with ground nesting species showing increased abundance within recent fire footprints (Holmes and Robinson 2013). Moreover, ungulates also have been shown to have a varied response to the occurrence of wildfire. Pronghorn have been shown to increase use of recently burned landscapes (Courtney 1989), while mule deer (*Odocoileus hemionus*) have demonstrated reluctance to use recently burned areas (Roerick et al. 2019). Because of the historical importance of the high-quality sagebrush habitat available on the INL Site and because of the conservation concerns associated with sagebrush obligate species, especially sage-grouse, post-fire recovery strategies on the INL Site will often favor reestablishment of sagebrush steppe habitat.

The resprouting of forbs and grasses during early post-fire recovery phases can be advantageous for most wildlife species, however for sage-grouse, the lack of cover and suitable nesting habitat can have delayed negative effects. Sage-grouse, due to their philopatric behaviors, will continue to visit traditional lekking and nesting areas despite the occurrence of wildfire (Foster et al. 2019, O'Neil 2020). The use of leks by male sage-grouse has also been shown to decline after fire induced disturbance (Connelly et al. 2000) which may have an observable effect on lek attendance totals recorded during sage-grouse surveys on the INL. This continued use of less than desirable habitat results in declining nest success and adult survival in the immediate years following wildfire (Tyrrell et al. 2023). However, sage-grouse populations have been observed to alter habitat usage five to seven years after the occurrence of wildfire ultimately selecting for areas with intact suitable habitat (Schuyler et al. 2022), resulting in limited use of fire affected areas.

In areas where natural recovery of sagebrush habitat is progressing slowly, or in areas where the natural recovery trajectory has been altered by climatic or biotic stressors, post-fire treatments may be particularly effective for improving habitat quality over a shorter timeframe than would occur naturally. Degraded sites where pre-fire habitat condition is considered to be poor, as indicated by low sagebrush and perennial grass cover, are more likely to transition to annual grass dominated landscapes (Riginos et al. 2019). To offset populations declines associated with sagebrush loss and to mitigate the effects of altered fire regimes that may result from poor recovery (Coates et al. 2016), post-fire treatments should be targeted to both areas that have historically high sage-grouse use and areas where the risk annual grass dominance is high. Assisted recovery treatments, particularly the combination of seeding and application of herbicides, may also influence sage-grouse populations and habitat selection and provide an offset to expected population declines immediately following wildfire (Germino et al. 2022).

2. POST-FIRE ECOLOGICAL RESOURCE ASSESSMENT

Before post-fire treatment options can be evaluated for a specific wildland fire, the potential impacts to natural resources from the wildland fire and associated fire suppression activities must be characterized. For previous INL Site fire recovery plans, potential impacts to natural resources were characterized using an ecological resource assessment, and we found this approach useful for identifying areas that should be prioritized for treatment. Potential treatment areas may be prioritized based on minimizing the risk of poor ecological recovery, accelerating the recovery of important or high-use habitats, and limiting overall loss of ecosystem function. In many cases, results of an ecological resource assessment can be synthesized to focus restoration efforts within the context of the landscape, so that areas with maximum benefit in terms of restoring habitat connectivity or limiting vectors for weed spread can be targeted.

To allow for timely planning and execution of proposed treatments, an ecological resource assessment and a fire-specific natural resource recovery plan should be completed as quickly as possible. The ecological resource assessment process can be expedited by completing analyses at a high level, using existing natural resource data. This approach necessitates an understanding that ground-based evaluations are often required prior to initiating a treatment to ensure current on-the-ground conditions are as expected and that treatment criteria are met.

The first step of an ecological resource assessment is obtaining post-fire imagery and producing an accurate fire footprint that reflects the actual burn edge and all unburned patches or islands within the footprint. The actual fire footprint is then compared to spatially explicit natural resource datasets, like the INL Site soils, Special Status Plant (SSP) occurrences, and vegetation maps, and to sampling locations for tabular datasets, like the Breeding Bird Survey (BBS) and Long-Term Vegetation Plots. Relevant spatial and tabular data are summarized, and data summaries are used to evaluate the potential ecological impacts from the wildland fire and from related suppression actions. Results of these analyses form the basis of the ecological resource assessment, and a summary of the assessment will be included in fire-specific natural resource recovery plans to provide context for recovery treatment recommendations. In addition to ecological resources, we will consider logistical constraints like access and administrative restrictions such as those associated with cultural resource sites or CERCLA sites with institutional controls (e.g., closed landfills and unexploded ordnance areas).

2.1 Mapping the Fire Footprint

Although an initial wildland fire boundary is often available soon after a fire, it is typically not produced at a scale necessary for accurate resource assessment. Wildland fire boundaries are commonly collected on the ground while driving the outer perimeter along bladed containment lines or sometimes aerially from helicopters assisting with suppression activities. This results in a generalized outer footprint of the fire but does not necessarily define the actual burned area, which does not always extend to the outer bladed containment line. In most cases, there are also internal unburned patches of vegetation, such as sagebrush habitat, that are included in the more generalized fire boundary and are inaccurately characterized as burned.

The INL WFMC authorizes funding for post-fire acquisition of high-resolution multispectral imagery which is used to map the burned area for fires 40 ha (100 ac) or larger. Imagery can be collected from both aerial and satellite platforms; however, the spatial resolution should be sufficient to accurately map the burned area and to delineate unburned patches of vegetation.

Wildland fire burned area is mapped through manual delineations digitized within a Geographic Information System (GIS) leveraging a variety of editing tools available. The post-fire mapping scale is selected to match the scale of base data layer that will be updated (i.e., vegetation map) to maintain consistency in the dataset and allow for updates to be made after the fire. Burned area map classes are removed from the original vegetation map and remain as unmapped regions until the vegetation map is updated. The wildland fire burned area boundary can then be used to evaluate the impacts to natural resources, such as calculating the areas of sagebrush habitat lost in a fire.

2.2 Assessing Soils Affected by Wildland Fire

One component of the post-fire ecological resources assessment is to characterize the types of soils within an area impacted by wildland fire and fire suppression activities and to document any concerns associated with those soils. Soils on the INL Site are generally characterized using a report titled, "*The Status of Soil Mapping for the Idaho National Engineering Laboratory,*" (Olson et al. 1995) which was extrapolated from existing data about soil map unit distribution across the INL Site. These data were derived from a combination of county soil surveys, special surveys, and BLM unpublished surveys within grazing allotment boundaries and are managed as a GIS layer (hereafter, INL Soils Dataset). There are 69 unique soil map units delineated in the INL Soils Dataset. The soil groups and units, including the complexes identified within each unit, are described in the corresponding report. Common soil groups on the INL include loess, sands, cinder cone, flood plain, lava, mixed sand loess over basalt, mountains, playa, sands over basalt, and terrace. Soil distribution across the INL Site is a consequence of the alluvial, fluvial, and colluvial process described in Section 1.3. It is important to note that soil map units may not be mapped accurately, as the data have not been validated, but they can lend insight into possible challenges and threats associated with a particular fire footprint. In addition to INL Soils Dataset, information about some soils on and around the INL Site that have been assessed more recently can be accessed using Web Soil Survey (USDA-NRCS 2024), an online tool managed and maintained by the Natural Resources Conservation Service.

2.2.1 Potential Impacts of Fire Suppression Activities on Soils

Generally, soil stabilization efforts and therefore ecological resource assessments, will be focused on soils disturbed during fire suppression efforts. This is because mechanically disturbed soils are more severely disturbed and less likely to stabilize naturally when compared to other soils within the wildland fire footprint (see Section 1.4.1.1 for discussion). The first step towards restoring soils disturbed during fire suppression activities is identifying the extent of impacted area. High resolution imagery can be used to delineate several types of soil disturbance including containment lines, new two-track access roads, damage to existing two-track roads, and staging/laydown areas. Additional field-based data collected during surveys conducted by the INL CRMO may also be useful for characterizing disturbed areas, if available. Once the extent of the impacted area and all associated types of soil disturbance are identified and delineated, they can be compared to the INL Soils Dataset to characterize which specific soil map units were impacted and to quantify the severity and potential long-term effects of the impact.

Following the characterization of soil map units impacted by fire suppression activities, the specific risks and threats of erosion and invasive species encroachment associated with each soil map unit will be evaluated. This is crucial for assessing and prioritizing which restoration or remedial actions should be performed. The INL Soils Dataset contains some discussion on risks and threats associated with each soil map unit, but more recent and updated information for each soil map unit may be described in the Web Soil Survey for similar soils surrounding the INL Site. Once all associated risks and threats are understood they can be weighed as part of the decision-making process for which recovery actions should be implemented.

Within mechanically disturbed soils, areas impacted by more severe disturbance may be a higher restoration priority than areas with less severe disturbance. For example, containment lines where vegetation was completely removed, and only exposed mineral soil remains are not likely to recover well naturally because they lack nutrients, organic substrate, and intact root masses for natives to resprout (DOE 2003). Therefore, containment lines with more severe disturbance may be a higher restoration priority than containment lines where only surface vegetation was removed and at least some vertically distributed soil properties and root masses from native perennial species remain intact.

The INL Soils Dataset includes generalized restoration action recommendations in relation to particular soil map units and the soil types within those units and can be used to influence recovery decision making. These recommendations are limited to the generalized descriptions of the soil map unit, and while these descriptions can be used to complete a high-level post-fire ecological resource assessment, ground-based monitoring should also be conducted immediately prior to the initiation of any treatment to ensure that current, local conditions are appropriate for the prescribed treatment.

2.2.2 Potential for Soils to Impact Recovery Treatments

Stabilization of soils that were not mechanically disturbed but that pose a high risk of impact to people or infrastructure from erosion should also be considered when prioritizing treatment options. If wind erosion becomes appreciable on large, burned areas there is often little that can be done to control it (Chambers et al. 2016). However, hazards from blowing soil around INL Site facilities or infrastructure that result in potential threats to staff or to the public from dust storms, which reduces visibility and causes respiratory stress, can make stabilization of certain areas a priority. Stabilization should also be prioritized in areas where soils accumulate on roadways, impacting ingress or egress. Many areas that pose these types of post-fire risk can be identified in the post-fire ecological resource assessment.

The presence of highly erodible soils, as identified in the post-fire ecological resource assessment, may inform the decision of whether to use machinery such as a rangeland drill which can influence erodibility in a negative manner. These decisions can be nuanced because short-term risks may sometimes be outweighed by longer-term benefits, like enhancing perennial vegetation recovery. In these scenarios, some risk may be mitigated by increased attention to details like soil moisture as some soils may be less erodible when they are not too wet or too dry. Likewise, the decision to use herbicide as a recovery treatment to discourage the establishment of invasive weed species may need to be deferred or may require additional actions to prevent soil containing herbicide from moving to non-target areas.

2.3 Assessing Vegetation Affected by Wildland Fire

Vegetation resources and concerns addressed in a post-fire ecological resource assessment will include the distribution and abundance of plant communities within the fire footprint, known and potential occurrences of rare and sensitive plant species populations, and known populations as well as areas at increased risk for invasive and noxious weeds. Based on the results of the vegetation component of an ecological resources assessment, we will consider several factors related to natural resource recovery goals and objectives when prioritizing restoration treatments in areas affected by wildland fire and fire suppression activities. Overall, areas where treatments are expected to provide the greatest benefit will receive the greatest consideration for active treatment. We will also use the results of the post-fire ecological resource assessment to identify areas where active treatments may be detrimental or are less likely contribute to overall restoration goals.

2.3.1 Plant Communities

The vegetation of the INL Site consists predominantly of an overstory of shrubs and an understory of grasses and forbs. Nearly 500 vascular species have been documented occurring on and adjacent to the INL Site (Anderson et al. 1996). Big sagebrush and green rabbitbrush are the most common shrubs (Forman and Hafla 2018). However, communities dominated or co-dominated by low sagebrush (*Artemisia arbuscula*), black sagebrush (*Artemisia nova*), and three-tip sagebrush (*Artemisia tripartita*) are frequently distributed around the periphery of the INL Site, and salt desert shrub communities are generally associated with playas and floodplains. Junipers (*Juniperus osteosperma*) are common at higher elevations associated with the buttes and foothills on the INL Site. Native grasslands may be dominated by rhizomatous species like streambank wheatgrass (*Elymus lanceolatus*) and western wheatgrass (*Pascopyrum smithii*) or by bunchgrasses like bluebunch wheatgrass (*Pseudoroegneria spicata*), needle and thread (*Hesperostipa comata*), or Indian ricegrass (*Achnatherum hymenoides*); they are most abundant in burned areas but are also understory components of most native shrublands. Non-native species like crested wheatgrass (*Agropyron cristatum*), cheatgrass, saltlover (*Halogeton glomeratus*), and annual mustards (*Sisymbrium* spp., *Descurainia* spp.) occasionally dominate INL Site plant communities, but typically occur as minor components of native communities.

Characterizing pre-fire vegetation composition, distribution, and condition provides insight into the plant communities likely to reestablish post-fire and will help us identify areas that may require active treatment to restore ecological function as well as important habitat. Results from several INL Site vegetation monitoring projects demonstrate how the general trajectory of fire recovery can be understood within the context of pre-fire abundance and composition (Blew and Forman 2010, Forman and Hafla 2018, INL 2023b). Therefore, we can use information about general recovery trends in combination with fire-specific information about the spatial distribution, extent, and context of plant communities affected by a wildland fire to identify areas where treatments may be most effective or beneficial.

2.3.1.1 Spatial Distribution of Plant Communities

The most recent update to the INL Site plant community classification and vegetation map was published by Shive et al. in 2019. In the INL Site plant community classification that was completed to support the vegetation map, 16 discrete vegetation classes were identified. Twelve are natural vegetation classes and four are ruderal classes, or classes dominated by non-native species. Within the native classes, there was one woodland class, six shrubland classes, two shrub grasslands, and three grasslands. Within the ruderal classes, there was one shrubland, two grasslands, and a class characterized by mixed weedy forbs. Two vegetation classes that are indistinguishable in multispectral imagery were combined for a total of 14 map classes that were delineated using aerial imagery and interpretation techniques.

The Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class contained the largest amount of total area mapped with 85,120 ha (210,330.9 ac). The second largest class mapped was the Green Rabbitbrush / Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class with 57,080 ha (141,035 ac). The three largest map classes cover 73.2% of the vegetated area on the INL Site, suggesting most vegetation communities are dominated by big sagebrush or species most associated with post-fire communities where big sagebrush was previously present. The Big Sagebrush – Green Rabbitbrush (Threetip Sagebrush) Shrubland class also had the greatest number of map polygons with 2,388 and an average polygon area of 36 ha (88.1 ac). The class containing the second largest number of polygons was the Cheatgrass Ruderal Grassland class with 1,435 polygons. However, the mean area of Cheatgrass Ruderal Grassland class was much smaller at 6 ha (15.9 ac) and many of the polygons mapped were isolated individual patches rather than larger contiguous areas (Figure 2-1).

Although the distribution of plant communities across the INL Site is expected to shift over time, the plant community classification, or the way plant communities are defined, is relatively stable. Therefore, the map is scheduled to be updated approximately every five years using the existing vegetation classification. Because it is produced at a scale meaningful for the type of assessment described here, and we found it imperative for assessing potential vegetation impacts from the Sheep Fire and from four wildland fires that burned in 2020 (Forman et al. 2020, Forman et al. 2021), we will continue to use the most current iteration of the map to characterize the distribution of plant communities affected by a wildland fire for the ecological resource assessment process described here.

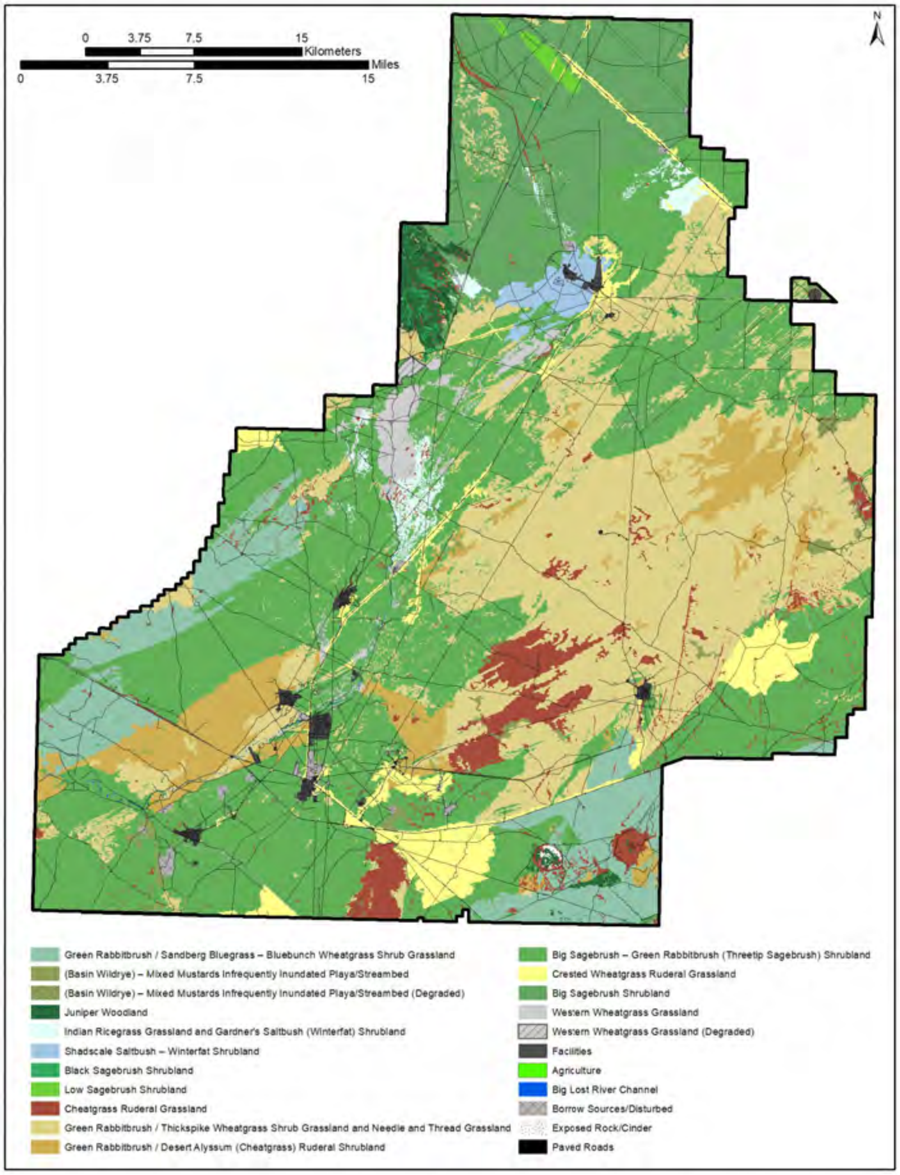


Figure 2-1. Distribution of vegetation classes across the Idaho National Laboratory Site in 2019.

Both the total amount of each vegetation class affected by a wildland fire and the distribution of those classes on the landscape are important results and these components are summarized in a post-fire

25

ecological resource assessment. These summaries can be used to estimate the total area of the wildland fire footprint that should be considered for active treatments to hasten recovery, which can be useful for estimating the magnitude and cost of treatment options. The context and distribution of pre-fire vegetation classes will also be summarized spatially to provide information we can use to target areas with the greatest potential benefit from post-fire treatments. Understanding the location and extent of cheatgrass dominated communities, identifying areas with poor herbaceous abundance and diversity, and measuring the proximity of remaining sagebrush habitat will facilitate targeting treatments to minimize vectors for weeds and maximize the amount of functional sagebrush habitat restored.

2.3.1.2 Ecological Condition of Vegetation

Results from the most recent mapping effort (Shive et al. 2019) indicated that approximately 85% of the INL Site was dominated by native species and would be characterized as being in fair to good ecological condition. About 5% of the INL Site was mapped as a non-vegetative class (facilities, borrow sources, roads, etc.) and the remaining 10% was dominated by cheatgrass or other non-native species, a sign of poor condition. Plant communities in relatively good ecological condition included mature big sagebrush shrublands that have not recently burned and plant communities that had previously burned and have naturally recovered to a mix of green rabbitbrush shrublands and native grasslands. Degraded communities tend to occur in areas with recurring disturbance such as low-lying topography that experience occasional flooding, basalt outcroppings with thin unstable soils, and areas that have burned previously. Poor condition cheatgrass-dominated communities ranged from vegetation characterized by cheatgrass monocultures to communities with substantial remnant cover from native grasses and/or green rabbitbrush.

Ecological condition is temporally dynamic, especially in less stable post-fire communities (INL 2023b). Cheatgrass can fluctuate dramatically from one year to the next and trends in cheatgrass cover can reverse over relatively short time spans of five to ten years (Forman and Hafla 2018). Understanding how vegetation composition and condition change in response to both abiotic and biotic factors is an important aspect of a post-fire ecological resource assessment because the environmental conditions prevalent at the time the data used for the assessment were collected will affect those data values and how they are interpreted. Both annual and longer-term variability inherent to vegetation condition data should be considered when planning treatment. Therefore, we will use plot-level vegetation condition data in combination with results from longer-term trend analyses to evaluate potential treatment locations in the post-fire ecological resource assessment.

Discrete vegetation condition plots have been sampled annually for the past ten years (e.g., INL 2023b) and periodically over the past seventy years (e.g., Forman and Hafla 2018) to monitor changes or trends in vegetation abundance and composition across the INL Site. Where applicable, we will use data from these plots to support characterization of pre-fire ecological condition within specific fire footprints. Results from INL post-fire studies (Blew and Forman 2010, Forman and Hafla 2018) will be applied to each post-fire ecological resource assessment to provide context for how environmental conditions can affect vegetation condition so that treatment recommendations can be made accordingly. We will also use these datasets to understand how vegetation response to environmental conditions could affect potential treatments options. For example, late summer precipitation can lead to an increase in saltlover and Russian thistle (*Salsola tragus*). While this abundance of non-native is visually impactful, it is often short-lived and at the INL Site we have found that natives easily outcompete these species in the long-term (Forman and Hafla 2010). An abundance of these species initially points to poor ecological condition, which highlights the critical importance of considering additional factors when developing post-fire treatment recommendations.

2.3.2 Special Status Plants

Plants that have been designated SSP species are important components of post-fire ecological recovery planning because they are recognized as regionally and/or globally rare and sensitive species by local, state, and/or federal agencies. There are 20 SSP species – 19 flowering herbs and one cactus species – that occur within the INL Site (Cholewa and Henderson 1984, Anderson et al. 1996, Forman 2015, INL 2023c). These species are of current conservation significance, but the list of SSP species changes because plants species conservation statuses are continually evaluated (Faber-Langendoen et al. 2012). The distribution of these species on the INL Site is related to key habitats. The sagebrush steppe ecosystem hosts a myriad of key habitats ranging from jagged rocky ledges with unstable soils, exposed ridges of basalt, ephemerally flooded playas, sheltered microhabitats, to north facing slopes with persistent snowbanks. To maintain our knowledge of SSP population abundance and distribution, the NRG surveys known SSP population occurrences, in addition to areas with appropriate habitat, using standard methodologies (e.g., Elzinga et al. 1998, US DOI BLM 2008) and, we have discovered new populations of species like Hooker's buckwheat (*Eriogonum hookeri*) and Middle Butte bladderpod (*Physaria obdeltata*).

A post-fire ecological resource assessment will include generating a list of potentially impacted SSP species within a fire footprint. Lists are created by intersecting the spatial boundary of a wildland fire with all known SSP population occurrence data. We will also use additional data sources for SSP occurrences from Idaho Fish and Wildlife Information System at the IDFG (e.g., INPS 2022), online herbaria such as the Consortium of the Pacific Northwest Herbaria (e.g., CPNWH 2023), relevant technical reports (e.g., Mancuso et al. 2019, Forman 2015, Colket et al. 2009, Cholewa and Henderson 1984), and the most current Idaho Native Plant Society Rare Plant List. If SSP occurrence data are unavailable, or it is not feasible to conduct field surveys to determine the presence or absence of SSP species within the fire footprint, then key habitats which coincide with the fire footprint will be used to indicate which additional SSP species need to be added to the list.

The list of potentially impacted SSP species will be used to inform a holistic restoration approach to determine which treatment options have the greatest recovery benefits to SSP species and to align with restoration efforts for an individual fire recovery plan. A SSP species life history characteristics determine its key habitats, population dynamics, and potential impacts from restoration treatments. For example, the white sand verbena's (*Abronia mellifera*) life history is that of a perennial herbaceous forb which occurs in sandy soils and mature individuals wait for ideal conditions to reproduce by seed. Recovery plans which apply this knowledge are better able to recommend post-fire treatments that favor reseeding techniques that minimize impacts to the soil because if restoration efforts require drill seeding, the equipment is likely to severely damage the remaining underground roots of this perennial species. Contrastingly, SSP species like Hooker's buckwheat, are likely to recover well in disturbed soils because this species' life history is that of an annual herbaceous forb which occurs in loose chalky talus soils on steep hillsides and completes a life cycle within one growing season.

In addition to the initial evaluation completed during the post-fire ecological resource assessment, it is also important to continue to monitor SSP populations within post-fire treatments because we can follow SSP population recovery trajectories for each species. These results are used to gain ecological insights for how a SSP species population is likely to respond to wildland fire effects. An example of SSP population monitoring is highlighted by the Middle Butte bladderpod. Field survey results documented mature populations within naturally recovering wildland fire footprints which indicated this SSP species is capable of natural recovery.

2.3.3 Invasive and Noxious Weeds

Addressing both noxious and invasive weed species to prevent their establishment and further spread is required under federal and state legislation (see Section 1.1.1.2) and it is an important aspect of a post-fire ecological resource assessment. Following a wildland fire, the resistance of plant communities to invasive and noxious weeds is greatly reduced making actions related to preventing these species' establishment and spread increasingly important. Treatment of any invasive or noxious weeds on the INL Site is done using Integrated Pest Management (IPM) principles designed to guide treatment, decision making, and actions. Using IPM is an approach to pest control that combines physical, mechanical, biological, cultural, chemical, and other control methods to maintain pest levels below economically damaging levels (Takatori and Hirnych 2019).

Following a wildland fire, monitoring the burned area for noxious and invasive weeds, beginning with known populations, gives INL the best chance for preventing large infestations and allows for the opportunity to use less impactful treatment actions within the confines of administrative budgeting. A post-fire ecological resource assessment will utilize all spatial and abundance data available for invasive weeds and noxious species known to occur on the INL Site. These data will be used to guide post-fire noxious weed inventories and to provide recommendations for initial post-fire treatments.

2.3.3.1 Invasive Weeds

There are multiple instances when invasive weeds should be addressed during recovery actions following a wildland fire. As discussed in Section 2.3.1, the presence of some invasive weeds alone should not lead decision makers to target those species during recovery actions. Some invasive weeds are only a concern when the native component of the vegetation community does not have the capability of competing with invasive weeds and there is the potential for invasive weeds to become a monoculture and provide little to no ecosystem services. An example of invasive weeds that may trigger a need for treatment are some invasive annual grasses. Invasive annual grasses have the potential to alter fire regimes by increasing the amount and continuity of fine fuels that can potentially lead to larger and more frequent wildfires (Chambers et al. 2016). On the INL Site, cheatgrass is currently the only documented invasive annual grass.

Habitat condition data from the INL Site indicates that cheatgrass is more abundant in burned areas than intact sagebrush habitat, however, post-fire areas on the INL Site are still largely dominated by native, perennial species (INL 2023b). Cheatgrass cover can fluctuate considerably from one year to the next and a decrease in cover is as likely as an increase (Forman and Hafla 2018), so it is important to interpret annual changes within the context of longer-term patterns. Because cheatgrass cover generally does not increase at the expense of cover from native perennial species, it does not appear to be affecting overall habitat condition across the INL Site currently. There are, however, localized areas on the INL Site mapped as Cheatgrass Ruderal Grassland (Figure 2-2) where cheatgrass has become dominant (Shive et al. 2019), and the risk of future cheatgrass impact remains high.

During post-fire ecological resource assessment development, areas at risk of being impacted by invasive weeds can be identified first by using the 2019 Vegetation Map (Shive et al. 2019). The risk of invasive weed dominance is greatest in those areas previously mapped as ruderal classes. The Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland is a map class that is commonly found in regions that have been burned and sagebrush has been removed. The understory contains undesirable species, and the Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland can be viewed as a transitional class that is shifting towards the Cheatgrass Ruderal Grassland if control measures are not implemented or natural processes do not promote an increase in native species cover.

At-risk areas can be recommended and prioritized for treatment in the post-fire ecological resource assessment, but these areas should also then be evaluated through the monitoring process (see Section 4.0) to verify that field-based conditions are appropriate prior to treatment. Areas that would be considered optimal for treatment are characterized by high cheatgrass cover with relatively homogenous and contiguous distribution over a large spatial extent. Communities may retain some native herbaceous species, but native grasses and forbs would generally contribute less than half of the total cover of the vascular vegetation. Areas with a substantial resprouting shrub component would be a lower priority than areas lacking shrubs entirely, but they should continue to be monitored for changes in condition (see Section 4.0 for monitoring guidance).

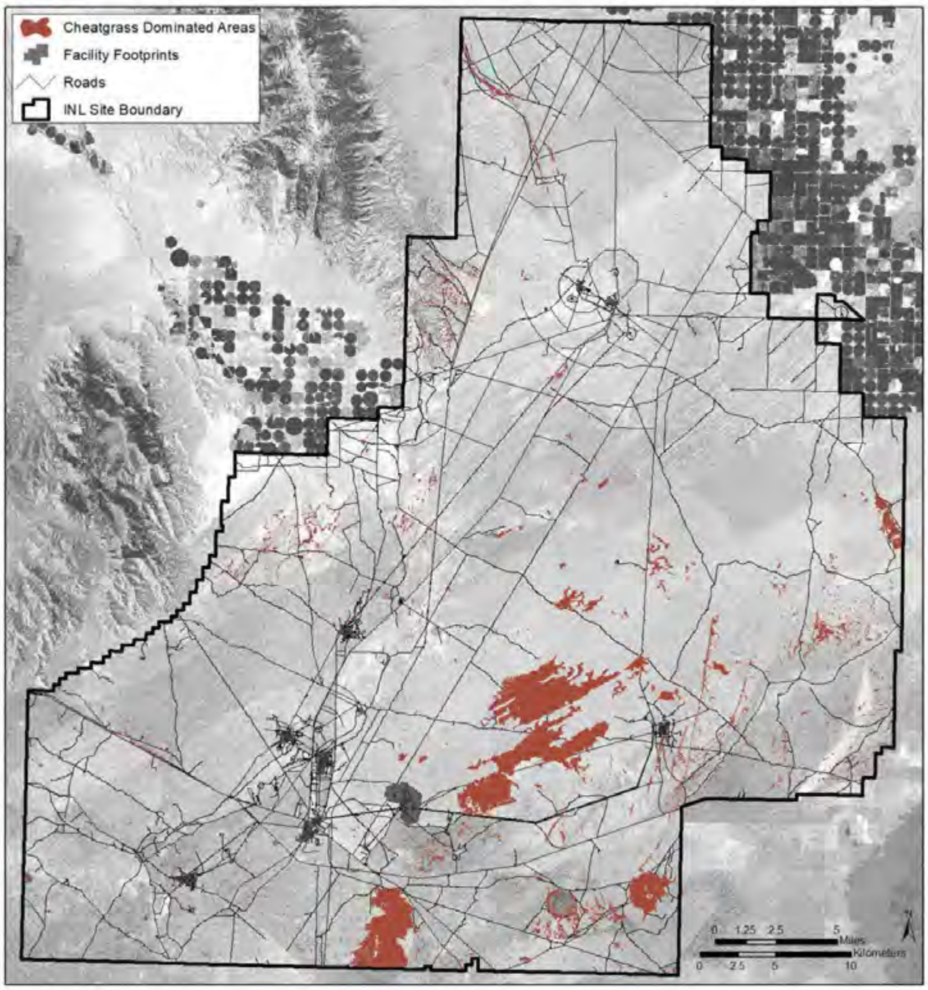


Figure 2-2. Areas mapped as Cheatgrass Ruderal Grassland Class on the Idaho National Laboratory Site.

2.3.3.2 Noxious Weeds

Sixteen species of noxious weeds have been documented on the INL Site (Table 2-1). Data on location, population size, and past treatments are collected opportunistically by either the NRG or F&SS. Any spatial data associated with noxious weed observations should not be considered a comprehensive understanding of weed distribution across the INL Site, but in a post-fire ecological resources assessment they can be used as a starting point for identifying areas that may be at greater risk for spread following wildland fire.

While known noxious weed populations pose the greatest risk for increased spread, all areas burned during a wildland fire should be considered at risk for noxious weed invasion due to the reduced resistance of the existing plant communities. Following a wildland fire, any noxious species as defined by criteria in Section 1.1.1.2. should be identified, monitored, and treated accordingly to prevent spread. Any new individual occurrences or populations of noxious weeds discovered within the fire footprint during post-fire monitoring should be added to the INL Site's annual noxious weed treatment schedule.

Once a species is identified in the post-fire ecological resource assessment or during post-fire monitoring (Section 4.0) for a specific fire, the appropriate treatment can be evaluated based on the extent of the population and the species' characteristics. Table 2-1 presents all noxious weeds known to have occurred on the INL Site in the past and lists the species characteristics that can be used to determine the correct treatment using the seasonality of plan phenology.

Inventory and monitoring of noxious weeds on the INL Site is generally executed by F&SS under the direction of PLN-611, "Sitewide Noxious Weed Management Plan" (INL 2013). Under PLN-611, noxious weed control is conducted to the extent practical and within the administration budgetary limits. Noxious weed inventory and treatment efforts should be prioritized according to risk and the post-fire ecological resources assessment can be used to evaluate risk and establish treatment priorities in the post-fire natural resources recovery plan. Additionally, when noxious weeds are encountered, they should be marked using a standardized format and shared with F&SS for appropriate treatment.

Table 2-1. Noxious weed species known to occur on the Idaho National Laboratory Site as of 2023. Specific characteristics of each species are included.

Scientific Name	Common Name	Duration	State Noxious Weed Designation	Dispersal Method	Germination	Rosette Stage	Growth	Flowering	Seed
Acroptilon repens	Russian knapweed/ hardheads	Perennial	Control	Roots	Spring – Summer	Year-round	Spring – Fall	Summer	Summer
Cardaria draba	whitetop/ hoary cress	Perennial	Containment	Roots	Spring – Fall*	Spring – Summer*	Spring – Fall	Spring – Summer	Summer – Fall*
Carduus acanthoides	plumeless thistle	Biennial	Containment	Seed	Spring – Fall*	Year-round	Spring – Fall	Spring – Summer	Spring – Summer
Carduus nutans	musk thistle	Perennial	Control	Seed	Spring – Fall	Year-round	Spring – Fall	Spring – Summer*	Spring – Summer
Centaurea stoebe	spotted knapweed	Biennial	Containment	Seed	Spring – Summer	Spring – Fall	Spring – Summer	Spring – Fall	Summer
Chondrilla juncea	rush skeletonweed	Perennial	Containment	Roots & Seed	Spring* – Fall	Spring – Fall	Spring – Summer	Summer*	Summer*
Cirsium arvense	Canada thistle	Perennial	Containment	Roots & Seed	Spring* – Fall*	Summer – Fall*	Year-round*	Spring – Summer	Spring – Summer*
Convolvulus arvensis	field bindweed	Perennial	Containment	Roots & Seed	Spring – Summer*	N/A	Spring – Summer	Spring – Summer*	Summer – Fall
Cynoglossum officinale	houndstongue	Biennial	Containment	Seed	Spring	Spring – Fall	Spring – Fall	Spring – Summer	Summer – Fall
Euphorbia esula	leafy spurge	Perennial	Containment	Roots & Seed	Spring	N/A	Spring – Summer	Spring – Fall*	Spring – Fall*
Hyoscyamus niger	black henbane	Biennial	Control	Seed	Spring & Fall	Spring – Fall	Spring – Fall	Spring – Summer	Summer – Fall
Lepidium latifolium	perennial pepperweed	Perennial	Containment	Roots	Spring & Winter*	Summer – Fall	Year-round*	Spring – Summer	Spring – Summer
Linaria dalmatica	Dalmatian toadflax	Perennial	Containment	Roots & Seed	Spring	Summer – Fall	Spring – Fall*	Summer	Summer
Linaria vulgaris	butter and eggs/ yellow toadflax	Perennial	Containment	Roots & Seed	Spring*	Summer – Fall	Spring – Fall*	Spring – Summer	Summer – Winter*
Onopordum acanthium	Scotch thistle	Biennial	Containment	Seed	Spring & Fall*	Spring – Fall	Spring – Summer	Spring – Fall*	Summer – Winter
Sonchus arvensis	perennial/ field sowthistle	Perennial	Control	Roots & Seed	Spring – Summer	Spring – Fall	Spring – Summer	Spring – Fall	Summer – Fall

* Indicates species requires favorable weather conditions to complete the growth phase

31

2.4 Assessing Wildlife Affected by Wildland Fire

Wildlife resources and concerns addressed in a post-fire ecological resource assessment will include an identification and evaluation of impacts to areas of known importance to key life events of wildlife species. Results of the wildlife component of an ecological resources assessment will be used to aid in the prioritization of habitat restoration treatments that will provide the greatest benefit to sagebrush obligate species, sagebrush associated species, or species with elevated conservation concern.

The sagebrush steppe ecosystem prevalent across the INL Site hosts a diverse collection of wildlife species with varying habitat requirements and temporal/spatial usage. The largely undeveloped nature of the INL Site is conducive for large ungulates, such as elk and pronghorn which can be found year-round with larger populations present during the winter months. Ten species of bats, including the Townsend's big-eared bat (*Corynorhinus townsendii*) and the western small-footed myotis (*Myotis ciliolabrum*) can be found throughout the INL Site with several hibernacula onsite that are frequented on an annual basis. Herpetofauna, such as the Great Basin rattlesnake (*Crotalus oreganus lutosus*) and the sagebrush lizard (*Sceloprus* graciosus) can be found sitewide with the Great Basin spadefoot (*Spea intermontana*) using locally appropriate habitats that typically coincide with seasonal flows of the Big Lost River. Over 100 species of birds (e.g., raptor, waterfowl, passerine, and upland game species) frequent the INL Site including resident populations of sagebrush obligate species such as the sage-grouse and the sage thrasher.

The high amount of wildlife diversity at the INL Site may be attributed to the wildland-urban interfaces at developed facilities and supporting infrastructure that provide unique opportunities for wildlife not typically found in a sagebrush steppe ecosystem. These "islands" of additional resources (e.g., artificial water sources and cover) may bolster species richness and favor generalist wildlife species like the barn swallow (*Hirundo rustica*) and the common raven (*Corvus corax*). These oases also provide unique opportunities for anomalous and migratory species like the blue-winged teal (*Spatula discors*) and the northern shoveler (*Spatula clypeata*), however, species detected near these facilities are atypical for the INL Site and will not likely become the focus of restoration efforts.

With over 99% of the INL Site considered unoccupied by facilities, much of the wildlife utilizing these areas are considered sagebrush obligates or sagebrush associated species. Many of these animals, including the burrowing owl (*Athene cunicularia*), Brewer's sparrow, pronghorn, and sage-grouse, are present on the INL Site and have been identified as having elevated conservation concerns by the IDFG or by the BLM. Conjointly, species like the little brown myotis (*Myotis lucifugus*), which are not typically associated with sagebrush habitat, are also of elevated conservation concern along with at least 19 other species (INL 2023c; Table 9-1). Post-fire ecological resource assessments of wildlife species will need to focus on these wildlife species, particularly those whose reproductive strategies (e.g., sage-grouse) are dependent on the sagebrush habitat located on the INL.

Several long-term wildlife survey efforts across the INL Site may provide insight as to the pre-fire abundance and distribution of key species as well as impacts of wildland fire on species populations, both of which are key components of the post-fire ecological resource assessment. The North American BBS, managed by the United States Geological Survey (USGS), provides long-term species abundance and distribution trends for birds across a broad-geographic extent (Sauer and Link 2011). The INL Site is home to five official USGS BBS routes and eight additional routes around INL Site facilities that have been surveyed nearly each year since 1985 (i.e., except 1992 and 1993). Two midwinter eagle survey routes, also administered by USGS, were established on the INL Site in 1983. These counts focus on eagle populations; however, biologists also record all owls, hawks, falcons, corvids and shrikes. Bats represent over 30% of mammal species described on the INL Site and are monitored on an annual basis near facilities and at their hibernacula. Greater-sage grouse are also surveyed annually across the INL Site to support the CCA.

Of the wildlife datasets at the INL, monitoring efforts associated with the CCA will perhaps be the most valuable as it not only provides insight as to the status of greater sage-grouse populations, which are considered an umbrella species, it also contains a wealth of habitat information from across the INL Site. Specifically, annual lek monitoring data may be used to inform areas where assisted recovery efforts may occur as this species exhibits high fidelity to breeding and nesting sites. Furthermore, comparisons of historic lek attendance to those observed post-fire and post treatment may be advantageous when evaluating treatment area selection and methodology. Post-fire and treatment responses of wildlife may also be evaluated using BBS datasets, particularly USGS routes as they survey large areas of sagebrush and grasslands and tend to detect the sagebrush obligate and sagebrush associated passerine species (Bybee and Willams 2023). Despite loose associations with sagebrush habitat, other wildlife data collected on site such as those used for site characterization or annual bat and raptor monitoring should be utilized in the post-fire ecological resource assessment because they may also be informative when evaluating wildlife responses to restoration and recovery efforts.

Gaps in wildlife information do exist within the INL Site. Formalized surveys for large ungulate species occur infrequently near the INL Site and are conducted by the IDFG. Large ungulates are known to calve or fawn and winter on the INL Site, however, specific numbers and preferred locations for calving and fawning are currently unknown. Specific areas currently used by sage-grouse for nesting and brood rearing are also unidentified, but analysis of existing habitat datasets may provide insight as to where these areas may be located. Predator populations including the American badger (*Taxidea taxus*) and the coyote (*Canis latrans*), are observed frequently along with various other wildlife species including waterfowl and herpetofauna, yet no formalized survey efforts exist for these species. Various research projects conducted by partnering universities have occurred within the boundaries of the INL Site over the years can provide some accounts of historic species occurrence and distribution for various taxa, which may be informative when performing a post-fire ecological resource assessment. In the interim, these gaps in wildlife knowledge can be addressed through targeted research and monitoring efforts (e.g., identification of sage-grouse nesting areas).

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3. NATURAL RESOURCE RECOVERY OBJECTIVES AND TREATMENT OPTIONS

The overarching goals that guided the development of this framework focus on maintaining a healthy, functional ecosystem at the INL Site through a proactive land stewardship approach to wildland fire recovery. To address these goals, fire recovery treatment options are organized into four objectives based on the types of ecological risks they address. The INL's wildland fire recovery objectives are:

1. To stabilize soils and minimize erosion,
2. To limit cheatgrass dominance and control the spread of noxious weeds,
3. To facilitate the recovery of a resilient native herbaceous layer, and
4. To speed the recovery of functional sagebrush habitat.

The natural resource recovery objectives presented in this framework reflect those addressed in the two most recent wildland fire recovery plans developed for the INL Site, one for the 2019 Sheep Fire (Forman et al. 2020) and one for four 2020 wildland fires (Forman et al. 2021). The structure and organization of both documents and the process for prioritizing treatment actions presented therein were useful to the WFMC. Therefore, this framework will follow a similar format. For each wildland fire recovery objective, discussion will include a summary of the ecological risks, treatments that can be used to minimize ecological risks, and challenges associated with implementing those treatments. All recovery treatments, or restoration tools included in this framework were evaluated by INL and DOE representatives during a series of internal stakeholder meetings to ensure that implementation is practical and feasible on the INL Site. Table 3-1 provides a summary of restoration tools presented in this document. A discussion of the challenges associated with various restoration tools is included to help summarize potential efficacy and describe limitations that should be considered when selecting treatment options for a particular wildland fire.

Table 3-1. Treatments outlined in the Wildland Fire Recovery Framework for the Idaho National Laboratory Site, their intended benefits, and potential risks/limitations. Treatments are broken out into the four wildland fire recovery objectives.

Treatment	Benefits	Potential Risks/Limitations
	Soil Stabilization and Erosion Control	
Dust control for wind erosion (water, tackifier, mulch, etc.)	Reduce impacts from fugitive dust to INL staff, facilities, and infrastructure.	Treatments may be difficult to implement over large areas and effects are short-lived.
Sediment control for soil deposition (snow fence, silt fence, straw wattles, etc.)	Reduce impacts from soil deposition to INL infrastructure and ensure the ability to use established INL transportation corridors, especially for emergency egress.	Treatments may cause unforeseen impacts elsewhere.
Recontour and revegetate disturbed soils (restore containment lines and staging areas)	Return areas impacted by direct disturbance to pre-fire condition, thereby reducing the risk of creating vectors for weed spread.	Revegetation of cold desert environments may prove difficult and resource intensive.
Limit traffic to designated roads (installing signs, barriers, or other deterrents)	Reduce the amount of ongoing disturbance in areas utilized for fire suppression activities to minimize long-term effects of habitat fragmentation.	Physical barriers must remain for several years following placement.
	Cheatgrass and Noxious Weed Control	
Chemical control (use of approved herbicides consistent with label instructions)	Prevent, control, contain, or eradicate invasive species in an area impacted by wildland fire and suppression activities to limit loss or degradation of habitat and ecosystem function.	Potential for treatments to impact non-target vegetation or wildlife.
Control by native competition (plant native herbaceous species)	Restore native species to improve the area's resistance to invasive species and resilience to ecosystem stressors.	Can be costly and time intensive, may need to be coordinated with other treatments.
Environmental control (use of inoculants or nutrients to ameliorate soil conditions)	Reduce dominance of invasive species by improving the competitive ability of native, perennial, thereby improving ecological condition.	Very condition specific, efficacy is variable, and research is still limited.
Noxious weed inventory (comprehensive survey to document weed abundance and distribution)	Provides the ability to prioritize treatments based on risk inherent to the species and its abundance and distribution, and the risk of invasion to biological resources or neighboring properties.	Can be logistically challenging and resource intensive to conduct over a large area.
Mechanical treatment (hand pulling, mowing, digging, tilling to remove weeds of concern)	Limits invasive species spread and creates less of an environmental risk when compared to chemical control; effective for improving habitat condition in ecologically sensitive areas.	May exacerbate invasion invasive species if conducted incorrectly or inconsistently.
	Native Herbaceous Recovery	
Rest grazing allotments (collaborate with BLM to ensure implementation of deferral)	Reduce potential livestock impacts to naturally recovering vegetation and prevent damage to planting treatments to promote a positive recovery trajectory.	Grazing on the INL Site is administered by BLM and any changes to grazing permits are limited to BLM policies and agreements.

Table 3-1. continued.

Treatment	Benefits	Potential Risks/Limitations
Plant native species (use locally sourced or locally adapted plant materials)	Using native herbaceous species that are locally adapted to the INL Site increases the potential of restoration success, which improves biodiversity and ecosystem resilience.	Commercial seed availability is limited, and local collections can be cost prohibitive.
Broadcast seeding (apply seed to the soil surface with a broadcast spreader)	Limits soil disturbance where there are intact recovering root systems or other resource concerns and may enhance local diversity in high-priority habitats.	Soil contact and germination conditions may not be ideal for some species.
Hydroseeding (apply seed mixed with water and hydro mulch to the surface)	Limits soil disturbance, improves seed contact, provides temporary stabilization, and may enhance nutrients availability, ultimately resulting in improved ecological condition.	May be logistically challenging where water is not readily available.
Drill seeding (plant seed with a rangeland drill)	Ensures proper planting depth is achieved and soil contact is adequate for successful germination, appropriate for restoration areas where native species are sparse.	May damage root structures of recovering native species.
Planting containerized stock (out planting greenhouse grown seedlings)	Plant species that have been grown in a nursery setting with developed root structures in a nutrient dense soil medium to provide greater chances of establishment.	Can be cost prohibitive to implement over larger areas.
Utilize soil or growth medium amendments (fertilizer, organic material, mycorrhizae, etc.)	Use supplemental treatments to ameliorate poor planting conditions related to soil texture, pH, nutrient deficiencies, and limited microbiome to enhance diversity of the restoration site.	Implementation may cause additional soil disturbance and nutrients may benefit invasive species as well.
Apply surface protection (mulch in the form of straw, gravel, woodchips, bonded fiber matrix, etc.)	Limit soil erosion, reduce seed exposure, increase soil moisture, and retain soil amendments to improve the re-establishment of native herbaceous species.	Lighter materials may be dispersed by wind and application may not be feasible over extensive planting areas.
Supplement water availability (irrigate with a temporary sprinkler system)	Provide supplemental water to seeds or seedlings to improve germination and establishment, resulting in improved ecological condition.	Access and application may be difficult in backcountry areas.
	Sagebrush Habitat Restoration	
Plant locally appropriate sagebrush material (collect local seed or acquire locally collected seed from a vendor)	Use locally appropriate plant material to enhance the establishment of both sagebrush seed and seedlings, to ensure that resulting habitat provides adequate forage, and to restore ecosystem services.	If locally appropriate seed is not available, seed collection will need to be scheduled and contracted within a short time.
Seeding (apply sagebrush through aerial or ground-based broadcasting or drill seeding) with option for imprinting (using an implement to improve seed/soil contact)	Sagebrush seed can be efficiently broadcast over large areas via aerial or ground application and it limits the amount of additional soil disturbance, preventing further habitat degradation. Drill seeding can be used under certain conditions to ensure the seed is placed at the proper depth. Imprinting can be used to improve the success of broadcast seeding, either aerially or ground based.	Seasonal weather conditions must be favorable for germination and establishment to be successful.
Planting seedlings (install nursery grown seedlings with hand tools)	Planting seedlings that have been grown in a nursery setting with developed root structures and a nutrient dense soil medium improves likelihood of sagebrush establishment and overcomes limitations on seed establishment.	Can be expensive and logistically difficult to implement across a large area.

37

3.1 Soil Stabilization and Erosion Control

Soil stabilization is often the first recovery objective for natural resources to be addressed post-fire because destabilized soils are at risk of erosion. Erosion, primarily from wind, can move large volumes of soil in a relatively short post-fire timeframe (Sankey et al. 2012). Because of the high hazard for wind erosion following a wildland fire, fugitive dust and blowing sand can be expected and may cause potential impacts downwind of disturbed areas. The high hazard for wind erosion following wildland fire may lead to fugitive dust and blowing sand, causing potential impacts downwind of disturbed areas. Temporary measures to limit impacts to personnel and facilities may be necessary, and road repair may be required where roads are impacted by blowing soil. It is also likely that areas within the fire footprint will erode under certain types of precipitation events such as those associated with significant thunderstorms and rain-on-snow events by downcutting the soil surface. Both natural and assisted restoration should be considered to prevent further erosion and to decrease the likelihood of the introduction of invasive species (Pyke et al. 2015).

In addition, soil disturbance often results from firefighting activities (e.g. laydown areas, containment lines, etc.) and emergency infrastructure repair on mission critical structures (e.g., power poles, railways, etc.), which further exposes soils and decreases their stability. For example, when damaged roadways are repaired, they become vulnerable to invasive species dominance because the soil disturbance may damage and permanently remove existing native vegetation structures. Natural resource post-fire recovery plans must address specific circumstances as well as potential effects of each recommended treatment on other natural resource recovery objectives outlined in this document because every area affected by wildland fire will have unique challenges in addressing soil stabilization and erosion control.

SUMMARY – RECOVERY OBJECTIVE 1

- Soil stabilization and erosion control are important for minimizing habitat fragmentation, preventing weed spread, and reducing impacts to personnel, facilities, and transportation routes.
- Primary restoration tools include applying water, tackifier, or mulch; installing snow fence, silt fence, or straw wattles; recontouring and revegetating containment lines; and installing signs or barriers to discourage traffic on temporary roads.
- Challenges to these approaches are identifying high priority treatment locations in a timely manner, minimizing unforeseen impacts to adjacent resources, and a lack of sufficient soils data to evaluate probability of treatment success.

3.1.1 Summary of Risks to Ecological Resources from Soil Erosion

There are five primary concerns related to soil erosion that may necessitate stabilization after a wildland fire on the INL Site. The first three concerns are the effects of fugitive dust on INL Site operations, the effects soil loss may have on the recovery of native plant communities, and the encroachment of undesirable species in areas where soils and related nutrients have been redistributed. These concerns stem from wind erosion and loss of soil immediately after vegetation has been removed from a burned area. The remaining two concerns are associated with the increased risk of creating corridors of weed invasion where vegetation was removed or disturbed during firefighting activities and soil disturbance associated with emergency infrastructure repair. Potential risks related to native vegetation recovery and post-fire weed encroachment into burned areas will be addressed in more detail under subsequent sections on other natural resource recovery objectives. This section will focus on the immediate effects of post-fire wind erosion on INL Site operations, soils disturbed by firefighting activities, and soils disturbed during emergency infrastructure repair.

Burned areas on the INL Site experience substantial movement of soil up to six months post-fire (Sankey et al. 2010). In some cases, this soil movement has resulted in concerns for INL Site employee safety. Concerns range from poor air quality to reduced visibility at INL facilities and along transportation corridors. Increased post-fire soil movement also increases the challenges associated with mitigating the effects of dust on INL facility operations. Examples may include increased frequency for changing air filters in buildings, increased need for road maintenance, and providing additional personal protective equipment for personnel working in or around the burned area.

The risks associated with soil movement via wind erosion may also impact actions taken to accomplish other natural resources recovery objectives. For example, soils must stabilize before chemical weed treatments to avoid the risk of herbicide moving with the soil, affecting non-target areas. Soil movement should also be minimized prior to seeding, to prevent seeded areas from being buried, impacting the ability of seeds to germinate below the soil surface, or even from removing soil nutrients necessary for seedling establishment. Stabilizing all soils exposed by a wildland fire is unrealistic and, in most cases, not necessary. When considering the potential risks of soil movement to INL operations, however, stabilization of strategic areas adjacent or upwind to facilities, increased focus on soil stabilization could prove worthwhile. Targeted areas where planting has been prioritized should also be evaluated for stabilization needs.

Containment lines used during fire suppression can result in large linear footprints of exposed soil. These exposed soils generally have reduced recovery of native, perennial species when compared to adjacent burned areas without mechanical soil disturbance. Additionally, disturbed soils associated with containment lines are often dominated by non-native, weedy species many years post-fire (Blew et al. 2003). Containment lines pose a concern to post-fire recovery because they contribute to habitat fragmentation, and they create corridors for weed encroachment much the same as roads (Halford 2003). Cheatgrass is particularly well-adapted to establishing on disturbed soils and can have significant impacts on native habitats at the INL Site. Some potential treatments for mitigating these risks include recontouring containment lines, performing weed control to prevent the introduction of invasive species, and restoring a healthy native herbaceous community.

On previous wildland fires, continued use of the containment lines by vehicles, up to several years post-fire, was noted (Blew et al. 2010). Continued use of containment lines as roads is detrimental to both natural recovery and to active restoration efforts. Traffic on containment lines also reinforces habitat fragmentation and potential weed vectors created by those lines. Potential actions to address these concerns may include installation of signs and/or barricades; barricades may be constructed from fences, concrete barriers, or riprap. Additional administrative controls, like specific instructions in work planning packages for backcountry work, and educational materials that stress the importance keeping vehicles on designated roadways may also be used to limit traffic in recently burned areas.

Lastly, soil disturbances caused by infrastructure repair could increase the amount of human caused damage after a fire leading to similar concerns as those related to containment lines and will be addressed similarly. Potential actions for addressing these specific risks may include recontouring and stabilizing disturbed soils; stabilization actions may include graveling and maintaining an area weed-free (see Section 3.2 for weed control options) or replanting with native herbaceous species (see Section 3.3 for a discussion of potential planting techniques).

3.1.2 Tools for Improving Post-Fire Recovery of Exposed Soils

As discussed above, it is not feasible to stabilize soils across the entire footprint of a wildland fire. It is also unnecessary across much of the burned area because natural recovery will sufficiently stabilize soils after the first post-fire growing season (Chambers 2016). Therefore, the options for improving post-fire recovery of exposed soils that will be included in post-fire natural resource recovery plans are generally limited to mitigating the impacts to INL operations from fugitive dust, stabilizing areas impacted by firefighting activities, and stabilizing areas impacted during emergency infrastructure repair following a wildland fire. Treatment options related to stabilizing soils through the means of herbaceous recovery will be addressed in more detail in Section 3.3. The recovery tools associated with impacts to soils are organized into three topical areas: erosion from vegetation removal/loss, soil disturbance from fire suppression activities, and soil disturbance associated with infrastructure repair.

3.1.2.1 Erosion From Vegetation Removal/Loss

Dust Control for Wind-Driven Erosion

Actions to control dust and wind driven erosion may include use of water cannons, surfactants, tackifier, and/or mulch to reduce the concentration of soil particles in the air. The extent of these proposed actions would be limited to the area immediately adjacent to facilities and the roadways used to access facilities. The duration of this activity would be up to one year post fire, at which time soil will be stabilized naturally by resprouting vegetation or by formation of a soil crust. Any materials or chemicals considered for use as a tackifier, mulch, or surfactant will be a product with demonstrated efficacy for the intended application. These products must be approved for use at the INL Site and will be applied according to manufacturer instructions.

Using water applied to the soil surface is a common cost-effective practice in many industries to reduce the impact of blowing dust. When the soil surface is wet it aids in soil particle agglomeration, reducing the likelihood individual particles will move with the wind (Jones 2017). While this technique can be effective in reducing impacts of soil movement and dust to facilities, the result of water application is temporary and limited to the amount of time it would take for the soil surface to dry. Therefore, repeated applications will be necessary, likely over an extended period. When utilizing this technique, it is important to consider additional impacts the application may have on the area such as equipment further disturbing soil when transporting water and costs associated with labor and fuel. For this reason, application of water should only be considered along roadways that will not be further impacted by equipment and should only be used in specific, priority areas until a longer-term solution can be reached (Jones 2017).

In most cases the effectiveness of dust control can be greatly improved by utilizing additives to the water such as a surfactant. Many surfactants are a soap-based solution, which improves the wetting ability of water and can remain on soil surface after water has evaporated and aids in soil particle agglomeration (Yonkofski 2018). This approach will add to the cost of water application because of surfactant cost and possibly for specialized equipment needed for application.

A longer-term treatment for stabilizing soils and minimizing impacts from wind erosion is the use of soil tackifiers. Soil tackifiers can be organic or inorganic products applied in solution to the soil surface and form a protective surface film or infiltrate. Tackifiers bind the soil particles together and can be utilized with other treatments such as seeding and mulching to aid in preventing those treatments from moving off the treatment area by attaching seed and mulch to the surface (Rivas 2006). When used alone soil tackifiers both aid in soil particle agglomeration and can create a surface crust which can greatly reduce soil movement following wildland fire. Although not a permanent solution soil tackifiers can be applied once and can remain effective longer than just applying water. Soil tackifiers should be considered in areas where repeated applications of water to minimize soil movement would be difficult or cost prohibitive.

An additional longer-term treatment for stabilizing soils and minimizing impacts from wind erosion is the use of mulches on the soil surface. Mulches can be a layer of either organic or inorganic materials applied to the soil surface to keep soil particles in place by weighing them down, providing cover from wind/saltation action, and retaining moisture leading to improved agglomeration. Organic mulches can be used in revegetation treatments to aid in providing soil nutrients to the soil (See Section 3.3). Mulch treatments may consist of distributed agricultural straw (e.g., wheat, barley, rice), wood-based mulch (i.e., shreds or strands), larger aggregate inorganic material (i.e. gravel or stones), or application of a wet hydro mulch made up of organic fibers such as paper and seeds bonded by a tackifier (Chambers 2016). Lightweight organic mulches like paper or straw can blow off the treatment area rendering them ineffective and should be applied with an additional treatment such as a soil tackifier or crimping them into the soil to keep them in place. Additionally, organic mulches such as straw must be certified weed free to be used on the INL Site.

Sediment Control for Wind- and Water-Driven Soil Deposition

Where wind erosion is moving soil into unwanted areas, artificial temporary structures can provide protection from soil movement by allowing soil to accumulate behind them in an area where soil accumulation will not be impactful. These can include plastic snow/silt fences or rows of straw bales. This treatment may only be effective along shorter distances and should be implemented with additional treatments such as soil tackifiers or mulches to ensure their effectiveness (Chambers 2016).

In areas where slope or contouring is leading to erosion and accumulation of material in access roads or undesirable areas due to water runoff following the removal of vegetation, treatments that slow the progression of water down slope or direct it to move laterally across the slope should be implemented (Chambers 2016). Examples of treatments to slow the flow of water and reduce soil movement and erosion include placing straw wattles or silt fences.

3.1.2.2 Soils Disturbed by Firefighting Activities

Recontour and Revegetate Disturbed Soils

Once containment lines and staging areas have been identified and prioritized for restoration, the highest priority areas should be recontoured and planted with a native grass mix (see Section 3.3 for revegetation actions and treatments). Containment lines should be recontoured prior to demobilization of the heavy equipment used for fire suppression efforts to prevent continued disturbance to recovering vegetation. There is no advantage to making the re-graded lines conform to a certain construction specification. In fact, it is much better for revegetation if the recontoured containment lines are imperfect and thereby provide favorable microsites for re-sprouting plants or sprouting seeds. In many cases, minimizing additional disturbance is preferable to achieving ideal contours. Planting during the recontouring process also eliminates additional visits to the containment lines and limits traffic on the already disturbed areas. Minimization of disturbance is key to successful revegetation because it also limits soil compaction and risk of introducing non-native species. In addition to planting containment lines and staging areas, any vegetation debris that has accumulated at the edge of bladed areas should be scattered and redistributed over the area to provide additional advantageous microsites for recovering vegetation. See Section 3.3 for information about selecting appropriate plant materials, planting techniques, and any supplemental survival enhancement methodology that should be considered for soils that have been disturbed by fire suppression activities.

Limit Traffic to Designated Roads

Once the need to access containment lines to support immediate recontouring and revegetation efforts has been addressed, barriers should be added to all containment lines where they bisect existing roads to prevent vehicular travel on the recovering lines. This can either be done with signage, jersey barriers, or simply with T-posts placed close enough together to deter traffic. A brief memo reminding all fieldworkers to avoid vehicle travel on containment lines prior to each field season may also be helpful.

3.1.2.3 Soil Disturbance Associated with Infrastructure Repair

Because infrastructure repairs are often related to public safety, they are time sensitive and a high priority after a fire. An assessment of potential damage to natural resources is often not completed prior to the initiation of repairs. Instead, this assessment may occur after the repairs have been completed as part of the post-fire monitoring effort and mitigative measures. Additional treatment will be considered if the damage is severe enough to warrant weed treatment or revegetation. One example may be excessive soil disturbance that removes re-sprouting perennials species. Recontouring of the area may be required to ensure topsoil is redistributed, followed by revegetation treatments to enhance long-term stabilization. Tools associated with revegetating these areas can be found in Section 3.3.

3.1.3 Challenges to Implementing Soil Erosion Treatments

There are many challenges associated with stabilizing soil following a wildland fire. The first is the fact that when wind erosion becomes appreciable across a wildland fire footprint there is often little that can be done to stop it (Chambers 2016). We acknowledge this challenge and will prioritize the areas with the highest potential impacts on INL operations and infrastructure to mitigate and minimize blowing dust.

Some actions, like the application of water for dust suppression can lead to further erosion of resources such as road shoulders or along slopes by introducing water that moves across the unstable surface moving soil particulates with it as it travels down a slope. It will be important to understand any long-term consequences of short-term treatment solutions and address those consequences in the post-fire natural resources recovery plan. For example, treatments intended to target water driven deposition of soil can be ineffective if revegetation efforts to address the long-term source of the problem are not successful. Additionally, these treatments are more effective when placed prior to events causing erosion (i.e., rain), however areas vulnerable to erosion are not identified until erosion is already taking place, making treatments more difficult.

When addressing soils impacted by fire suppression activities and emergency infrastructure repair, challenges may arise each time the area is revisited with vehicular traffic. Continued use of these areas could lead to compaction of soils making revegetation difficult, and the likelihood of introducing more invasive species increases with each visit. Recovery plans will balance the benefits of stabilization treatments with the risks of continued disturbance associated with those treatments.

An additional challenge for conducting soil stabilization on the INL site is the lack of site-specific soils information and data. Across a fire footprint it can be challenging to determine the soil types most vulnerable to erosion, but prioritizing areas based on threats to infrastructure and where INL employees and contractors will be working will aid in choosing areas to implement treatments. Ground-based characterization associated with post-fire monitoring will also help us tailor treatments to areas with the greatest likelihood of success and using equipment and materials best suited to site-specific conditions.

3.2 Cheatgrass and Noxious Weed Control

The risk of increased pressure by non-native species is an important post-fire concern and reducing that risk is a critical natural resource recovery objective. There are several non-native species of concern (i.e., not classified as noxious) that are widely distributed across the INL Site. These species do not dominate large extents of the INL Site, but they can form localized, degraded stands (Shive et al. 2019) that are characterized by little diversity, limited habitat value, and low ecological condition. These species are introduced annual forbs including saltlover, Russian thistle, desert alyssum (*Alyssum desertorum*), kochia (*Bassia scoparia*), and various mustards (*Sisybruim* spp. and *Descurainia* spp.). Generally, these species are not very competitive in the high condition plant communities that dominate much of the INL Site but cheatgrass typically poses a more immediate risk. Therefore, cheatgrass will be the focus of invasive species treatment recommendations in most post-fire natural resource recovery plans.

In addition to the regulations that require land managers to control these species, they are highly competitive and can easily displace desirable native vegetation. To successfully address the risks to sagebrush habitat recovery posed by non-native species, control strategies for all noxious weeds and other undesirable non-native species should be addressed as an integral component of every post-fire natural resource recovery plan. In this section, invasive annual grasses and noxious weeds will be discussed along with the tools available to treat them and mitigate the risks they present.

SUMMARY – RECOVERY OBJECTIVE 2

- Cheatgrass and noxious weed control are important for minimizing habitat degradation, maintaining ecosystem function, and preventing a shift toward an altered fire regime.
- Primary restoration tools include applying herbicides, increasing native competition, using nutrients or soil inoculants, completing comprehensive inventories, and implementing mechanical treatments like digging or mowing.
- Challenges involve mobilizing enough resources to complete comprehensive inventories, maintaining enough native diversity to outcompete invasives, aligning treatment priorities with current or future land use, ensuring conditions are appropriate for maximum treatment efficacy, and preventing unintended chemical movement.

3.2.1 Summary of Risks to Ecological Resources from Invasive and Noxious Weeds

Invasive species, like cheatgrass and noxious weeds arguably pose the greatest risk to the sagebrush steppe ecosystem because in their absence, altered fire regimes would be less probable. On the INL Site, areas at increased risk for post-fire dominance of non-native species are areas where they were known to occur pre-fire and areas where ecological condition was low prior to the fire. Areas with low pre-fire ecological condition include plant communities with reduced cover and diversity of native, perennial species, with an abundance of non-native annual forbs like those listed above, and areas with periodic stochastic disturbance, like flooding. Treatments that reduce the cover of invasive species and noxious weeds, impact their ability to reproduce, or make them less competitive provides desirable native species the opportunity to recover enough to provide long-term resistance via competitive exclusion.

3.2.1.1 Risk of Cheatgrass Spread and Increased Dominance

As discussed in Section 2.3.3, there are multiple risks associated with invasive annual grasses and cheatgrass is currently the only invasive annual grass on the INL Site. Cheatgrass often functions as a winter annual, where it can germinate in late fall or very early spring. It will then sit dormant until it can take advantage of favorable early season growing conditions, which gives it a competitive advantage over natives that germinate or emerge later in the growing season. The impacts of cheatgrass invasion and the resulting change in fire cycles on sagebrush steppe ecosystems across the western United States have been well-documented (Balch et al. 2013). Burned areas are less resistant to invasion and are at greater risk for shifts toward cheatgrass dominance than areas that have not recently burned (Chambers et al. 2014). Plant communities that have become dominated by cheatgrass post-fire reflect a serious decline in ecological condition because cheatgrass fragments sagebrush steppe and generally reduces habitat value (Knick and Rotenberry 1997), drastically impact ecosystem function (Norton et al. 2004), alters mycorrhizal function that is beneficial to sagebrush growth and reestablishment (Dierks et al. 2019), and further alters the historical fire cycle (Knick 1999).

Before the 2019 Sheep Fire, fire recovery plans for the INL Site didn't specifically address the risk of increased cheatgrass dominance in post-fire plant communities (e.g., Blew et al. 2010). Cheatgrass has documented to be widely distributed across the INL Site, but until the mid-1990s, it typically occurred at very low densities that weren't considered a threat to post-fire recovery of good condition sagebrush steppe habitat (Forman et al. 2010). Since that time, cheatgrass abundance has begun exhibiting larger fluctuations from one time period to another (Forman and Hafla 2018). Over the last several years, cheatgrass has also become much more abundant in post-fire plant communities than in sagebrush-dominated shrublands that have not burned in recorded history (INL 2023). Coincident with increases in abundance are notable increases in the distribution of cheatgrass-dominated plant communities across the INL Site, as documented by the differences in distribution of cheatgrass vegetation classes between the two most recent vegetation mapping efforts (Shive et al. 2011, Shive et al. 2019). Nearly all the increase in distribution of the cheatgrass-dominated vegetation class was in post-fire plant communities. Because changes in the abundance and distribution of cheatgrass across the INL Site over the past decade appears to be somewhat related to wildland fire, it is now an important consideration for post-fire vegetation management.

Invasive annual grasses can be treated using selective herbicides that target annual functional groups specifically. With selective herbicide treatments comes challenges to other treatment activities, such as restoring a native herbaceous component to the area (see Section 3.3 for details on revegetation methods). Additionally, it may be possible to combat cheatgrass through environmental controls such as applying soil amendments to post-fire areas containing cheatgrass stand to provide native vegetation a competitive advantage.

3.2.1.2 Importance of Invasive and Noxious Weed Management

Noxious weeds and other invasive plants have the potential to modify the structure and function of the ecosystem (Crowl et al. 2008). Their vigorous growth and prolific reproductive capabilities cause changes in soil chemistry, hydrological conditions, and fire regimes that favor their growth and spread and impede natural succession. Native vegetation does not have the ability to compete with these aggressive species, resulting in a change of native plant communities, a reduction in biodiversity, and habitat degradation. Forage production is also diminished for all classes of herbivores and habitats for small birds and mammals are reduced making rangelands unusable for wildlife and livestock. Noxious weeds are also a factor for Threatened or Endangered species as it is estimated that approximately 42% of these species are at risk due to non-native, invasive species (Pimentel et al. 2005). The longer the presence of noxious or invasive species is overlooked, the harder and more expensive it is to control them. Noxious weeds on the INL Site can be treated following wildland fire by inventorying their occurrences within a fire footprint and applying chemical control and mechanical control.

3.2.2 Tools for Limiting Post-Fire Weed Spread

Treatments for limiting post-fire weed spread are organized by those treatments that are specific to cheatgrass and those that are specific to noxious weeds. Cheatgrass and other invasive annuals are addressed as a separate functional group from noxious weeds because their biology, the mechanism on which treatments act, and their invasion patterns are different. Cheatgrass functions as a winter annual and most noxious weeds are deep-rooted perennials. Within each functional group, chemical options are available, and they will often be the most feasible and cost-effective option for large treatment areas, but because INL uses an IPM-based approach to weed management, other options are discussed in this framework and should be evaluated and recommend where appropriate within each natural resources post-fire recovery plan.

3.2.2.1 Cheatgrass Control

Chemical Control

Any chemical used as an herbicide for invasive annual grass control must be approved under FIFRA and be assigned an EPA registration number. Additionally, the herbicide must be approved for use at the INL through the Chemical Services Processes (INL 2022). There are specific instructions included on each label of an approved pesticide and those instructions must be followed per FIFRA. No matter the product being used, the directions of use must match the label and the planned application.

Potential actions may include use of pre-emergent herbicides, and/or in limited circumstances, post-emergent herbicides applied from the ground using tanks and spray booms mounted to trucks or utility terrain vehicles (UTV)s or from the air using tanks and spray booms mounted to helicopters, fixed-wing aircraft, or drones. Both liquid and granular chemicals will be considered and the form most appropriate to the intended application will be selected. The extent of these proposed actions would be limited to the areas where cheatgrass was dominant or co-dominant pre-fire, and where ground conditions (i.e., native species abundance, thatch cover, etc.) are conducive to favorable treatment outcomes.

The most recent INL Vegetation Map indicates that approximately 4.0% of the INL Site was dominated cheatgrass in 2019, prior to the Sheep Fire. Though vegetation distribution is always changing, only a portion of the total cheatgrass-dominated area would be affected by individual wildland fires, and within a given wildland fire, a smaller portion would be expected to meet the field-based criteria for treatment. For reference, a large portion of the contiguous areas dominated by cheatgrass on the INL Site were burned in the Sheep Fire and a total 3,200 ha (7,000 ac) were prioritized for treatment. Under current conditions, it is unlikely that an area substantially larger than that recommended for treatment in Sheep Fire would be recommended for treatment in future fires.

Several herbicides have been used in sagebrush steppe to control cheatgrass with various levels of success. Imazapic is a pre-emergent chemical herbicide and has probably been the most frequently used chemical for cheatgrass control across the arid West; it is an agency standard and, when used correctly, it can reduce cheatgrass effectively in the short term (Applestein et al. 2018). The use of Imazapic is a reasonable approach to cheatgrass control; however, there are additional chemical herbicides that should be considered. Local agencies have recently reported high success rates in controlling cheatgrass using Indaziflam. This herbicide is a pre-emergent herbicide which is best applied during the late fall, winter or spring shortly after a fire; it is most effective when the thatch layer has been reduced, but it should not be applied before soils have stabilized to prevent down-wind movement. This timing also protects established grasses, forbs and shrubs because they are not actively growing. Precipitation is needed to activate the herbicide, but it should not be applied during heavy rain events nor to frozen or snow-covered ground. Examples of herbicide that are commonly used to treat cheatgrass may include but are not limited to Esplanade 200 SC (EPA Reg. No. 432-1516), Rejuvra (EPA Reg. No. 432-1609) and Plateau (EPA Reg. No. 241-365). As additional chemical treatment options are developed and tested, they will continue to be evaluated for use in post-fire cheatgrass treatments at the INL Site.

Control by Native Competition

An additional control method for cheatgrass is through the re-establishment of the native plant community. In most cases, resistance to invasive species depends on the composition and ecological condition of a native plant community, which influences whether it has the capacity to effectively compete with the invasive species (Chambers et al. 2014), and whether the area was dominated by introduced annuals before wildland fire (Humphrey and Schupp 2001). Reestablishing the native plant communities in areas at risk of post-fire cheatgrass dominance can be an effective way to increase ecological resistance against further invasive species dominance. This method of control may need to be considered in combination with other control methods. For example, herbicide treatment may only be effective in an area with sufficient remaining perennial species or in areas where herbaceous species restoration is implemented in combination with herbicide treatment. If an area is treated without consideration of native, herbaceous species recovery, the treated area will likely return to a cheatgrass dominated plant community.

Environmental Control

Environmental control of invasive annual grasses may include the application of soil inoculants or the addition of nutrients to the soil surface using tanks and spray booms mounted to trucks or UTVs or from the air using helicopters or fixed-wing aircraft. Mechanical or hand spreaders may be used for the application of organic materials. The extent of these proposed actions would be limited to areas where cheatgrass was a substantial component of the pre-fire community. The duration of this activity extends from one growing season post fire after soils have stabilized and up to five years post fire. Proposed treatments will be limited to the use of products with demonstrated efficacy for the intended application. Examples may include but are not limited to chemical fertilizers and natural materials containing carbohydrates or other natural organic solids.

The use of environmental control to combat invasive annual grasses can be effective by either boosting native soil bacteria, mycorrhizal communities, and other nutrients that are advantageous for native species and in some cases detrimental to invasive annual grasses. For example, cheatgrass invasion can alter community structure of arbuscular mycorrhizal fungi in the sagebrush-steppe ecosystem decreasing the ability of native species, like sagebrush, to develop robust root structures (Dierks et al. 2019). This shift in arbuscular mycorrhizal fungi can be combated by either cultivating native, beneficial mycorrhizal fungi or acquiring commercially available products and inoculating the soil of cheatgrass dominated sites prior to revegetating the area. Although this approach is relatively recent and should be considered cautiously, the interactions among arbuscular mycorrhizal fungi are actively being researched to understand their implications on restoration efforts in semi-arid ecosystems (Hovland et al. 2019). Inoculation may be implemented through spraying the soil surface with a liquid suspension or spreading a granular form and harrowing or discing the area. Harrowing and discing the area should be avoided unless necessary because of the additional risks of further invasion after disturbing the soil.

Weed-suppressive bacteria have also been considered as an option for cheatgrass control in sagebrush-steppe ecosystems. However, at the time of publication, there were no commercially available sources for these bacteria and results of recent studies have failed to confirm their efficacy (Pyke et al. 2020, Reinhart et al. 2020, Lazarus and Germino 2019). As such, other forms of environmental control should be utilized in an experimental fashion and only applied in large areas when efficacy has been proven elsewhere.

3.2.2.2 Noxious Weed Control

Noxious Weed Inventory

A noxious weed survey typically includes surveying the entire burned area and documenting the presence of individual weeds or larger infestations of weeds. If possible, weeds should be treated at the time of survey using chemical herbicides or other appropriate control methods. Noxious weed surveys should begin on the burned area during late spring/summer following the fire when weeds can be identified and surveys should continue until five years post-fire, when the wildland fire footprint becomes part of the ongoing site-wide noxious weed treatment plan (PLN-611 INL 2013). Surveys may take place along roadsides, as pedestrian surveys, or as aerial surveys (i.e., drones) in the backcountry. For surveys to effectively address the risk of post-fire noxious weed infestation, they should encompass the entire fire footprint, which could be over 40,000 ha (99,000 ac) based on the size of largest INL Site wildfire to date. Surveys may also be augmented utilizing incidental observations from both F&SS and NRG field workers.

Mechanical Treatment

Mechanical treatment of noxious weeds may be successful and more cost effective than chemical treatment depending on plant phenology and the size of the infestation. Mechanical treatment includes hand pulling, digging, mowing, and tilling, depending on the weed of concern and the most appropriate technique. The extent of these proposed actions would be limited to hand-pulling and digging small, dispersed populations and mowing and tilling more extensive patches. Mowing or tilling is only appropriate where severely disturbed noxious weed monocultures exist. Noxious weeds that are annuals or biennials may be controlled within a couple growing seasons as long as the treatments are conducted prior to seed set. Perennial weed species may prove more difficult to control through mechanical means because repeated actions will be required and in some cases within the same growing season, to achieve effective control. The duration of this activity extends from one growing season post-fire, when weeds can be accurately identified, until five years post fire, when the wildland fire footprint becomes part of the ongoing site-wide noxious weed treatment schedule.

Chemical Treatment

Potential treatment actions for noxious weeds after a wildland fire may include applying INL-approved chemicals using ground-based methods like backpacks, or tanks and booms mounted to UTVs and trucks, or using aerial-based methods like tanks and booms mounted to drones, helicopters, or fixed-wing aircraft. The extent of these proposed actions would be limited to noxious weed occurrences, which are often distributed as dispersed populations or as relatively small monocultures < 10 ha (25 ac). The duration of this activity extends from one growing season post-fire, when weeds can be accurately identified, until five years post fire, when the wildland fire footprint becomes part of the ongoing site-wide noxious weed treatment schedule.

Any herbicide considered for post-fire noxious weed application will be a product with demonstrated efficacy for the intended application, including approval for rangeland use. Any chemical used as an herbicide for noxious weed control must be approved under FIFRA, assigned an EPA registration number, and approved for use at the INL through the Chemical Services Processes (INL 2022). There are specific instructions included on each label of an approved pesticide and those instructions must be followed per FIFRA. Examples of herbicide that may be appropriate for treating noxious weeds include, but are not limited to Milestone (EPA Reg. No. 62719-519), Panoramic 2SL (EPA Reg. No. 66222-141-81927), Escort XP (EPA Reg. No. 432-1549), Landmark XP (EPA Reg. No. 432-1560), Open-Site (EPA Reg No. 62719-597), Piper (EPA Reg. No. 59639-19380), Platoon (EPA Reg. No. 228-145), Round-up Custom (EPA Reg. No. 524-343), Round-up Pro Concentrate (EPA Reg. No. 524-529), Tordon 22 K (EPA Reg. No. 62719-006), and Weedar 64 (EPA Reg. No. 71368-1).

3.2.3 Challenges to Implementing Weed Control Treatments

Challenges associated with weed control treatments begin with being able to adequately inventory and characterize areas that should be prioritized for treatment. Inventorying a fire footprint for noxious weeds can prove challenging because of the potential size of the fire footprint. In some cases, the entire area may not be able to be surveyed extensively. Instead, high risk areas that are already degraded or where noxious weeds were known to occur prior to wildland fire should be prioritized for treatment. Of equal importance are field-based pre-treatment monitoring surveys to characterize conditions at the time of treatment. Initial treatment areas can be targeted during the post-fire ecological assessment, but field-based surveys prior to treatment will be critical to evaluate treatment success because the efficacy of the treatments recommended in the natural resources post-fire recovery plan will depend on meeting criteria for current local conditions, like native herbaceous cover ranges and depth of organic thatch.

Maintaining enough of a native component to enhance long-term success of areas being treated for both noxious and invasive species can also prove challenging. Generally, noxious and invasive weed treatments should not be utilized without complementary herbaceous planting treatments in areas that are lacking sufficient density of desirable native species. Once the undesirable species is removed from a plant community lacking sufficient remnant native cover, it remains susceptible to further invasion until a competitive native community can be restored. A combination of weed control and herbaceous restoration treatments are often costly and time consuming. Given the amount of investment that may be required to successfully restore areas in this condition, recommendations for restoration will be limited to areas identified as having particularly high habitant importance during the post-fire ecological resources assessment.

To ensure the investment of substantial resources into cheatgrass treatments is justified, current and future land uses of the area under consideration will be evaluated. The long-term effectiveness of cheatgrass treatments in high-use areas of livestock allotments is likely to be low unless extensive changes are made to the grazing permit for the allotment. Additionally, current grazing practices and preferred cheatgrass treatment options may not always be compatible, which should also be considered before pursuing treatment. Finally, large investments in treatments should be avoided where future infrastructure development to support INL mission activities has been planned.

Chemical treatment options present some distinct challenges associated with post-fire soil movement. Inadvertent movement of chemicals can result in damage to resources outside the targeted treatment area, or even damage to neighboring agricultural properties. While spot treatments may be used within a few months post-fire, application of chemicals across a larger extent will not occur until at least one growing season post-fire to ensure soils have stabilized and the risk of soil and chemical movement are minimized. Additionally, wind speed should be considered during chemical application because wind has the potential to move herbicide off the target area. It is important to account for potential soil erosion from high intensity precipitation events because leached herbicides can be transported into unburned habitats and potentially have unintended effects in those areas (Zaller et al. 2014). Another consideration for chemical application is the potential volatilization of the chemical when applied in warmer temperatures. Like impacts from wind, volatilization of chemical treatments may also move chemicals to off target areas and render the application on the target area ineffective.

With many products applied to treat invasive annual grasses, achieving proper soil contact is crucial in herbicide activation to prevent seed germination, but this can often prove challenging when a thatch layer has formed. When choosing herbicides to treat invasive annual grasses, considering multiple products in a mix that addresses different modes of action can help overcome some of the issues associated with thatch layers and lack of soil contact. Ultimately, many challenges associated with chemical treatments, including those highlighted here, can be minimized by following the manufacture label of the chosen pesticide as well as choosing effective adjuvants when appropriate.

When using mechanical means of treating noxious weeds, understanding the phenology of the species (Table 2-1) being targeted is critically important to ensure that treatments are effective. This can prove challenging when multiple species are collocated but have differing phenology. One species may be effectively targeted through mechanical means and the other may not, increasing the risks of furthering the spread of one species. Additionally, timing of mechanical treatments for noxious weeds is crucial to ensure that seeds have not been developed and mechanical treatments will not cause further spread of the species. Timing may prove challenging because various conditions across a population may cause some individuals to produce seed earlier than others.

For mechanical, chemical, and environmental treatments, cost and effectiveness can vary widely. The range of conditions under which a treatment may be effective can have a lot of variation as well. Some treatments may have a very wide range of weather or ground-based conditions under which optimal results can be achieved, while others may be much more limited. We will consider results from the post-fire ecological resource assessment, field-based post-fire monitoring surveys, and logistical constraints associated with personal and equipment availability when providing weed treatment recommendations in the natural resources post-fire recovery plan. In many cases multiple options will be provided so that treatments can be flexible and responsive to specific conditions and available funding.

3.3 Facilitation of Native Herbaceous Recovery

Improving recovery of native herbaceous vegetation post-fire was identified as a natural resource recovery objective for several reasons. A healthy and diverse herbaceous layer can impart resilience to a plant community (Anderson and Inouye 2001), which can improve natural recovery after a disturbance like wildland fire or in response to an abiotic stressor like drought. Resistance to weed invasions and infestations is generally much higher in vegetation with an abundant native perennial component, and habitat for taxa ranging from plants and invertebrates to birds and mammals is improved by a healthy herbaceous stratum. Habitat benefits of an herbaceous layer in good ecological condition can include concealment, ameliorated microclimate conditions, improved forage, and increased prey resources.

Natural recovery of the herbaceous stratum is likely for plant communities across much of the INL Site because they are still in good ecological condition with a diverse, native composition (INL 2022, Forman and Hafla 2018, Blew and Forman 2010). Where possible, natural herbaceous recovery is preferable because it limits potential impacts from treatments, like soil disturbance associated with planting or the introduction of novel genetic material. However, if results of the ecological resource assessment indicate that successful natural herbaceous recovery is unlikely in a particular area, then assisted recovery treatments should be considered to minimize the risks associated with poor herbaceous recovery. Conditions under which facilitated or assisted recovery should be considered may include areas susceptible to erosion; areas with high cover of invasive annuals, especially where relative cover of native perennials is low; areas where weed invasion risk is high; or to reduce habitat recovery time for special status species.

Some INL Site plant communities have abundant and diverse herbaceous layers, while others are inherently sparser and more homogenous, even when in good

SUMMARY – RECOVERY OBJECTIVE 3

- Improving native herbaceous recovery is important for increasing resistance and resilience of plant communities, improving biodiversity and ecosystem function, and for maintaining high quality habitat.
- Primary restoration tools include resting grazing allotments, using native and locally adapted plant materials, broadcast seeding, hydroseeding, drill seeding, planting containerized stock, amending the soil or growth medium, and providing supplemental water, where feasible and appropriate.
- Challenges to herbaceous restoration stem from the inherently harsh conditions of the cold desert sagebrush steppe and include the pressure from invasive species, unpredictable precipitation patterns, and limited availability of appropriate plant materials.

ecological condition (Shive et al. 2019). The amount of herbaceous biomass and diversity of a native plant community is often related to soils and other abiotic factors. Although it is important to ensure that herbaceous diversity is maintained, it is also important to recognize that native plant communities exhibit a range of historical variation across the INL Site and increasing native diversity beyond its historical range is not a reasonable or achievable goal. Therefore, low herbaceous cover or diversity is indicative of poor recovery only when it occurs in areas where cover or diversity would be expected to be higher based on historical data.

3.3.1 Summary of Risks to Ecological Resources from Poor Herbaceous Recovery

Poor post-fire recovery of the herbaceous stratum in sagebrush steppe ecosystems could result in the loss of habitat for special status plant and animal species, insects, and major wildlife functional groups. Loss of ecosystem services that are related to biodiversity, including loss of productivity, loss of ecosystem function, loss of resilience, and increased risk of invasion and dominance by non-natives are also ecological risks of poor recovery. To mitigate these effects, post-fire treatment strategies should not only address areas at risk of poor recovery, but they should also address all factors that may impact the ecological condition of the herbaceous layer.

In areas where herbaceous diversity is lower than would be expected, there are often factors beyond wildland fire affecting ecological condition. Additional factors that could increase the risk of poor herbaceous recovery on the INL Site include poor pre-fire ecological condition, noxious weed infestations or dominance by invasive annual species, livestock operations, drought, and soil disturbance. These factors often occur in combination, which may increase the magnitude of their overall impact on recovering native vegetation.

For example, livestock grazing can negatively impact recovering herbaceous communities by damaging recovering grasses and increasing the risk of spread and dominance by undesirable non-natives. Reestablishing natives in a vegetation community that is strongly dominated by invasive species is the best long-term solution for increasing the future resilience of the plant community and for improving local habitat conditions. However, successful herbaceous restoration would require an area be rested from livestock grazing, so those treatments should be considered in combination.

3.3.2 Tools for Improving Post-Fire Herbaceous Recovery

Options for improving post-fire ecological condition where herbaceous recovery is expected to be poor include working with BLM to reduce grazing pressure and planting native herbaceous species. There are two potential reasons for reducing grazing pressure; to decrease stress on naturally resprouting and reseeding species and to allow seedlings from active treatments to become established. The restoration tools associated with planting are organized into three topical areas: plant materials, growing and planting techniques, and additional practices that can be used to improve restoration success.

3.3.2.1 Rest Grazing Allotments

Closure of a burned area to livestock grazing is often appropriate to facilitate soil stabilization and both natural and assisted vegetation recovery. Within grazing allotments, BLM typically communicates closures to the affected permittees through modifications to grazing permits. These closures are generally not lifted until monitoring results show stabilization and rehabilitation objectives have been met (BLM 2007).

In addition to their standard post-fire grazing deferral practice, BLM can facilitate specific post-fire herbaceous recovery strategies through changes in grazing management. Therefore, it is important to communicate any treatment plans where outcomes can be improved by changes to stocking rates or season of use to the Upper Snake River District – Eastside, Idaho Falls Field Office (BLM-USRD 2004). Where possible, the BLM may be able to temporarily shift or defer grazing to allow for treatments like seeding. Collaboration with BLM will also be useful to the WFMC in understanding the terms of grazing permits and prioritizing treatments to take advantage of scheduled rest periods.

3.3.2.2 Plant Native Species

Areas that have been evaluated and determined to be a high priority for herbaceous restoration during the post-fire ecological resource assessment should first be treated for cheatgrass (see Section 3.2.2.1), if applicable, and then planted with a native species mix. This action would apply to localized areas where pre-burned conditions indicated a depauperate understory unlikely to recover without assistance, and it would include areas where soils have been impacted by firefighting activities like containment line construction. A site-specific seed mix will be included in each post-fire restoration plan to ensure that it is consistent with local plant communities and appropriate to the habitat restoration goals for the area. Several planting techniques will be evaluated and the options with the greatest likelihood of success, best logistical feasibility, and highest benefit with respect to cost will be included in the recovery plan. All post-fire herbaceous revegetation treatments should be implemented consistently with the INL Revegetation Guide (INL 2012).

Native Seed Acquisition

Native plant materials that should be considered for herbaceous restoration may include grasses and forbs. Although native grass seed can be locally hand collected, it is also produced commercially and is often much easier and less expensive to procure, especially under time constraints. There are locally appropriate cultivars available for many grass species and in some cases, cultivars have been shown to outcompete introduced annuals on a disturbed landscape (Prodgers 2013, Waldron et al. 2011). However, the use of local seed sources is preferable because these seeds are likely better adapted to the site-specific conditions and avoid maladaptation (Richardson and Chaney 2018) and prevent outbreeding depression (McKay 2005). There are some areas of the INL Site, like the Sagebrush Steppe Ecosystem Reserve, where locally collected seed is required (DOE-ID 2004). Regardless of the source, a diverse seed mix should be considered with the context of the historical range of variability for the location and given the availability of appropriate seed at the time of planting. Additionally, a more diverse seed mix applied at a higher seeding rate generally results in more successful revegetation (Barr et al. 2017).

Some native forb species are also available through commercial vendors. Availability of these species is typically much more limited than for grasses and they are less likely to be derived from genetic material consistent with local populations. Additionally, commercially available forb seed can be quite expensive relative to grass seed. For these reasons, forbs will be included in a post-fire herbaceous restoration mix only when there is a clear ecological benefit (e.g., to address pollinator habitat restoration goals) and local collection vs. commercial procurement will be evaluated based availability of appropriate genetic material and cost.

Additional considerations for native seed acquisition to support post-fire herbaceous restoration include verifying the quality of the seed and adding amendments to the seed, where appropriate. All grass and forb seed used on the INL Site should be certified weed-free by the Agriculture Department in the state from which it was procured. In addition, a list of seed contaminants should be provided with all seed to ensure there are no unintentional introductions of non-native species that may not be covered by the weed-free certification. All seed should be tested for purity and viability and this information will be provided by the vendor at the time of purchase. Inoculants like mycorrhizae or rhizobium may be considered where they could improve and establishment, or seeds may be treated with fungicide to prevent deterioration.

Fire-specific restoration plans will include a list of appropriate species and cultivars for areas where herbaceous restoration has been recommended. The species in this list should be consistent with the INL Revegetation Guide (INL 2012); seed application rates should also be calculated according to the Guide. It is important to note that crested wheatgrass is not a native species and will not be utilized for post-fire restoration. Where possible, crested wheatgrass will also be avoided as a contaminant in seed procured for restoration.

Growing and Planting Techniques

There are several methods available for planting native herbaceous seed and some have been used extensively by neighboring state and federal agencies for post-fire applications. Appropriate planting techniques may include ground-based broadcast seeding with or without a land imprinter or cultipacker, hydroseeding, drill seeding, use of seed impregnated mats, aerial broadcast seeding, or planting containerized stock. For all planting techniques, the equipment should be properly calibrated and in good working order. Drill seeding equipment should be appropriate for and demonstrated to be effective in backcountry applications. Aerial seed planting vendors should have applicable experience, comply with Federal Aviation Administration rules, and address pertinent DOE and INL requirements (INL 2020b, INL 2023d, INL 2020c). Containerized stock should be grown by an experienced vendor using standard industry practices, appropriate growth medium, and inoculants, when appropriate. Hand tools like hoedads or spades will be used to install all containerized stock. Seedlings should be spaced appropriately to meet restoration goals and care should be taken to ensure that roots are orientated properly and have adequate soil contact.

The timing and seasonality of planting treatments should be carefully considered and will be specified in individual post-fire recovery plans where herbaceous restoration is recommended. Seed and seedlings should be planted during the appropriate season and under desirable environmental conditions to increase the likelihood of success. Some species have precise requirements for environmental variables, like cold stratification or photoperiod length, for germination. Other important, but less specific environmental conditions that can be leveraged to improve herbaceous restoration success include planting when air temperatures are cooler and precipitation patterns increase soil moisture without creating muddy soils that are easily disturbed. These conditions occur in autumn, after daytime high temperatures remain below about 10 °C (50 °F) and before the soil freezes, typically early October through mid-November. Appropriate conditions may also occur in the spring, from mid-April to late May, but ideal spring planting conditions are less predictable and consistent than ideal autumn planting conditions.

Seedbed preparation, such as discing or tilling would be limited to minimize impacts to existing soil structure, minimize any additional risk of erosion, and increase the probability of planting success. Areas where soils have been disturbed, like containment lines will often be prioritized over areas without substantial soil disturbance because of the increased risk of habitat fragmentation and weed spread associated with mechanically disturbed soils. If herbaceous restoration resources are limited, proposed treatment areas may also be prioritized for planting according to criteria associated with risk of poor natural recovery or criteria associated with best potential outcome. Planting techniques will be evaluated and selected based on probability of success, feasibility, and logistics. All post-fire herbaceous planting treatments should be consistent with planting techniques outlined in GDE-8525 (INL 2012).

3.3.2.3 Approaches to Enhance Restoration Success

There are additional treatments that can be used in combination with seeding or planting seedlings to increase the success of native herbaceous restoration efforts. These treatments include options like adding fertilizer, mulch, and supplemental water. Some of these treatments would be utilized during a specific time period, before or after planting, while others could be used any time they would be situationally appropriate. Many of these complementary treatments can also be considered for use across an entire planting area or can be used on a very localized basis to address site-specific concerns.

Utilize Soil or Growth Medium Amendments

Treatment options that fall within the category of amendments include fertilizer, organic supplements, mycorrhizae, or other materials used to ameliorate poor planting conditions. If an area proposed for herbaceous planting is deficient in the macro and micro-nutrients necessary for successful establishment, traditional chemical fertilizers and biological products like animal waste or food processing byproducts should be evaluated as supplemental treatment options. If agricultural byproducts are selected, they will be required to be certified weed free. In addition to adding nutrients, biological products can be used to add organic material to the soil and adjust the soil texture. Compost and peat are two treatment options that may be considered in addition to the agricultural byproducts mentioned above. Mycorrhizae are naturally occurring fungi that grow symbiotically on plant roots and can improve herbaceous restoration success by enhancing nutrient uptake. If used, mycorrhizal inoculant mixtures should be as regionally specific as possible. Finally, other materials that can be used to address challenging planting conditions include products like hydrogels with moisture retaining polymers to increase plant available soil moisture.

Some of these supplemental materials may be added to the seed mixture prior to planting, to the growth medium for seedlings grown in the greenhouse, or to the soil surface. Soil amendments that require discing or tilling are not included as treatment options in this framework because of the increased ecological risks of poor post-fire recovery associated with soil disturbance. Fertilizers and organic supplements can be spread across the surface before or after planting, but the application of organic material should allow for adequate soil contact for seed or roots. Mycorrhizae can be effectively added to seed, growth medium, or the soil surface and products like hydrogels must be added to the growth medium or directly to plant roots prior to planting.

The desert soils predominant across the INL Site are typically lower in nutrients and have a different texture profile than would be considered ideal in agricultural situations and augmenting nutrients to an agricultural ideal is not reasonable or necessary. In some cases, however, adding nutrients or adjusting soil textures can help improve herbaceous restoration success. This is especially true in areas that have been exposed to multiple wildland fires, where soils may be redistributed by erosion, and where nutrient islands associated with sagebrush may have been homogenized. Adding nutrients to a native ecosystem, more than concentrations that would be expected to occur naturally, can result in an increased risk for invasion by non-native species. Therefore, use of mineral or organic amendments should only be considered for areas where soil conditions deviate from their historical condition.

Apply Surface Protection

Surface protection can be used to limit soil erosion, reduce seed exposure, increase soil moisture, and retain soil amendments, thereby improving re-establishment of native herbaceous species in post-fire areas that have been planted. Materials traditionally used for surface protection include mulches like gravel, straw, or woodchips. Any of these materials may be appropriate for improving surface protection, depending on site-specific conditions. Under some circumstances, organic materials used as soil amendments, can also provide surface protection. More recently available materials, like bonded fiber matrix or flexible growth medium should also be considered to enhance herbaceous establishment, especially for applications where these materials utilize the same equipment and process as those used for planting.

When agricultural or other organically based materials are selected for surface protection, they should be applied immediately after seeding and prior to installing any seedlings. Lighter materials that are at risk of being dispersed by the wind may be pressed into the soil surface with a land imprinter or crimped into the ground with a disc. Gravel mulch should also be applied after seeding and care should be taken to ensure that aggregates are an appropriate size (< 1 cm on average) and do not exceed 75% areal coverage of the soil surface (e.g., Anderson and Forman 2002). Products like bonded fiber matrix or flexible growth medium are often used in conjunction with hydroseeding, though they can also be used as a hydro mulch after broadcast or mechanical seeding. Applications of hydro mulch materials should be consistent with the manufacturer's label instructions. If seedlings are to be installed, then the hydro mulch should be applied prior to seedling planting.

Surface protection applications may not be a realistic post-fire treatment option across extensive planting areas. They may be more appropriate and provide the greatest amount of benefit on smaller revegetation sites that have experienced a higher level of disturbance. Containment lines, equipment staging areas, or emergency fire access roads are examples of areas with greater soil disturbance that may be considered a higher priority for post-seeding surface protection. Options for enhancing surface protection will be evaluated and selected based on probability of success, feasibility, and logistics.

Supplement Water Availability

Spring precipitation on the INL Site is often less than ideal for the germination and establishment of native herbaceous species. Supplementing precipitation can greatly enhance revegetation efforts and reduce overall recovery time, particularly during drought conditions. Several approaches to supplemental irrigation are available, though any equipment or infrastructure necessary to support supplemental water application would be temporary. Irrigation approaches may include spraying areas with a water truck, where accessible from an existing roadway or piping water to a temporary sprinkler system from a facility, temporary tank, water truck, or production well.

There are also circumstances where passive approaches to increasing soil moisture for germination and seedling establishment can be used to enhance herbaceous restoration success. For linear features, like containment lines, temporary structures like snow- or drift-fences may be considered as a means of increasing snow accumulation on recently planted areas. At a finer scale, "cages" placed over individual seedlings could be used to accumulate snow and provide some protection from wind exposure as well as protection from foraging animals.

Supplemental irrigation should be considered for up to four months during the spring and early summer after planting in years where the spring season is excessively dry. The frequency and total amount of water applied will depend on weather conditions. Up to six water applications sufficient to achieve a 20-40 cm wetting front with each application would be considered optimal. However, providing supplemental water can be resource intensive in terms of labor and equipment. If an optimal watering schedule is not feasible, even a few supplemental water applications can improve herbaceous restoration success under severely water limited weather patterns and excessively dry soil moisture conditions. Because supplemental irrigation is cost-prohibitive across extensive planting areas, plantings should be prioritized according to the site-specific restoration challenges and the relative benefit of achieving successful herbaceous restoration. Care should be taken to ensure that supplemental irrigation treatments do not create any additional disturbance and treatments should be consistent with GDE-8525 (INL 2012).

3.3.3 Challenges to Implementing Native Herbaceous Restoration Treatments

Assisted herbaceous recovery through active restoration treatments is challenging in a cold desert environment like the sagebrush steppe of the INL Site. In general, deserts can take decades to recover from disturbance, especially soil disturbance, and recovery is not a linear process (Sankey et al. 2008). For the first few years after planting, weedy annual species may be more abundant than the perennial herbaceous species that were planted. If early monitoring results indicate that the cover and distribution of desirable species is sufficient to support continued recovery and the weedy species are not highly competitive, then the areas should be left to continue recovering without additional intervention. If there are localized patches within herbaceous plantings where the cover and distribution of desirable species is not sufficient to support continued recovery, those patches should be considered for replanting. Replanting should be limited to patches where initial germination and establishment was poor, as replanting larger areas where sufficient recovery is progressing could introduce additional disturbance and set back herbaceous recovery. If highly competitive or noxious weeds are present within an herbaceous planting, they should be treated to limit their impacts on areas that have been planted.

Treatments to help control cheatgrass will likely be considered in some of the areas where herbaceous plantings are recommended and vice versa. However, cheatgrass treatments and native herbaceous restoration treatments will not always be co-located and treatment recommendations for each will be based on the post-fire ecological resource assessment as well as post-fire monitoring results. Herbaceous planting after cheatgrass treatments will be prioritized where the abundance of native species is particularly low and replanting with native perennial species is necessary to improve local ecological condition. In some instances, areas treated to control cheatgrass may have enough remnant perennial, herbaceous natives remaining that reducing cheatgrass abundance for a few years may allow the natives to recover sufficiently to improve the recovery trajectory of the area. When cheatgrass and herbaceous restoration treatments are co-located, cheatgrass treatments should be completed prior to herbaceous planting and they should be timed so that any residual herbicide does not impact germination and establishment of planted native seed.

There are situations where the post-fire ecological resource assessment or initial post-fire monitoring results indicate that active herbaceous restoration could improve the ecological condition or function of an area, but current land use may preclude treatment of the area. For example, results from the 2020 Lost River Fire ecological resource assessment indicated that a portion of the burned area had a depauperate understory and would benefit from herbaceous restoration. The area was being actively used for livestock watering operations and the amount of ground disturbance associated with the activity would reduce the successful establishment of any herbaceous plantings. Because the current land use activities were not compatible with post-fire recovery goals, herbaceous planting treatments were not recommended at that location and post-fire recovery efforts were directed to areas where they could provide greater benefit. Other scenarios where herbaceous planting may not be appropriate include areas where there is expected to be additional or repeated disturbance, areas that have been sited for project activities or infrastructure expansions, or areas where habitat is fragmented, and connectivity would remain low regardless of restoration treatments.

The scenario discussed above illustrates the importance of considering land use planning and ongoing project activities when evaluating an area for herbaceous planting treatments. Communication and collaboration with the BLM-USRD will also be important to the success of any herbaceous plantings that occur within BLM-administered grazing allotments. Even if they do not have a lot of flexibility in adjusting grazing schedules to facilitate a specific treatment, BLM staff can help identify areas where stocking rates or seasons of use may be changing, so that post-fire herbaceous recovery recommendations are more informed.

Another challenge to replanting herbaceous species post-fire in some years is a lack of locally sourced, well adapted seed. If weather conditions are conducive to good seed production, this challenge can be addressed by collecting local seed, though this approach is more expensive. Alternately, if seed availability is limited, then herbaceous seed mixes obtained from larger commercial vendors may be less diverse and will contain only the species with locally appropriate cultivars. Limiting seed mix diversity is a better solution to limited seed availability than including a wider range of cultivars because cultivars that are not adapted to local climate conditions are unlikely to germinate and successfully establish. Forb seeds are particularly difficult to procure because the available cultivars appear to be genetically distinct from populations native to the local area and they are very expensive to buy commercially or harvest locally.

A final challenge to be considered for post-fire herbaceous plantings is soil texture, depth, and structure. Many soils on the INL Site are fragile or erodible. Soil structure can be lost from overworking the soil or attempting revegetation treatments during seasons when soils are particularly vulnerable to disturbance. Soils are evaluated as part of the post-fire ecological resource assessment (Section 2.2) and their characteristics, especially in terms of structure and revegetation potential should be considered in herbaceous recovery recommendations. Areas that have burned previously may have already experienced changes to soil nutrient distribution that increase challenges associated with native herbaceous restoration (Germino et al. 2018). Therefore, fire history can be used to inform post-fire restoration treatments as well.

3.4 Sagebrush Habitat Restoration

Sagebrush is a foundation species of the ecosystem occupied by the INL Site, and healthy sagebrush stands are crucial for the structure and function of the natural landscape. Sagebrush shrublands are the primary food source for many wildlife species, especially through the winter months, and they provide much of the vertical structure for concealment and protection from exposure year-round. Additionally, deep rooted sagebrush shrubs effectively return soil moisture to the atmosphere and maintain the heterogeneous distribution of soil nutrients characteristic of natural arid systems. For these reasons, facilitating the recovery of functional sagebrush habitat was included as one of our four post-fire recovery objectives.

Natural recovery of big sagebrush to pre-burn cover values has been estimated to take up to a century on the INL Site (Blew and Forman 2010, Colket 2003). Because sagebrush does not resprout like most other native shrubs and perennial grasses, it must reestablish from seed. Sagebrush seed availability may be limited across extensive fire footprints (Meyer 1994), but more importantly the weather conditions conducive to seed germination and seedling establishment may occur only once or twice a decade in burned areas where vertical structure has been removed and solar and wind exposure is high (Forman et al 2013). Sagebrush establishment occurs more frequently near unburned edges and around unburned islands. Post-fire establishment of sagebrush shrublands often begins in conducive microsites such as slight depressions where water accumulates and the leeward side of small hummocks or hills. Once sagebrush becomes established in small patches, those patches grow and eventually coalesce as they increase seed availability and ameliorate local microsite conditions (Blew and Forman 2010).

SUMMARY – RECOVERY OBJECTIVE 4

- Sagebrush habitat restoration is important to increase available functional habitat for sagebrush obligate species, to improve nutrient patterning and cycling, and to provide ecosystem stability against stressors like climate change.
- Primary restoration tools include sourcing plant materials appropriate to habitat restoration goals; seeding via aerial application, ground-based broadcasting, or drill seeding; and planting seedlings with hand tools.
- Challenges include the high cost and limited availability of seed, the narrow range of conditions appropriate for germination and establishment, the limited amount of area that can be feasibly planted with seedlings, and the increasing pressures from climate change and non-native species.

Sagebrush planting is resource intensive and can be logistically challenging and therefore not feasible across the entire burned footprint of INL's largest wildland fires. To most effectively leverage resources allocated to post-fire sagebrush restoration across large areas or among several areas burned in one year, restoration efforts should be prioritized according to the locations where they will provide the greatest habitat value, as identified in the ecological resource assessment. These will often include important wildlife seasonal use areas, areas where sagebrush restoration could improve connectivity, and migration routes or corridors. Anywhere sagebrush restoration is used to improve habitat value, it will also improve ecosystem function like water and nutrient cycling.

3.4.1 Summary of Risks to Ecological Resources from Sagebrush Loss

The risks of poor sagebrush recovery after wildland fire include excessively long time periods with limited habitat value, reduced ecosystem function, and lowered ecological resilience. For wildlife species that require sagebrush for part or all their lifecycle, landscapes where sagebrush has been lost to wildland fire provide less habitat value (Lawes et al. 2013, Holmes 2007, Fischer et al. 1996). Some sagebrush obligate species require large expanses of contiguous sagebrush habitat and wildland fire can impact habitat usability in adjacent, surviving shrublands when resulting fragmentation interrupts habitat continuity and increases habitat edge. Where pre-fire sagebrush cover provided vertical structure and compositional diversity, post-fire habitat quality is also reduced for species with more generalized habitat requirements.

Because sagebrush has a deep taproot and an extensive root system, ecosystems where sagebrush cover has been lost have a reduced capacity to extract water from deep within the soil profile. This results in less water being returned to the atmosphere and more water moving below the rooting zone and into the subsurface, which may result in desertification if sagebrush does not eventually recover (Germino et al. 2016). Along with an altered water cycle, ecosystems where sagebrush has been lost exhibit nutrient cycle changes, which could ultimately impact the ecosystem services provided by intact sagebrush steppe, like carbon sequestration capacity (Fusco et al. 2019, Rau et al. 2011). Local researchers have shown that sagebrush effectively excludes tap rooted noxious weeds (Prevey et al. 2010), making the local ecosystem more resistant to degradation. Therefore, plant communities are more susceptible to noxious weed invasion and will require more active management during the period where sagebrush cover is below pre-fire ranges.

The effects of competitive pressure from non-native species and changes in temperature and precipitation patterns associated with climate change are likely to further slow or stall sagebrush recovery (Bradley 2010). Historically, changes to the post-fire ecosystem were less of a concern than they are today because less of the landscape was impacted by wildland fire at a given time and the recovering ecosystem was not subject to current pressures like invasive species and climate change. Without strategic post-fire recovery actions, the risk of some plant communities transitioning to a less desirable final condition is much higher than it was in the past (Chambers et al. 2007).

Although natural sagebrush recovery is progressing across many of the footprints of fires that have burned over the past thirty years on the INL Site, the process is slow. There are several factors that can affect the trajectory of sagebrush recovery after a wildland fire and consequently, there are a range of post-fire conditions within and among the burned footprints of various fires. The spatial discontinuity of abiotic factors like localized weather patterns and abrupt soil transitions influence plant community distribution and composition before a wildland fire and the post-fire recovery trajectory of sagebrush. The pre-fire ecological condition of plant communities also varies across the INL Site, and the disturbance history of an area can affect the speed at which sagebrush recovers. Specifically, overgrazing and multiple wildland fires within the span of a few decades typically results in more invasive and noxious weeds, less biological stability, and more homogenous nutrient resources, all of which can impact sagebrush recovery. Finally, post-fire weather patterns can slow sagebrush recovery. At the INL Site, we found that natural post-fire sagebrush recovery is much more spatially limited for areas where precipitation was below normal for the first three to five years after a wildland fire (Blew and Forman

2010). Planting sagebrush in a burned area can be used to overcome some of the limitations that impact natural recovery. While sagebrush planting will not immediately restore ecosystem function and habitat resources to their pre-burned condition, it can reduce overall recovery time by several decades.

3.4.2 Tools for Improving Post-Fire Recovery of Sagebrush Habitat

Options for reducing sagebrush habitat recovery time after wildland fire include identifying and prioritizing areas where sagebrush restoration can provide the greatest benefit using the post-fire ecological assessment process, and planting sagebrush seeds or seedlings to augment natural recovery. For planting either seeds or seedlings, there are several factors related to selecting plant materials and planting techniques that should be considered depending on the ecological goals and site-specific conditions of the area. Considerations like sagebrush forage value, habitat connectivity, seasonal use, the size of the area to plant, and the context of surrounding habitat, will be used to guide the selection of plant materials and the techniques used to plant them. Typically, areas prioritized for sagebrush habitat restoration through the post-fire ecological resource assessment will already have herbaceous understories with the potential to recover to high ecological condition communities. However, there will also be circumstances under which both herbaceous and sagebrush habitat restoration will be considered at the same location.

3.4.2.1 Plant Material Acquisition

The choice of plant materials directly impacts the success of a revegetation project. Because restoration goals associated with this fire recovery objective are related to habitat, and wildlife species often demonstrate forage preferences among sagebrush species, subspecies, and populations, the genotypes of the selected plant materials factor into the habitat value of the habitat restoration end state. Selection of appropriate plant material also enhances the establishment of sagebrush after planting. Once materials have been selected, planting techniques should be carefully evaluated to balance habitat restoration goals, cost, logistics, and probability of success.

Seed

The INL Wildland Fire Management EA (DOE 2003) and the INL Revegetation Guide (INL 2012) both encourage using locally adapted seed for sagebrush reestablishment. Short-term germination and establishment, and long-term viability are both typically greater for seed that is genetically like stands lost in a wildland fire (Germino et al. 2019, Meyer and Monson 1992). Options for collecting local sagebrush seed may include using available internal resources, coordinating an outreach program, or tasking a commercial vendor. If the amount of seed necessary to support sagebrush planting is limited to approximately 90 kg (200 lb) bulk or less, INL NRG staff can collect seed and have it processed at the U.S. Forest Service Region 6 Seed Extractory.

If larger amounts of seed are required, as with aerial seeding, INL could engage local outreach service programs like the Master Naturalists or IDFG volunteers to coordinate a seed collection effort. Several commercial seed vendors will also perform custom seed collections at specified locations. These latter two options may be more logistically feasible on BLM lands adjacent to the Site but will require applying for a BLM seed collection permit. Sagebrush seed ripens in late-October to early-November in the Upper Snake River Plain, so local seed collections would have to be planned within a few months post-fire for seed or seedlings to be planted the next year. Seed should be collected for as many years as necessary to meet natural resource recovery objectives.

Local seed collections may not be feasible in the seed-ripening timeframe following a wildland fire. Alternative options include sourcing seed available from commercial vendors or coordinating seed acquisition through the BLM seed warehouse. Several commercial vendors stock sagebrush seed from previous years' collections. There can be a lot of variability in seed quality among vendors and these differences are often related to the cleaning and storage processes for sagebrush seed. Care should be taken to select a vendor who is cleaning and storing seed appropriately to increase the likelihood that seed acquired through that vendor have relatively high purity and good viability.

Many of the same vendors also supply seed to the BLM seed warehouse and DOE may be able to purchase seed from the warehouse. Seed from the warehouse is typically well-documented in terms of source location and must meet minimum purity standards. All sagebrush seed considered for restoration at the INL Site must be source identified so that biologists can evaluate it in terms of habitat value and likelihood of a successful establishment outcome. Seed acquired from the warehouse should be selected from collections as close to the INL Site as possible. At a minimum, seed should come from the same provisional seed zone as the INL Site, as seed from sites with similar temperature regimes and aridity should perform better than seed from elsewhere, but it should also be noted that generalized provisional zones are a starting point and not intended to be used for species with unknown genetic data (Bower et al. 2014). Sagebrush seed loses viability as it ages, so seed should be no more than two seasons old for optimal germination and establishment.

Supplemental materials may be added to sagebrush seed to enhance germination success. These materials include mycorrhizal inoculants, mold inhibitors, and herbicide protection treatments. The soil microbial community is reflective of the vascular species that inhabit a site and in post-fire landscapes where sagebrush is low or absent, the microbial community symbiotic to sagebrush has likely diminished (Prado-Tarango 2021, Dangi et al. 2010). Mycorrhizal inoculation of sagebrush seed is one approach to overcoming this challenge. Sagebrush seed may also be treated with agents to inhibit the growth of molds to prevent deterioration either in storage or after planting and prior to germination. Finally, sagebrush seeding activities may coincide with pre-emergent application for control of invasive annuals. To prevent the effects of pre-emergent herbicide on sagebrush seed, seed can be coated with an herbicide protection treatment. Many of these supplemental materials are in the early stages of development and may be cost prohibitive. Therefore, they will not be utilized as a primary treatment strategy but will be considered under specific circumstances where other treatment strategies may not be effective without supplementation.

Seedlings

There are several regional greenhouses that specialize in growing sagebrush seedlings, and they include commercial, agency, tribal, and university facilities. Ideally, the selected grower would be provided with seed collected from the INL Site. The U.S. Forest Service Region 6 Seed Extractory typically has a small amount of INL collected seed available for growing seedlings. Alternately, seed could be procured from a commercial vendor or seedlings could be purchased directly from a native greenhouse, depending on genetic source of the stock they have available. As discussed above, the more local the seed source, the greater likelihood of long-term sagebrush establishment and persistence. If local seed is used, seedlings should be ordered during late-winter to early-spring of the year they are to be planted. Seeds should be started in time for an October planting date and the amount of time required to grow seedlings will depend on the container used and the desired size of the seedlings at the time of planting.

Seedlings have been planted on the INL Site regularly since 2015, and we have used both 6-inch and 10-inch cone-tainers, (i.e., tapered, cone-shaped pots). Though bareroot stock may be considered for use under specific conditions, containerized sagebrush seedlings are thought to have greater survivorship. The growth medium around the root of the containerized stock provides additional nutrients and moisture to the seedlings during the first few months after planting. Smaller cone-tainers have been preferred over larger sizes in the past few years because the shorter tap roots associated with the smaller pots can be planted with roots in the proper vertical orientation more consistently. Seedlings grown in cone-tainers also tend to be less unwieldy and easier to transport and handle in a backcountry environment when compared to traditional pots. Seedlings grown in traditional pots should be considered only when stock grown in cone-tainers is unavailable or it is logistically feasible to transport seedlings grown in traditional pots. Sagebrush seedlings should be healthy, thinned to one plant per cone-tainer or pot, free of pathogens, and have a well-established tap root. These conditions should be specified in the subcontract to the seedling grower.

Growing media can influence seedling survivorship before and after planting, and growers often add supplements to the growth media in the greenhouse. Common supplements include materials to adjust the texture or water-holding capacity of the growth media, nutrients, and mycorrhizal inoculants. Natural materials like vermiculite and engineered materials like hydrogels can be used to improve growth media texture and increase water holding capacity. Growers typically add nutrients based on current industry standards and their own experience. Mycorrhizal inoculants are used more commonly in media for seedlings than they are mixed into seed intended for direct seeding. Standard mycorrhizal inoculants are available, but as research continues to advance on this topic, more localized inoculant mixes are quickly becoming available. As with other plant materials, the more local the mycorrhizae, the greater the expected benefit. Site specific conditions and post-fire restoration goals should be considered as decisions are made about container type and growth media supplements.

Occasionally, the timing of an infrastructure project that requires the removal of vegetation, including sagebrush will coincide with post fire restoration. If feasible, salvaging seedlings from the project footprint and planting them in a post-fire restoration area should be considered. Seedlings that are less than 20 cm (7.9 in) in height will have the greatest probability of surviving. Survivorship of salvaged seedlings will also be enhanced by ensuring that the entire tap root is removed, and some soil is removed with the seedling. For this reason, cool conditions with adequate soil moisture are ideal.

3.4.2.2 Planting Techniques

Sagebrush planting techniques can generally be divided into planting seeds or installing seedlings. To increase the likelihood of success for sagebrush planting, multiple planting techniques should be considered, and some techniques may be more useful at certain times in post-fire recovery than others. For example, aerial or mechanical seeding may be appropriate immediately post-fire when recovering biomass that could interfere with seed to soil contact is minimal. Alternately, seedlings grown from container stock may be more effective in subsequent years when the herbaceous community has begun to recover, and naturally establishing plant materials may interfere with aerial or mechanical techniques.

Seeding

Broadcast seeding is the most straightforward technique for seeding sagebrush, and seed can be applied aerially or from the ground. Aerial seeding generally has the least amount of impact with respect to soil disturbance. Seed is typically applied on snow using a helicopter, or occasionally a fixed-wing aircraft. Seed can be applied as early as January or February during the first winter post-fire. Practitioners have found that preferred conditions for aerial sagebrush seeding include fresh snowfall within the previous 48 hours, minimal winds during application, and warm or sunny conditions immediately following seeding (BLM 2007). These conditions are thought to provide conditions necessary for successful spring germination, to facilitate placement of the seed where it is intended, and to allow seed to settle into the snowpack so that it is not moved by the wind after seeding has been completed. Vendors considered for aerial sagebrush planting should have applicable experience, comply with Federal Aviation Administration rules, and address pertinent DOE and INL requirements (INL 2020b, INL 2023d, INL 2020c).

Where appropriate, ground-based broadcast sagebrush seeding should be conducted using properly calibrated instruments, which will often be mounted to or pulled behind a tractor or UTV. Broadcasting often results in better placement of seed within the soil profile than drill seeding because the sagebrush seed is very small and emergence is most successful when planting is at or near the soil surface, <3mm

(1/8-inch; NRCS 2011). Germination can be enhanced by ensuring good contact between sagebrush seed and the soil using implements like a land imprinter, cultipacker, or roller and these implements can be used after any broadcast application, aerial or ground based. Impacts to the soil surface should be minimized by avoiding the use of discs or harrows. Soil surface impacts can also be reduced by avoiding planting activities when soils are excessively wet or dry.

Seeding with a rangeland drill should be restricted to areas where native herbaceous recovery is poor to avoid damaging recovering grasses and forbs. Oftentimes, areas with poor herbaceous recovery will be identified in the post-fire ecological resource assessment and will be prioritized for sagebrush habitat recovery as well. At locations where sagebrush habitat recovery goals coincide with herbaceous recovery goals, both herbaceous species and sagebrush species should be seeded at the same time. A rangeland drill with multiple hoppers should be selected for this application. Herbaceous species should be planted at an appropriate depth using the drill mechanism and sagebrush seed should be dribbled onto the soil surface in front of a pressing or rolling implement. If an appropriate drill is not available, or if this approach is not otherwise feasible, herbaceous species should be planted with a drill first and sagebrush can be planted with a broadcast seeder or using seedlings later.

Sagebrush seeding rates will vary depending on site specific ecological conditions inferred from the ecological resource assessment and any monitoring data that may be available. The habitat restoration goals for the area, the availability of seed, and seed quality will also be used to inform the planting specifications for each restoration area. In general, seeding rates will range from 0.28 kg to 1.12 kg per hectare pure live seed (0.25 lb to 1.0 lb per acre; BLM 2007). The lower end of the range is more appropriate for overseeding, where there are some surviving sagebrush individuals and restoration goals focus on increasing sagebrush cover to functional habitat values. The higher end of the range is more appropriate for areas where sagebrush was completely removed by wildland fire. Additionally, sagebrush seeding is often implemented in blocks or strips across the landscape, where only about ¼ to ½ of the targeted restoration is planted (Meyer and Warren 2015) and the actual amount and configuration of the area planted will be informed by the post-fire ecological resource assessment and the restoration goals.

As with herbaceous seeding, sagebrush seeding success can be improved by planting when air temperatures are cooler and precipitation patterns increase soil moisture without creating muddy soils that are easily disturbed. These conditions occur in autumn, after daytime high temperatures remain below about 10ºC (50°F) and before the soil freezes, typically early October through mid-November. Appropriate conditions may also occur in the spring, from mid-April to late May, but ideal spring planting conditions are less predictable and consistent than ideal autumn planting conditions.

Analyses of soils affected by a wildland fire will be summarized in the post-fire ecological resources assessment. Tailoring mechanical treatments based on results of those assessments will be important for minimizing impacts to soils and other biological resources. Any seeding that requires off-road travel, especially with a tractor, rangeland drill, or roller will be reviewed by the CRMO during project planning and any additional changes that need to be made to the planting area or planting technique to avoid or minimize effects to historic properties will be made at that time. Additionally, the ICP Notice of Soil Disturbance/Munitions Response Area Activity Notification coordinator will be contacted to determine if the proposed work location is within a CERCLA site/munitions response area and to identify all concerns or restrictions associated with contaminated soils or unexploded ordnance.

Planting Seedlings

At the INL Site, sagebrush seedling planting is generally subcontracted to a restoration company with planters who are trained in proper installation techniques. Sagebrush seedlings are planted using hand tools, like hoedads or dibble bars. The earliest optimal planting window for seedlings that have been grown post-fire is in the fall after the first post-fire growing season. Sagebrush seedlings should be planted in October, once high temperatures are no greater than about 10ºC (50ºF). Precipitation events are desirable in the two- to four- weeks preceding planting as they will enhance soil structure, making it easier to plant and they will increase the moisture available to seedlings immediately after planting.

Planters will be trained to select good microsites, which include areas with increased nutrients around pre-fire shrub coppices, areas with appropriate soil bulk density, areas with fewer weedy species, small depressions, and the leeward sides of hills or hummocks. Seedlings will be planted at the correct depth, so that the root/shoot interface is level with the soil surface. Seedlings will be oriented as upright as possible, and the depth of the hole will be sufficient to ensure that roots are straight to avoid forming a "J" shape at the tip. Soil around each seedling will be lightly pressed back into the hole so that there is good contact between the soil and the seedling root.

The goal of planting sagebrush seedlings is not to replace sagebrush at a density typical of functional sagebrush habitat, but to establish a seed source from which habitat can become established. Planting densities for sagebrush seedlings should be evaluated based on the restoration goals specific to an area. Planting patterns should also be determined relative to natural resource recovery goals. Seedlings may be planted in blocks, strips, islands, or in a pattern that follows the natural contours of the landscape in which they are being installed. There are advantages of each planting pattern. Blocks are one of the easiest patterns to execute. Strips, especially when oriented perpendicular to the prevailing wind direction tend to maximize the potential of the seedlings to disperse seed once they mature. Islands and contour planting mimic natural recovery patterns and may increase seedling survivorship by creating or utilizing protected microsites. The logistics of seedling planting are often limited by access. The use of UTVs to move and stage seedlings further from established roads can greatly increase the amount of area that can be considered for planting. However, there are some remote areas of the INL Site where road access is limited, and seedling planting will likely never be feasible.

As with other planting approaches, there are supplements, materials, and post-planting care techniques that can be evaluated to enhance seedling establishment success. Treatments that can be added to the soil at the time of planting include mycorrhizae, nutrients, or hydrogels. If precipitation is below average, application of supplemental water during planting or during the spring and summer after planting may also enhance seedling survivorship, though the amount of area that could be reasonably treated would be smaller than most recommended planting areas, so supplemental water would have to be targeted to high priority restoration areas. Installing snow fences or small seedling cages are additional options for increasing moisture available to seedlings by accumulating snow around them throughout the winter. Seedling cages provide the additional benefit of deterring grazing by both native wildlife and livestock. Temporary electric fencing may also be considered as a means of restricting livestock grazing in areas where seedlings have been planted. In collaboration with BLM, areas planted with seedlings should be rested from grazing for at least two growing seasons post planting, therefore temporary fencing for grazing exclusion would not be necessary for seedlings planted the first two years post-fire. Alternatively, for any portion of the post planting period that exceeds the post-fire rest period, grazing exclusion may be coordinated with BLM, but changes to permit conditions require a two-year lead time.

3.4.3 Challenges to Implementing Sagebrush Restoration Treatments

There are a number of approaches for reestablishing sagebrush, but success is variable and is often dependent on factors outside of human control. The primary factor regulating the potential success of sagebrush restoration is the timing and amount of precipitation. Although the success of sagebrush restoration is ultimately weather dependent, there are several challenges that can be addressed by thoughtful analyses in the post-fire ecological resource assessment and well-executed restoration recommendations. Some challenges that will be considered during post-fire natural resource plan development include the availability of appropriate plant materials, the most effective planting approach given the condition of the area to be restored, and the goals of the restoration actions.

Deploying well-adapted and ecologically appropriate plant materials is a core component of successful restoration projects (Bower et al. 2014). Collecting locally adapted seed can substantially increase the long-term success of a planting. Identifying appropriate seed consists of more than finding the same subspecies and may be more specific than finding seed from the same provisional seed zone (Bower et al. 2014). Seed and seedlings from climate zones inconsistent with the restoration area may result in shrubs that appear similar to local stock at the beginning of a planting but deteriorate in condition or fail to continue reproducing over time. Survival of plant material derived from colder sites is generally better than survival of plant material derived from warmer sites (Chaney et al. 2017). However, common garden studies show that the greatest survival occurs with plants from locally collected seed, where temperature and aridity are similar (Germino et al. 2019).

The quality of the habitat resulting from a restoration project is strongly influenced by the genetics of the selected plant material. Forage selection and palatability are determined by the genetic composition and phenotypic expression of sagebrush that dominates the occupied habitat (Rosentreter 2005). As with the germination and establishment of sagebrush restoration, choosing locally sourced plant materials can increase the probability of reestablishing usable habitat.

Planting seedlings, rather than drilling or broadcasting sagebrush seeds is typically more successful because seed germination and establishment are dependent on specific weather events, including timing and amount of precipitation and microtopography of the planting location (Boudell et al. 2002, Young et al. 1990). The suite of environmental conditions that can facilitate successful germination of seed and establishment of new plants fluctuates from year to year (Forman et al. 2013, Colket 2003), and in many years, few or no seeds may germinate and survive the summer (Brabec et al. 2015). Survivorship of seedlings is consistently higher than seeding options as plants already have a root mass and can reasonably survive more adverse conditions. For this reason, seedlings should be used strategically where they can provide the greatest habitat benefit. Specifically, seedlings should be used where they can improve high priority habitat and/or habitat connectivity and they should also be considered in areas where risk of poor natural recovery is high and where conditions are unfavorable for sagebrush establishment from seed.

In addition to sagebrush seedling planting being more consistent and reliable, installation of healthy seedlings may also reduce the recovery time for sagebrush in the areas where they are planted. Seedling plantings require less sagebrush seed, but involve more labor and specialized greenhouse facilities, which also make them more expensive than aerial or mechanical seeding. The primary drawback of planting seedlings is the limited amount of area that can be covered. A much larger extent can be addressed with seeding, and aerial seeding in particular. Although a review of sagebrush seeding efforts across the Great Basin indicated relatively low success rates (Lysne 2004), seeding success may be improved by considering several landscape variables in the restoration strategy (Germino et al. 2018).

Studies from the INL Site do not provide any evidence for competitive exclusion of sagebrush by native, perennial grasses (Anderson and Inouye 2001) and sagebrush were found to germinate in mature stands nearly every year, even with a robust herbaceous layer (Forman et al. 2013). However, some restoration literature suggests that established herbaceous communities could limit sagebrush establishment from seed (Schuman et al. 1998) and this concern should be considered in determining which planting technique to use at various stages of restoration. As mentioned above, broadcast seeding or seeding with a rangeland drill may be more successful immediately post-fire, especially during the first growing season when the ground is mostly bare and soil to seed contact would be greatest. Seeding using a rangeland drill may also be less damaging to existing plants prior to the first growing season, but soil disturbance may also increase the risk of increases in non-native species.

Climate change is an additional and increasing challenge for native species restoration in semi-arid climates (Shriver et al. 2018). The temperature and precipitation conditions required for germination and establishment are likely to occur less frequently in the future. Furthermore, warmer and drier periods throughout the summer will increase mortality of established sagebrush seedlings during a season when they already experience a lot of stress from exposure. Changes in weather patterns that result in increases in non-native species would also be expected to impact sagebrush restoration success (Bradley et al. 2010, Chambers et al. 2007). Novel approaches to sagebrush planting that are designed to overcome these challenges include technologies like seed bombs. Though these approaches will not be considered a primary sagebrush restoration strategy, they will continue to be evaluated as they are developed and tested across the western U.S.

4. POST-FIRE NATURAL RESOURCE MONITORING

Monitoring should be considered a fundamental component of post-fire treatments or management actions and provides timely insight regarding the success of implemented actions or the necessity of implementing actions where conditions are deteriorating. Effective monitoring plans are those that establish a process to collect, analyze, and use data to track the status of the natural resources of interest and the effectiveness of any implemented actions. This two-pronged approach allows a project team to answer two fundamental questions:

1. Are natural resource recovery objectives being met through natural recovery processes, and

2. If actions are taken to assist the natural recovery processes, are the actions effective?

If a project team regularly collects and evaluates data designed to answer these two questions, it will be well-positioned to quickly adjust its approach if results do not occur as expected, which is the foundation for adaptive management.

The first step to developing a targeted and cost-effective monitoring plan is to clearly outline how recovery status and treatment effectiveness will be defined and how adaptive management principles will be applied in response to deviations from recovery objectives. Monitoring approaches for two scenarios will be presented, one for assessing areas at risk of poor natural recovery, and one for evaluating efficacy of treatments in areas that have received active restoration. Most post-fire natural resource recovery plans and resultant monitoring plans for the INL Site will require both.

4.1 Post-Fire Monitoring Strategy and the Adaptive Management Context

Post-fire ecological monitoring will ultimately be used to inform an adaptive management approach to post-fire recovery. Ecological communities are complex, and natural resource professionals often face uncertainties about which strategies will best contribute to achieving recovery goals following a large disruptive event such as wildfire. An adaptive management framework is a common, practical methodology that can be applied to post-fire recovery to determine if a restoration action is necessary to meet natural resource recovery goals.

The principles of adaptive management began being developed as early as the 1970's (Holling 1978, Walters 1986), and although various alternatives of the core concept have been explored over the last few decades, the underlying intent has remained consistent. Adaptive management is rooted in the idea that proposed treatments or management actions should not simply be trial and error over time, but rather purposeful, strategic actions that build upon lessons learned (Allan and Stankey 2009). Management goals or actions are generally defined, implemented, monitored, and lastly modified based on what was learned following the initial implementation. Adopting this management approach helps account for the uncertainty of natural systems experiencing ongoing or unplanned change and can improve the success of future treatments or management actions (Williams and Brown 2014). An adaptive management approach also provides a mechanism to modify treatments when management or funding priorities shift unexpectedly.

There are numerous conceptual diagrams published to represent the adaptive management cycle, and although the number of steps may vary, the logic remains the same. More commonly today, the adaptive management process can be represented as a six-step cycle (Williams et al. 2009): 1) assess problem; 2) design; 3) implement; 4) monitor; 5) evaluate; and 6) adjust. The adaptive management cycle is generally represented as a singular circle where each step progresses along a linear path to the next. Alternative representations of the cycle can range from simple to more complex with intermediate feedback loops nested throughout the cycle. Occasionally, goals of the adaptive management strategy may extend across large spatial extents or occur over long timeframes, and more localized internal mini-feedback loops may become more apparent among steps in the cycle (Bormann and Stankey 2009). Internal feedback loops can arise when unanticipated preliminary monitoring results suggest a change or adjustment to implemented treatments should be considered prior to reassessing the adaptive management framework.

Adaptive management can be considered active or passive (Walters and Holling 1990), and although there may be differences of opinion regarding definitions, they represent two distinct ways to implement adaptive management principles. Active adaptive management is generally an approach that can be used to evaluate the efficacy of management actions and how those decisions influence ecological processes. Active adaptive management involves testing hypotheses while adhering to statistical design considerations, such as randomization, controls and replication that are normally beyond most proposed treatments plans where funding may be limited. A passive adaptive management approach focuses more on management objectives rather than the result of management actions on ecological processes. Passive adaptive management generally doesn't involve experimentation or hypothesis testing making it more applicable to many treatment options proposed in natural resource post-fire recovery plans.

Most commonly, a passive adaptive management approach will be undertaken to track and monitor post-fire treatments on the INL Site. Treatment options are generally designed to address immediate post-fire concerns rather than taking a more exploratory approach of testing potential options which can take longer to complete, while some options may still result in little to no success. There may be times when recovery objective options are limited or results have shown unexpectedly low success, and new exploratory treatments or solutions need to be tested before they can be applied with confidence across a larger extent.

One example where an active adaptive management approach was recently implemented at the INL Site was a recent sagebrush seedling planting. Sagebrush seedling plantings have shown variable success for one-year survival rates despite similar greenhouse growth methods and planters. Because there are many confounding variables potentially responsible for decreased survivorship, it's hard to identify the cause, and subsequently, a solution to improve one-year survival rates. In fall of 2023, three different sagebrush seedling growth mediums (i.e., Terra-Sorb hydrogel, mycorrhizal inoculant, and vermiculite) were tested in addition to an experimental control group planted the same as previous years (INL 2024). A subset of the control group had protective mesh cages installed to eliminate the possibility of livestock or ungulate browsing during the first year of growth and allow for more direct comparisons of growth methods. A subset of seedlings from each experimental group were marked and will be monitored one-year and five-years post-planting to determine if any of the treatment options yielded higher survivorship.

4.2 Development of a Post-Fire Ecological Monitoring Plan and Reporting Schedule

A post-fire monitoring plan will be developed to support each natural resources wildland fire recovery plan. The monitoring plan will cover the duration of the natural resources wildland fire recovery plan and will be accompanied by an annual report to summarize monitoring results and identify suitable adaptive management responses when appropriate. The primary components and considerations of a monitoring plan include identifying monitoring needs, establishing benchmarks against which to evaluate progress, selecting appropriate monitoring techniques, defining the approach to data summary and analysis, and evaluating natural recovery or of additional treatment options that should be considered (Figure 4-1).

Monitoring will typically begin the first growing season post-fire, but the schedule, duration, and frequency of specific monitoring efforts will be dependent on the task (e.g., some monitoring tasks will require a few growing seasons to pass prior to evaluation). Most monitoring activities are expected to be conducted during summer or early fall the year following the fire. The annual monitoring report will be completed on a fixed schedule that will allow sufficient time for the WFMC and F&SS to prioritize and plan for any recommended actions the following year post-fire.

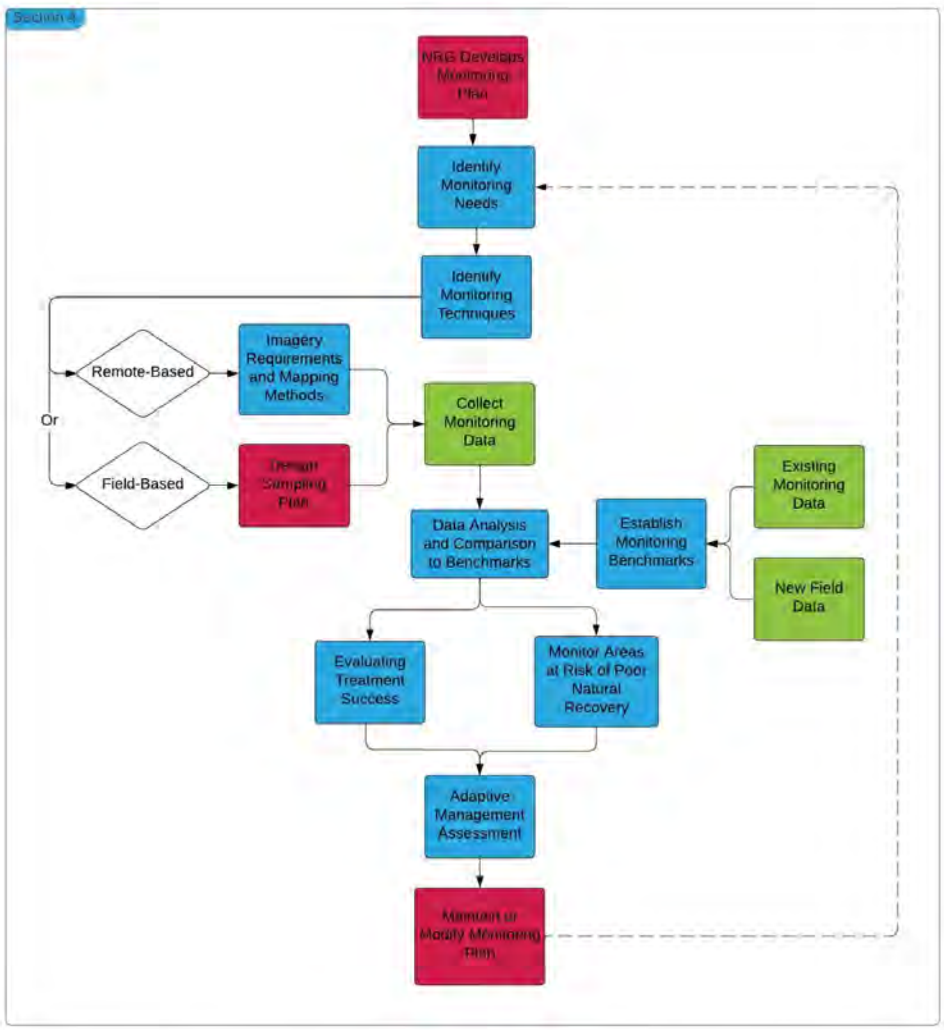

Figure 4-1. Overview schematic of the workflow for post-fire monitoring and adaptive management.

4.2.1 Identify Monitoring Needs

The first step when developing a monitoring plan is to start by identifying monitoring needs. Monitoring needs will generally fall into one of two categories; to determine whether additional treatment is warranted in an area at risk of poor natural recovery, or to evaluate the efficacy of a treatment that was implemented.

Areas at poor risk of natural recovery usually have a degraded status pre-fire and can be identified at a coarse scale from the INL Site vegetation map (Shive et al. 2019) during the post-fire ecological resources assessment. For example, a vegetation community that has an understory of undesirable or non-native grasses will expectedly have poor native species recovery following a wildland fire. The vegetation map can provide a broad overview of what potential ground conditions may be in a particular area, but field visits will usually be required to verify and document vegetation conditions at a finer scale. For areas at risk of poor recovery, monitoring should be used to ensure that current, ground-based site conditions are consistent with results of the post-fire ecological assessment and that current conditions meet criteria for any proposed treatments.

Monitoring efforts should be sufficient to determine whether the effects of the treatment are an improvement over natural recovery. It cannot be assumed that treatments will always yield positive results and comparisons to either pre-treatment conditions, or to areas untreated but within the vicinity can be used to evaluate treatment success. Quantitative monitoring using established data collection protocols is the preferred strategy because the results are often more defensible. However, under certain circumstances when funding or field sampling capability is limited, more qualitative methods (e.g., a time-series of photoplots) may be sufficient to understand or demonstrate treatment efficacy.

4.2.2 Establish Benchmarks for Evaluating Further Treatment Actions

The primary purpose of monitoring is to detect measurable changes in condition and progress towards meeting clearly defined natural resource recovery objectives. Before determining if assisted recovery is required and prior to initiating a treatment, a project team should outline its assumptions about what a successful outcome would look like. This outline should include defining measurable benchmarks and expected timeframes so the project team and other stakeholders will have a realistic understanding of when they can expect to see in short- and long-term results. The benchmarks defined in a monitoring plan should be realistic, logical, and achievable within the five-year recovery plan timeframe as these benchmarks will ultimately help guide decisions about whether further treatment should be considered.

A benchmark may be a selected value or range of values for cover, density, frequency, distribution, or spatial extent. In some cases, a benchmark may not define the desired final condition, but may be a trend indicating that a variable is increasing or decreasing on an expected trajectory towards a longer-term desired final condition. Some benchmarks can be developed using site-specific data which is generally more relevant than generalized data across large regions (e.g., Intermountain West). There are various monitoring datasets collected on the INL Site, such as Long-Term Vegetation plots, vegetation map community classification plots, or CCA habitat condition plots, that can be used to locally defined data-driven benchmarks. There may be times when pre-treatment data could be collected following a wildland fire to define a baseline that post-treatment monitoring results can be compared against to evaluate success. For example, a common benchmark for cheatgrass is that it remains lower in cover than the pre-fire community.

The datasets routinely collected on the INL Site commonly exceed the quantity and detail of data that are available for larger regions where modeled information or extrapolated data are used to fill data gaps. Benchmarks can be defined using accepted standards, values developed by other agencies or published in scientific literature when site-specific data are insufficient or not available. For certain treatments or management actions, the benchmark may be simplified to a detect/non-detect scenario. For example, the benchmark for noxious weeds within an area of recovery is typically that they are no longer detectable in regular surveys.

4.2.3 Evaluate Potential Monitoring Techniques

Monitoring techniques can be categorized into two main groups consisting of remote and field-based methods. Each type of monitoring has inherent advantages and disadvantages and selecting the most appropriate approach can be driven by project goals and data requirements, funding, or time constraints.

Remote-based methods, more commonly called remote sensing, is the science of collecting information about objects or areas from afar without making physical contact or through on-site observations, and typically involves a sensor mounted to aircraft or satellite. Remote sensing technology has played an integral role in mapping the environment and land cover across various spatial and temporal scales for over 30 years (Townshend 1992). Some advantages associated with remote sensing are that the data collection process is fast (i.e., typically only requiring one to a few days of imagery acquisition) so labor hours are minimized, and data are collected across very large spatial extents that would be prohibitively time consuming to collect on the ground. Calibrated sensors also collect data in a consistent and repeatable manner that makes change detection studies or comparisons over time more defensible. The disadvantage of remote sensing techniques is the ability to detect fine scale information, such as individual species presence or understory condition, particularly in a shrubland community with overstory canopy obstructing view of the ground. Some species are also difficult to accurately distinguish from other species in a community because of the spectral similarities recorded by the sensor, making it difficult to differentiate some community types in imagery (Okin et al. 2001). This problem can be exacerbated in arid or semi-arid ecosystems where total vegetative cover is commonly less than 50% (Huete 1988). Timing remote sensing acquisitions to coincide with phases of vegetation senescence when the plant color becomes much more detectable from the background community is one strategy to minimize this limitation.

Field-based monitoring is the more traditional approach where crews navigate to sampling locations and record information on the ground while in the field throughout the treatment area. The clear advantage of this approach is that much more detailed data can be collected on a finer scale, and if there's any uncertainty, closer inspection or repeat observations can be done to verify the accuracy of the data. Field-based monitoring will almost always be more accurate at finer spatial scales compared to remote approaches. The inherent disadvantage of field-based approaches is that it takes considerably longer to collect data across large spatial extents, especially when travel time among sampling locations is considered. The increased time it takes to collect field-based data usually equates to greater costs to complete sampling, but the quality and accuracy of field data will expectedly be higher.

4.2.3.1 Remote Monitoring

A major consideration for remote sensing imagery acquisition is whether to use satellite-based sensors or airborne sensors for monitoring purposes. Satellite sensors acquire imagery on a fixed return cycle with varying intervals depending on the sensor. Because satellites are constrained to acquiring images within specific windows, the flexibility to task a sensor for unplanned data collection may be limited. Or a high priority satellite tasking request may incur additional fees for that service, thus increasing the overall cost of imagery.

Airborne sensors have the flexibility to fly on specific days and to avoid cloud cover by postponing flights until appropriate conditions occur. Commercial airborne acquisitions require advance notice for project/flight planning, and costs can increase substantially based on the number of standby days, which are dependent on weather conditions. There are statewide aerial acquisitions collected periodically through the U.S. Department of Agriculture's National Agriculture Imagery Program, and those data are made publicly available at no cost, offering an attractive solution to imagery needs. National Agriculture Imagery Program data could be used to support post-fire treatment or restoration monitoring depending on the monitoring goals, the timing of imagery required to address those goals, and the accuracy required.

The use of drones capable of carrying various sensor payloads has become more commonplace in the last 10 years and provides an alternative to traditional airborne data acquisitions. The INL Site has access to airborne drones with imaging capabilities that can take advantage of deployment flexibility while largely eliminating the standby and ferrying costs for fixed-wing airborne data collections. Some drone capabilities here at the INL Site are still in the research and development stages of testing, but as technology improves so may the potential to deploy drones for widespread monitoring.

While remote sensing can provide a lot of useful data, there are fundamental shortcomings when trying to use remote monitoring for all aspects of post-fire treatments. Sensor technology continues to evolve every year, as does software computational capabilities augmented by machine learning or artificial intelligence integration. In many cases, additional field-based data will still be needed to provide the level of detail required to adequately evaluate treatment progress. However, remote-based data collection can provide some early insight regarding the initial recovering condition or some preliminary results that may inform a field-based visit for further verification and data collection.

Cheatgrass Monitoring

Cheatgrass monitoring should begin in areas at risk of becoming dominated during the first growing season post-fire. Monitoring should continue for several years, as post-fire cheatgrass response has been shown to be delayed in some vegetation communities on the INL Site. Cheatgrass has a unique spectral response pattern in multispectral imagery throughout the growing season that allows it to be detected easier than most native grasses. This species produces considerable above-ground biomass early in the season before most native species, and then abruptly senesces where it appears reddish-purple while most native species are still green. The distinct visual difference between cheatgrass and native grasses makes it a good candidate to be monitored with remote sensing imaging technology and can be used to determine if cheatgrass abundance is increasing or decreasing over time.

Each of the imagery options would require some effort by a remote sensing/GIS analyst to analyze and process the data. Manual delineations in a GIS can provide the most spatially accurate results, however this method is influenced by the experience of the GIS analyst and can take more processing time than automated image classification methods. Because cheatgrass has a unique spectral signature, automated methods, such as supervised image classification, could be successful minimizing the time an analyst needs to process imagery and provides an unbiased repeatable method for continued monitoring through time.

Native Herbaceous Recovery Monitoring

Remote sensing can function as a rapid assessment tool to support native herbaceous recovery monitoring. Multispectral imagery can be used to detect increasing vegetative cover through the use of classification algorithms or various vegetation indices. Vegetation indices, such as the Normalized Difference Vegetation Index (Rouse et al. 1974), are mathematical combinations of spectral bands intended to highlight 'greenness' indicative of vegetation presence when compared to bare ground. If naturally recovering areas or treatment areas show a marked increase in 'greenness' it may be an early indication that vegetative cover is increasing. Imagery alone may not be accurate enough to differentiate individual species or functional groups (e.g., native grasses or non-native grasses) within areas showing increased cover but may assist identifying areas where further ground-based data collection could target. There are currently pilot studies underway at the INL Site to evaluate the capabilities of high-resolution imagery from drones to assess ongoing revegetation efforts, and lessons learned from those studies may support new applications in the future.

4.2.3.2 Field-Based Monitoring

Field-based monitoring is not intended to be of comparable rigor to a research program, but does require enough effort to be repeatable, defensible, and yield sufficient data to support decision making. Quantitative sampling is preferred, but semi-quantitative approaches may be sufficient for some applications that only require broad characterization. The sections below describe field-based monitoring options with some discussion of when they would be most appropriate and how they would be implemented.

Cheatgrass and Native Herbaceous Monitoring with Rapid Assessment Techniques
Field-based rapid assessment techniques use traditional field methods to collect useful data on measurable vegetation attributes to evaluate specific areas. While remote sensing techniques can provide a great overview of cheatgrass status across a larger area, finer-scale data will be required to evaluate the need for treatment at specific locations. Areas of poor native herbaceous recovery aren't as readily identified in imagery, so field-based techniques will be required to determine if planting is warranted in those at-risk locations as well.

Qualitative and semi-quantitative plot assessments are techniques designed to evaluate the post-fire plant community composition to identify changes in cheatgrass or native perennial abundance in the herbaceous stratum. Methods appropriate for monitoring cheatgrass and native herbaceous species include photoplots (e.g., Elzinga et al. 1998) combined, basic species lists, and ocular estimates for rank abundance of species or absolute cover of functional groups on a defined scale (Bonham 2013). Appropriate quantitative techniques include density frames, line interception, and point interception. When possible, techniques utilized for post-fire monitoring should align with techniques used for ongoing vegetation monitoring across the INL, resulting in data summaries that are more readily comparable to existing dataset.

Implementing a monitoring plan targeting cheatgrass changes and poor native recovery should begin the summer following fire and supported annually if pre-defined recovery objectives are not being met. If available, pre-fire data documenting herbaceous conditions are useful to establish a baseline or known levels of herbaceous composition to assist in meeting certain recovery objectives. If cheatgrass begins to dominate the herbaceous stratum, herbicide treatment may be required. If native species presence declines, supplemental planting may be necessary. The monitoring approach for post-fire sagebrush planting will reflect the planting techniques that were used. Surveys to detect seedlings resulting from a seeding effort will differ from surveys used to estimate survivorship of planted seedlings.

Noxious Weed Surveys
Surveys should be routinely conducted within areas impacted by wildland fire to determine the presence, relative abundance and distribution of noxious weeds or invasive introduced species of concern. Priority for noxious weed surveys should be directed toward containment lines and those surveys should begin during the fall following the fire; the rest of the burned area should be surveyed beginning late spring next year. Field-based survey methods are most effective and should be conducted when plants are flowering. However, not all species flower at the same time; therefore, multiple surveys may be required to document distribution and for effective control.

Native Grass Recovery on Containment Lines
After containment lines have been reseeded with a native grass mix, it is appropriate to begin monitoring the results of the reseeding effort after the first growing season. The use of field-based rapid assessment techniques supports monitoring methods that are simple and easy to employ in the field. Native grass

recovery on containment lines should be monitored by appropriate methods to evaluate changes in the plant composition to meet recovery objectives. Suggested methods include photoplots, abundance ranking, presence/absence of species of interest, density frames, and a basic species list. Before work begins, a baseline should be established against which to measure change within vegetation composition as it may take several years for native grasses to meet recovery objectives.

Cheatgrass Abundance in Areas Treated with Chemical Herbicide

Remote sensing technology can be employed to initially evaluate whether the spatial extent of cheatgrass dominated areas has been reduced in response to treatment. To determine whether treatments have improved vegetation composition at a specific location, field-based rapid assessments should be able to detect directional changes of cheatgrass abundance before and after treatments. Generally, a combination of multiple methods is appropriate for monitoring cheatgrass including photoplots combined with density frames, point interception (e.g., Floyd and Anderson 1982), species lists, or rank abundance. Quantitative data from permanent plots already located in the area may provide absolute cover estimates to reasonably infer directional changes in cheatgrass abundance before and after treatments. An effective cheatgrass treatment monitoring plan should incorporate reasonable replication over an adequate spatial distribution to be able to interpret treatment results confidently within the context of the natural resource recovery objectives.

Sagebrush Establishment in Seeded Areas

A monitoring approach for an aerial seeding effort should include subsampling an adequate number of locations within the seeded area during late summer following winter application. Much of the initial mortality of seedlings would be expected during the first growing season, so monitoring later in the season will provide a more realistic approximation of initial establishment. Rapid assessment techniques can be used to efficiently estimate sagebrush establishment in seeded areas. The number of subsample locations, plot size, and shape should be considered for best estimating sagebrush establishment. Spatial distribution is also an important consideration for evaluating progress toward natural resource recovery objectives as seeding in some areas may be more successful than others. A monitoring approach for measuring sagebrush seeding efforts may include photo plots, presence/absence detection, or density frames to estimate seedling abundance. Results of seedling establishment monitoring should inform a decision about further restoration efforts as prescribed through an adaptive management framework.

Sagebrush Survivorship in Areas Planted with Seedlings

Seedling plantings are often easiest to assess during the fall, and because most of the expected mortality occurs during the first growing season, the most appropriate time to monitor sagebrush seedling survivorship is about one year after planting. Field-based assessments provide an efficient and straightforward option for describing overall sagebrush seedling condition and estimating survivorship. The method currently used for seedling monitoring on the INL Site involves collecting a subset of seedling locations as they are planted with a high-accuracy Global Positioning System receiver. The following year, seedling coordinates are revisited, and an observer collects data based on a ranking system to assess seedling vigor. Based on the data, a relative estimate of seedling survivorship can be obtained quickly with minimal effort. The acceptable survivorship results for the sagebrush seedling planting effort, with respect to natural resource recovery objectives should be evaluated against a defined benchmark.

4.2.4 Data Analysis and Sampling Design

When a monitoring plan is being developed, it is important to understand how the data will be used and the type of data analysis needed to determine natural recovery or treatment success. Once analysis objectives and goals are defined, the selection of the most appropriate field sampling techniques can be considered. Sampling plans are generally used to define the sampling methodology that will be used along with the amount of data required to evaluate success and the most appropriate distribution of samples across the area of interest.

The sampling plan should support a data collection process to produce objective, representative, and defensible information for the WFMC, DOE, and other stakeholders. Depending on funding availability, treatment goals, and the duration of treatment, each sampling plan will be tailored to suit project needs and will expectedly vary between different recovery plans. There are several considerations when designing a field sampling plan including plot-based or point-based surveys, sample size requirements, site selection and distribution, data variables, and data type, etc. and all those choices will need to be properly aligned with defined monitoring goals.

One of the first decisions addressed in a sampling plan is whether data will be collected on a plot basis or if point locations will be more appropriate. If a plot-based approach is taken, the size and shape of the plot will need to be determined to best address recovery or treatment objectives. The number of data points or plots sampled will need to be sufficient to meet sample size requirements and obtain enough statistical power to properly support the proposed analyses. The distribution of sampling locations should be widespread and representative of the recovering or treated area so the data can be interpreted as a meaningful gauge of success. In some cases, completely random or completely systematic sampling may be implemented, while other times sampling effort may be stratified across areas, or even directed to certain areas of concern or where previous results indicated lower success. Selecting the most appropriate field-based monitoring methods from the previous section will usually dictate the data variables and data types (e.g., a qualitative assessment using abundance ranks).

Data analysis results will be interpreted in comparison to the established benchmark for natural recovery or treatment evaluation. The annual reporting of monitoring activities will include a summary and discussion of documented success and challenges, and any modifications identified through an adaptive management context will be presented as options for future treatments.

4.2.5 Identify Areas with Deficiencies and Further Actions

Once sampling results are summarized and compared to the established benchmarks, areas where natural recovery is slow or poor or where treatments are not succeeding can be identified. There may be unknown or unanticipated reasons for some areas not to be recovering as well as adjacent treatment areas. Adaptive management principles support the potential to modify or adopt new actions or treatments in those areas showing deficient recovery.

It is beneficial to directly target the re-treated area to minimize project costs associated with additional treatment as well as avoid unintended consequences where recovering areas could be negatively impacted from repeated application. When possible, a causal factor analysis can be completed to isolate and understand the causes behind poor results and guide further treatment decisions. If a causal factor analysis is not feasible or yields inconclusive results, iterations of the adaptive management cycle through modified treatments may help improve success over time. Another alternative is to implement an active adaptive management approach, and through experimental research results may elucidate the underlying factors negatively influencing successful implementation in problematic areas.

Treatments can take many years to show progress in arid or semi-arid systems, so reasonable recovery times should be considered before additional actions are recommended. Current weather patterns and local site conditions, such as the soils and vegetation community present, should be considered when evaluating a recovery trajectory to set more realistic expectations.

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5. TEMPLATE FOR FIRE-SPECIFIC POST-FIRE NATURAL RESOURCE RECOVERY PLANS

The following section provides a general template for a post-fire natural resource recovery plan. Each subsection presents a summary of anticipated content that should be included in a plan.

5.1 Background

This section presents relevant information regarding the purpose and scope of the fire recovery plan. The section also includes summaries of INL natural resource guidance documents for consideration when preparing the post-fire recovery plan (e.g., CCA, BPP).

5.2 Ecological Resource Assessment

This section provides a summary of the ecological resources impacted by the wildland fire. Each summary is typically analyzed using the mapped outer boundary or burned area boundary spatial data layer to delineate the area impacted by the fire.

5.2.1 Fire Summary

The Fire Summary section should include specific details about the date of the fire, location, and fire suppression tactics employed particularly when bladed containment lines are created during fire-fighting activities. A map of the burned area should be included along with a description of the mapping process (e.g., imagery acquired and mapping methods) and a summary of total area burned in the fire. Occasionally, other wildland fire boundaries (i.e., initial outer containment line) are included on the map for comparison when the spatial data are available. A brief fire history of the area impacted may also be included when some of the burned area has also burned before in previous fires.

5.2.2 Soils

This section should summarize the impacts of wildland fire on the soil classes present within the burned area. A GIS is most commonly used to spatially delineate the soils impacted by wildland fire and to calculate summary statistics for each soil class within the burned area. The most recent INL soils GIS data layer (Olson et al. 1995) should be used for this analysis. A map or figure can be presented to visualize the spatial distribution of soil classes within the burned area. Any soil class that may be vulnerable to invasion by noxious weeds or may prove difficult for recovery efforts should be noted.

5.2.3 Vegetation

This section summarizes the impacts of wildland fire on the vegetation classes present within the burned area. A GIS is most commonly used to spatially evaluate vegetation classes burned by wildland fire and to calculate summary statistics for each class within the burned area. The most recent INL vegetation map GIS data layer (Shive et al. 2019) should be used for this analysis rather than a coarse regional dataset. A map or figure can be presented to visualize the spatial distribution of vegetation classes. When monitoring data are available, the pre-fire condition of vegetation classes is described to identify areas at risk of poor recovery post-fire. Any sensitive vegetation communities or SSP impacted by the fire should be identified, and any losses to sagebrush habitat should be considered due to CCA habitat trigger and sagebrush conservation bank (DOE and USFWS 2014).

5.2.4 Wildlife

This section summarizes the impacts of wildland fire on the potential wildlife present within the burned area. Current distributions of wildlife are usually unknown pre-fire, so previously documented locations or habitat associations can be used to infer what wildlife species may have been impacted by the fire. Any federally listed or state sensitive wildlife species with potential to occur within the fire boundary should be noted. Any sage-grouse leks that are located within the fire boundary should be reported and any potential effects to the sage-grouse population should be discussed in the context of potential impacts to the CCA population trigger (DOE and USFWS 2014).

5.3 Recovery Actions

This section will describe the proposed treatments associated with each of the four recovery objectives.

5.3.1 Soil Stabilization and Erosion Control

This section will describe the specific proposed treatment options for this recovery objective. A list of potential treatments is presented in Section 3.1.2 Treatments for Improving Post-Fire Recovery of Exposed Soils and subsections. Generally, only a subset of potential treatment options will be selected based on specific fire characteristics, what ecological impacts are identified, and funding availability and priorities.

5.3.2 Cheatgrass and Noxious Weed Control

This section will describe the proposed treatment options for this recovery objective. A list of potential treatments is presented in Section 3.2.2 Treatments for Limiting Post-Fire Weed Spread and subsections. Generally, only a subset of potential treatment options will be selected based on specific fire characteristics, what ecological impacts are identified, and funding availability and priorities.

5.3.3 Native Herbaceous Recovery

This section will describe the proposed treatment options for this recovery objective. A list of potential treatments is presented in Section 3.3.2 Treatments for Improving Post-Fire Herbaceous Recovery and subsections. Generally, only a subset of potential treatment options will be selected based on specific fire characteristics, what ecological impacts are identified, and funding availability and priorities.

5.3.4 Sagebrush Habitat Restoration

This section will describe the proposed treatment options for this recovery objective. A list of potential treatments is presented in Section 3.4.2 Treatments for Improving Post-Fire Recovery of Sagebrush Habitat and subsections. Generally, only a subset of potential treatment options will be selected based on specific fire characteristics, what ecological impacts are identified, and funding availability and priorities.

5.4 Post-Fire Monitoring

This section will describe the details of proposed post-fire monitoring activities.

5.4.1 Identify Monitoring Needs

This section will provide a written description of the proposed monitoring activities and associated treatment options for each natural resource recovery objective based on needs to monitor areas at risk of poor recovery and the condition of areas where treatments have been implemented. A timeline for when monitoring activities will commence and the most appropriate season for treatment should be included.

5.4.2 Develop Monitoring Plan

The section should include a description of the proposed monitoring plan, including proposed sampling plans and how they would be used to support the monitoring plan. The sampling plan should contain enough details regarding decisions about point or plot-based sampling, site selection, sample size considerations, data variables and data types that the WFMC, DOE, and stakeholders understand why certain methodologies are being proposed. The sampling plan should be thorough and contain enough information to be repeatable.

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6. REFERENCES

Allan, C., and G. H. Stankey. 2009. Adaptive Environmental Management. Vol. 351. New York, NY. Springer.

Anderson, J. E., and R. S. Inouye. 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs 71:531-556.

Anderson, J. E., and A. D. Forman. 2002. The Protective Cap/Biobarrier Experiment a study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory. STOLLER-ESER-46, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Anderson, J. E., K. T. Ruppel, J. E. Glennon, K. E. Holte, and R. C. Rope. 1996. Plant communities, ethnoecology, and flora of the Idaho National Engineering Laboratory. ESRF 005, Environmental Science and Research Foundation, Idaho Falls, ID.

Applestein, C., M. J. Germino, and M. R. Fisk. 2018. Vegetative community response to landscape-scale post-fire herbicide (Imazapic) application. Invasive Plant Science and Management. Doi: 10.1017/inp.2018.18.

Bagchi, S., D. D. Briske, B. T. Bestelmeyer, and X. Ben Wu. 2013. Assessing resilience and state-transition models with historical records of cheatgrass Bromus tectorum invasion in North American sagebrush-steppe. Journal of Applied Ecology, 50(5), pp.1131-1141.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin 34: 177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology, 19:173-183.

Barr, S., J. L. Jonas, and M. W. Paschke. 2017. Optimizing seed mixture diversity and seeding rates for grassland restoration. Restoration Ecology, 25(3), pp.396-404.

Blew, R. D., J. R. Hafla, J. Whiting, J. P. Shive, and A. D. Forman. 2010. Jefferson Fire Recovery: Options and Recommendations for Stabilizing the Burned Area and Addressing Habitat Conservation. STOLLER-ESER-137. Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Blew, R. D., and A. D. Forman. 2010. Tin Cup Fire recovery report. STOLLER-ESER-143, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Blew, R. D., S. Majors, and A. D. Forman. 2000. A Survey of Vegetation Recovery on Wildfire Containment Lines and an Ecological Evaluation of Pre-Suppression Firebreak Construction on the INEEL. STOLLER-ESER-83, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

BLM. 2007. Burned Area Emergency Stabilization and Rehabilitation. BLM Handbook H-1742-1.

BLM. 2004. Norman Fire Rehabilitation Plan and Environmental Assessment. ID-074-2004-003, Upper Snake River District – Eastside, Idaho Falls, ID.

Bonham, C.D. 2013. Measurements for terrestrial vegetation. John Wiley & Sons.

Bormann B. T., and G. H. Stankey. 2009. Crisis as a positive role in implementing adaptive management after the Biscuit Fire, pacific Northwest, USA. In Adaptive Environmental Management: A Practitioner's Guide (pp. 143-170). Dordrecht: Springer Netherlands.

Bower, A. D., J. B. St. Clair, and V. Erickson. 2014. Generalized provisional seed zones for native plants. Ecological Applications, 24: 913-919.

Boyles, J. G., and D. P. Aubrey. 2006. Managing forests with prescribed fire: implications for a cavity dwelling bat species. Forest Ecology and Management, 222: 108-115.

Boudell, J. E., S. O. Link, and J. R. Johansen. 2002. Effect of soil microtopography on seedbank distribution in the shrub-steppe. Western North American Naturalist, 62:14-24.

Brabec, M. M., M. J. Germino, D. J. Shinneman, D. S. Pilliod, S. K. McIlroy, and R. S. Arkle. 2015. Challenges of establishing big sagebrush (Artemisia tridentata) in rangeland restoration: effects of herbicide, mowing, whole-community seeding, and sagebrush seed sources. Rangeland Ecology & Management, 68:432-435.

Bradley, B. A., C. A. Curtis, E. J. Fusco, J. T. Abatzoglou, J. K. Balch, S. Dadashi, and M. N. Tuanmu. 2018. Cheatgrass (Bromus tectorum) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. Biological invasions, 20, pp.1493-1506.

Bradley, B. A. 2010. Assessing Ecosystem Threats from Global and Regional Change: Hierarchical Modeling of Risk to Sagebrush Ecosystems from Climate Change, Land Use and Invasive Species in Nevada, USA. Ecography, 33: 198-210

Bukowski, B. E., and W. L. Baker. 2013. Historical fire regimes, reconstructed from land-survey data, led to complexity and fluctuation in sagebrush landscapes. Ecological applications, 23(3), pp.546-564.

Bybee, B. F., and S. R. Williams. 2023. 2022 Breeding Bird Surveys on the Idaho National Laboratory Site. INL/RPT-23-71711, Idaho National Laboratory, Idaho Falls, ID.

Chambers, J. C., ed. 2016. Great Basin Factsheet Series 2016 - Information and tools to restore and conserve Great Basin ecosystems. Great Basin Fire Science Exchange. Reno, Nevada. 79 p.

Chambers, J. C., Bradley, B. A., Brown, C. S., D'Antonio, C., Germino, M. J., Grace, J. B., Hardegree, S. P., Miller, R. F., and Pyke, D. A. 2014. Resilience to stress and disturbance, and resistance to Bromus tectorum L. invasion in cold desert shrublands of western North America. Ecosystems, 17(2), 360-375.

Chambers, J.C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by Bromus tectorum? Ecological Monographs, 77(1), pp.117-145.

Chaney, L., B. A. Richardson, and M. J. Germino. 2017. Climate drives adaptive genetic responses associated with survival in big sagebrush (Artemisia tridentata). Evolutionary Applications 10:313-322.

Cholewa, A. F. and D. M. Henderson. 1984. A Survey and Assessment of the Rare Vascular Plants of the Idaho National Engineering Laboratory Site. The Great Basin Naturalist, 44(1), 140–144.

Clawson, K. L., J. D. Rich, R. M. Eckman, N. F. Hukari, D. D. Finn, and B. R. Reese. 2018. Climatography of the Idaho National Laboratory 4th edition.

Coates, P. S., M. A. Ricca, B. G. Prochazka, M. L. Brooks, K. E. Doherty, T. Kroger, E. J. Blomberg, C. A. Hagen, and M. L. Casazza. 2016. Wildfire, climate, and invasive grass interactions negatively impact an indicator species by reshaping sagebrush ecosystems. Proceedings of the National Academy of Sciences, 113(45), pp.12745-12750.

Colket, B., L. Hahn, and C. Murphy. 2009. 2008 Field inventory for special status plant species on BLM lands in the Little Lost River and Birch Creek Valleys, Idaho. Idaho Department of Fish and Game, Boise, ID. 111 pp. plus appendices.

Colket, E. C. 2003. Long-term vegetation dynamics and post-fire establishment patterns of sagebrush steppe. MS Thesis, University of Idaho, Moscow. 154 pg.

Connelly, J. W., S. T. Knick, C. E. Braun, W. L. Baker, E. A. Beever, T. J. Christiansen, K. E. Doherty, E. O. Garton, C. A. Hagen, S. E. Hanser, D. H. Johnson, M. Leu, R. F. Miller, D. E. Naugle, S. J. Oyler-McCance, D. A. Pyke, K. P. Reese, M. A. Schroeder, S. J. Stiver, B. L. Walker, and M. J. Wisdom. 2011. Conservation of greater sage-grouse: a synthesis of current trends and future management. In: S. T. Knick and J. W. Connelly (eds.), Ecology and Conservation of Greater SageGrouse: A Landscape Species and Its Habitats. pp. 549-563. University of California Press, Berkeley, California, USA.

Connelly, J. W., K. P. Reese, R. A. Fischer, and W. L. Wakkinen. 2000. Response of a sage grouse breeding population to fire in southeastern Idaho. Wildlife Society Bulletin, pp.90-96.

Consortium of Pacific Northwest Herbaria Specimen Database (CPNWH). 2023. Data provided by: Idaho State University, The Ray J. Davis Herbarium (IDS). https://www.pnwherbaria.org.

Courtney, R. F. 1989. Pronghorn use of recently burned mixed prairie in Alberta. The Journal of Wildlife Management, pp.302-305.

Creutzburg, M. K., J. E. Halofsky, J. S Halofsky, and T. A. Christopher. 2015. Climate change and land management in the rangelands of central Oregon. Environmental Management, 55, pp.43-55.

Crowl, T. A. T. O. Crist, R. R. Parmenter, G. Belovsky, and A. E. Lugo. 2008. The spread of invasive species and infectious disease as drivers of ecosystem change. Frontiers in Ecology and the Environment, 6: 238-246.

Dangi, S. R., P. D. Stahl, E. Pendall, M. B. Cleary, and J. S. Buyer. 2010. Recovery of soil microbial community structure after fire in a sagebrush-grassland ecosystem. Land Degradation & Development, 21(5), pp.423-432.

Dickinson, M. B., M. J. Lacki, and D. R. Cox. 2009. Fire and the endangered Indiana bat. In: Hutchinson, T.F., ed. Proceedings of the 3rd fire in eastern oak forests conference. 2008 May 20-22; Carbondale, IL. Gen. Tech. Rep. NRS-P-46. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 51-75.

Dierks, J., K. Denef, L. T. van Diepen, and M. A. de Graaff. 2019. Cheatgrass-associated AMF community negatively affects sagebrush root production but not C transfer to the soil. Plant and Soil, 436, pp.381-396.

DOE. 2003. Idaho National Engineering and Environmental Laboratory Wildland Fire Management Environmental Assessment. DOE-EA-1372.

DOE, 2023. DOE Standard Fire Protection. DOE-STD-1066-2023.

DOE-ID. 2018. Idaho National Laboratory Bat Protection Plan. DOE/ID-12002, U.S. Department of Energy Idaho Operations Office.

DOE-ID and USFWS. 2014. Candidate conservation agreement for greater sage-grouse (Centrocercus urophasianus) on the Idaho National Laboratory Site. DOE/ID-11514, U.S. Department of Energy Idaho Operations Office.

DOE-ID. 2004. INEEL Sagebrush Steppe Ecosystem Reserve: Final Management Plan, EA ID-074-02-067, and Finding of No Significant Impact, EA ID-074-02-067, U.S. Department of Energy Idaho, Operations Office, Idaho Falls, ID.

Douglas, J., T. Mills, D. Artly, D. Ashe, A. Bartuska, R. Black, S. Coloff, J. Cruz, M. Edrington, J. Edwardson, R. Gale, S. Goodman, L. Hamilton, R. Landis, B. Powell, S. Robinson, R. Schuster, P. Stahlschmidt, J. Stires, and van Wagtendonk. 2001. Review and Update of the 1995 Federal Wildland Fire Management Policy. Western Ecological Research Center.

Edgel, R. J., R. T. Larsen, J. C. Whiting, and B. R. McMillan. 2018. Space use, movements, and survival of pygmy rabbits in response to construction of a large pipeline. Wildlife Society Bulletin, 42(3), pp.488-497.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring & monitoring plant populations. US Department of the Interior, Bureau of Land Management.

Endangered Species Act of 1973. 16 U.S.C §§1531-1544.

Executive Order 14008. 2021. Tackling the Climate Crisis at Home and Abroad, January 27, 2021.

Executive Order 13751. 2016. Safeguarding the Nation from Impacts of Invasive Species, December 5, 2016.

Executive Order 436.1A. 2023. Departmental Sustainability, April 25, 2023.

Executive Order 13112. 1999. Invasive Species, February 8, 1999.

Faber-Langendoen, D., J. Nichols, L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe Conservation Status Assessments: Methodology for Assigning Ranks. NatureServe, Arlington, VA.

Federal Food, Drug, and Cosmetic Act (21 U.S.C. § 346a. (2008))

Federal Insecticide, Fungicide, and Rodenticide Act (7 U.S.C. §136 et seq. (1996)).

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996. An investigation on fire effects within xeric sage grouse brood habitat. Rangeland Ecology & Management/Journal of Range Management Archives, 49(3), pp.194-198.

Floyd, D. A., and J. E. Anderson. 1982. A new point interception frame for estimating cover of vegetation. Vegitatio 50:185-186.

Forman, A. D., C. J. Kramer, S. J. Vilord, J. P. Shive. 2021. INL Site 2020 Wildfires Ecological Resources Recovery Plan. VSF-ID-ESER-LAND-092, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Forman, A. D., J. R. Hafla, S. J. Vilord, J. P. Shive, K. N. Kaser, Q. R. Shurtliff, K. T. Edwards, and B. F. Bybee. 2020. Sheep Fire Ecological Resources Post-Fire Recovery Plan. VSF-ID-ESER-LAND-076, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Forman, A. D., and J. R. Hafla. 2018. The Idaho National Laboratory Site Long-Term Vegetation Transects: Updates through 2016. VSF-ID-ESER-LAND-003, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Forman, A. D. 2015. A Review of Special Status Plant Species on the Idaho National Laboratory Site. GSS-ESER-187, Education, and Research Program, Idaho Falls, ID.

Forman, A. D., J. R. Hafla, and R. D. Blew. 2013. The Idaho National Laboratory Site Long-Term Vegetation Transects: Understanding Change in Sagebrush Steppe. GSS-ESER-163, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Forman, A. D., R. D. Blew, and J. R. Hafla. 2010. The Idaho National Laboratory Site Long-term Vegetation Transects: A comprehensive review. STOLLER-ESER-126, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Forman, A. D., and J. R. Hafla. 2010. Big Lost River Trenches Revegetation Demonstration Project Progress Report and Formal Revegetation Assessment. STOLLER-ESER-125, Environmental Surveillance, Education, and Research Program Report, Idaho Falls, ID.

Foster, L. J., K. M. Dugger, C. A. Hagen, and D. A. Budeau. 2019. Greater sage-grouse vital rates after wildfire. The Journal of Wildlife Management, 83(1), pp.121-134.

Franklin, A. B., B. R. Noon, and T. L. George. 2002. What is habitat fragmentation?. Studies in Avian Biology, 25, pp.20-29.

Fusco, E. J., B. M. Rau, M. Falkowski, S. Filippelli, B. A. Bradley. 2019. Accounting for aboveground carbon storage in shrubland and woodland ecosystems in the Great Basin. Ecosphere, 10(8), p.e.02821.

Gaetani, M. S., K. Cook, and S. A. Leis. 2010. Fire effects on wildlife in tallgrass prairie. Natural Resource Report NPS/HTLN/NRR—2010/193. National Park Service, Fort Collins, Colorado.

Germino, M. J., C. R. Anthony, C. R. Kluender, E. Ellsworth, A. M. Moser, C. Applestein, and M. R. Fisk. 2023. Relationship of greater sage-grouse to natural and assisted recovery of key vegetation types following wildfire: insights from scat. Restoration Ecology, 31(3), p.e13758.Gaetani, M., K.

Cook, and S. Leis. 2010. Fire Effects on Wildlife in Tallgrass Prairie. U.S. National Park Service Publications and Papers. 237pp.

Germino, M. J., A. M. Moser, and A. R. Sands. 2019. Adaptive variation, including local adaptation, requires decades to become evident in common gardens. Ecological Applications 29 (2): info:doi/10.1002/eap.1842.

Germino, M. J., D. M. Barnard, B. E. Davidson, R. S. Arkle, D. S. Pilliod, M. R. Fisk, and C. Applestein. 2018. Thresholds and hotspots for shrub restoration following a heterogeneous megafire. Landscape Ecology, 33, pp.1177-1194.

Germino, M. J., J. Belnap, J. M. Stark, E. B. Allen, and B. M. Rau. 2016. Ecosystem impacts of exotic annual invaders in the genus Bromus. Exotic brome-grasses in arid and semiarid ecosystems of the western US: Causes, consequences, and management implications, pp.61-95.

Halford, D. K. 2003. Habitat fragmentation as a result of fire suppression: implications for wildland fire management on the Idaho Nation Engineering and Environmental Laboratory. Pages 75-79 in DOE. 2003. DOE-EA-1372, Idaho National Engineering and Environmental Laboratory Wildland Fire Management Environmental Assessment.

Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife society bulletin, pp.173-182.

Holling, C. S., editor. 1978. Adaptive Environmental Assessment and Management. John Wiley & Sons, New York, NY, USA.

Holmes, A. L., and W. D. Robinson. 2013. Fire mediated patterns of population densities in mountain big sagebrush bird communities. The Journal of wildlife management, 77(4), pp.737-748.

Holmes, A. L., 2007. Short-term effects of a prescribed burn on songbirds and vegetation in mountain big sagebrush. Western North American Naturalist, 67(2), pp.292-298.

Hovland, M., R. Mata-González, R. P. Schreiner, and T. J. Rodhouse. 2019. Fungal facilitation in rangelands: Do arbuscular mycorrhizal fungi mediate resilience and resistance in sagebrush steppe? Rangeland Ecology & Management, 72(4), pp.678-691.

Huete, A. R. 1988. A Soil-adjusted Vegetation Index (SAVI). Remote Sensing of Environment 25: 295-309.

Humphrey, L. D., and E. W. Schupp. 2001. Seed banks of Bromus tectorum–dominated communities in the Great Basin. Western North American Naturalist, pp.85-92.

IDFG. 2023. Draft Idaho State Wildlife Action Plan, Boise, ID, 427 pp.

Idaho Native Plant Society (INPS). 2022. INPS_Rare_Plant_List_2022_05_09.exl. Website https://idahonativeplants.org/rare-plants-list/.

ISDA. 2022. Rules Governing Pesticide and Chemigation Use and Application. Idaho State Department of Agriculture, Ag Resources Division, IDAPA02.03.03, Boise, ID, March 2022.

INL. 2024. Implementing the Candidate Conservation Agreement for Greater Sage-grouse on the Idaho National Laboratory Site: 2023 Full Report. INL/RPT-23-70807, Idaho National Laboratory, Idaho Falls, ID.

INL. 2023a. Idaho National Laboratory's Wildland Fire Protocol: Resource Assessment. GDE-769, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2023b. Implementing the Candidate Conservation Agreement for greater sage-grouse on the Idaho National Laboratory Site: 2022 Full Report. INL/RPT-23-70807, Idaho National Laboratory, Idaho Falls, ID.

INL. 2023c. 2022 Site Environmental Report Idaho National Laboratory. INL/RPT-23-74740, Rev 0, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2023d. INL Airspace Usage and Reporting. LWP-11108, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2022. Chemical Services Processes. LWP-8105, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2020a. Comprehensive Land Use and Environmental Stewardship Report Update. INL/EXT-20-57515, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2020b. Safety of Aviation Charter and Leasing Services. LRD-14104, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2020c. Commercial Aviation Services. Idaho National Laboratory Site, Idaho Falls, ID, LRD-14108.

INL. 2013. Sitewide Noxious Weed Management Plan. PLN-611, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2012. INL Revegetation Guide. GDE-8525, Idaho National Laboratory Site, Idaho Falls, ID.

INL. 2012. Idaho National Laboratory Wildland Fire Management Committee Charter. CTR-160, Idaho National Laboratory Site, Idaho Falls, ID.

Jones, T. A. 2017. Ecosystem restoration: recent advances in theory and practice. The Rangeland Journal, 39(6), pp.417-430.

Kramber, W. J., R. C. Rope, J. E. Anderson, J. E. Glennon, and A. Morse. 1992. Producing a vegetation map of the Idaho National Engineering Laboratory using Landsat thematic mapper data. Pages 217-226 in American Society for Photogrammetry and Remote Sensing/American Congress on Surveying and Mapping Annual Meeting Technical Papers Vol. 1.

Lawes, T. J., R. G. Anthony, W. D. Robinson, and G. A. Lorton. 2013. Movements and Settlement Site Selection of Pygmy Rabbits after Experimental Translocation. Journal of Wildlife Management 77(6): 1170-1181

Lawes, T. J., R. G. Anthony, W. D. Robinson, J. T. Forbes, and G. A. Lorton. 2012. Homing behavior and survival of pygmy rabbits after experimental translocation. Western North American Naturalist 72:569-581.

Lazarus, B. E., and M. J. Germino. 2019. An experimental test of weed-suppressive bacteria effectiveness in rangelands in southwestern Idaho, 2016-18. U.S. Geological Survey Open-File Report 2019-1050, 19 p.

Lord, J. M., and D. A. Norton. 1990. Scale and the spatial concept of fragmentation. Conservation Biology, 4(2), pp.197-202

Lysne, C. R., M. Pellant. 2004. Establishment of Aerially Seeded Big Sagebrush Following Southern Idaho Wildfires. Technical Bulletin 2004-01. Department of the Interior, Bureau of Land Management, Boise, ID.

Knick, S. T. 1999. Requiem for a sagebrush ecosystem. Northwest Science, Vol. 73, No. 1:53-57.

Knick, S. T., and J. T. Rotenberry. 1997. Landscape characteristics of disturbed sagebrush steppe habitats in southwestern Idaho (U.S.A.). Landscape Ecology 12:287-297.

Knight, E. C., N. A. Mahony, and D. J. Green. 2016. Effects of agricultural fragmentation on the bird community in sagebrush shrubsteppe. Agriculture, Ecosystems & Environment, 223, pp.278-288.

Mahood, A. L. and J. K. Balch. 2019. Repeated fires reduce plant diversity in low-elevation Wyoming big sagebrush ecosystems (1984–2014). Ecosphere, 10(2), p.e02591.

Mancuso, M., A. Halford, and K. Colson. (2019). Rare Plants of Idaho. U.S. Department of the Interior Bureau of Land Management, Idaho.

Maxwell, T. M., and M. J. Germino. 2022. The effects of cheatgrass invasion on US Great Basin carbon storage depend on interactions between plant community composition, precipitation seasonality, and soil climate regime. Journal of Applied Ecology, 59(11), pp.2863-2873.

McKay, J. K., C. E. Christian, S. Harrison, K. J. and Rice. 2005. "How local is local?"—a review of practical and conceptual issues in the genetics of restoration. Restoration Ecology, 13(3), pp.432-440.

Meyer, S. E., and T. W. Warren. 2015. Seeding big sagebrush successfully on Intermountain rangelands. Great Basin Factsheet Series Number 10. Sage Grouse Initiative. 5 p. http://www.sagegrouseinitiative.com/seeding-big-sagebrush-successfully-on-intermountain-rangelands/.

Meyer, S. E., 1994. Germination and establishment ecology of big sagebrush: implications for community restoration. Proceedings—ecology and management of annual rangelands. Gen. Tech. Rep. INT-313. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station, pp.244-251.

Mutter, M., D. C. Pavlacky Jr, N. J. Van Lanen, and R. Grenyer. 2015. Evaluating the impact of gas extraction infrastructure on the occupancy of sagebrush-obligate songbirds. Ecological Applications, 25(5), pp.1175-1186.

National Audubon Society. 2024. Important Bird Area List, National Audubon Society -> Important Bird Areas -> IBA List.

Norton, J. B., T. A. Monaco, J. M. Norton, D. A. Johnson, and T. A. Jones. 2004. Soil morphology and organic matter dynamics under cheatgrass and sagebrush-steppe plant communities. Journal of Arid Environments 57 (2004):445-466.

Noson, A. C., R. A. Schmitz, and R. F. Miller. 2006. Influence of fire and juniper encroachment on birds in high-elevation sagebrush steppe. Western North American Naturalist, 66(3), pp.343-353.

Okin, G. S., D. A. Roberts, B. Murray, and W. J. Okin. 2001. Practical limits on hyperspectral vegetation discrimination in arid and semiarid environments. Remote Sensing of Environment 77: 212-225.

Olson, G. L., D. J. Jeppesen, and R. D. Lee. 1995. The Status of Soil Mapping for the Idaho National Engineering Laboratory. INEL-95/0051. Lockheed Idaho Technologies Co., Idaho Falls, Idaho.

O'Neil, S. T., P. S. Coates, B. E. Brussee, M. A. Ricca, S. P. Espinosa, S. C. Gardner, and D. J. Delehanty. 2020. Wildfire and the ecological niche: Diminishing habitat suitability for an indicator species within semi-arid ecosystems. Global Change Biology, 26(11), pp.6296-6312.

O'Shea, T. J., Cryan, P. M., Hayman, D. T., Plowright, R. K. and Streicker, D. G. 2016. Multiple mortality events in bats: a global review. Mammal review, 46(3), pp.175-190.

Perry, R. W. 2012. A review of fire effects on bats and bat habitat in the Eastern Oak Region. In: Day, D.C., Stambaugh, M.C., Clark, S., Schweitzer, L., (Eds.), Proceedings of the 4th fire in Eastern oak forests conference. USDA Forest Service General Technical Report NRS-P-102, pp. 170–191.

Pierce, J. E., R. T. Larsen, J. T Flinders, and J. C. Whiting. 2011. Fragmentation of sagebrush communities: does an increase in habitat edge impact pygmy rabbits?. Animal Conservation, 14(3), pp.314-321.

Pimentel, D., Zuniga, R., and D. Morrison. 2005. Update on the environmental and economic cost associated with alien-invasive species in the United States. Ecological Economics 52. pp 273-288.

Plant Protection Act (7 U.S.C. § 7701 et seq. (2000)).

Pollinator Health Task Force. 2015. National Strategy to Promote the Health of Honey Bees and Other Pollinators. The White House.

Prado-Tarango, D. E. 2021. Mycorrhizal Fungi on the Sagebrush Steppe: Benefits for Restoring Keystone Rangeland Plant Species. Rangeland Ecology and Management.

Prevey, J. P., M. J. Germino, and N. J. Huntly. 2010. Loss of foundation species increases population growth of exotic forbs in sagebrush steppe. Ecological Applications 20(7): 1890-1902.

Prodgers, R. A. 2013. Case study: fitness more than diversity guides vegetational recovery. Journal of the American Society of Mining and Reclamation, 2(2), pp.113-141.

Pyke, D. A., S. E. Shaff, M. A. Gregg, and J. L. Conley. 2020. Weed-suppressive bacteria applied as a spray or seed mixture did not control Bromus tectorum. Rangeland Ecology & Management, 73(6), pp.749-752.

Pyke, D. A., J. C. Chambers, M. Pellant, S. T. Knick, R. F. Miller, J. L. Beck, P. S. Doescher, E. W. Schupp, B. A. Roundy, M. Brunson, and J. D. McIver. 2015. Restoration handbook for sagebrush steppe ecosystems with emphasis on greater sage-grouse habitat—Part 1. Concepts for understanding and applying restoration: U.S. Geological Survey Circular 1416, 44 p.

Ratzlaff, T. D., and J. E. Anderson. 1995. Vegetal recovery following wildfire in seeded and unseeded sagebrush steppe. Journal of Range Management 48:386-391.

Rau, B. M., D. W. Johnson, R. R. Blank, A. Lucchesi, T. G. Caldwell, and E. W. Schupp. 2011. Transition from sagebrush steppe to annual grass (Bromus tectorum): influence on belowground carbon and nitrogen. Rangeland Ecology & Management, 64(2), pp.139-147.

Reinhart, K. O., C. H. Carlson, K. P. Feris, M. J. Germino, C. J. Jandreau, B. E. Lazarus, J. Mangold, D. W. Pellatz, P. Ramsey, M. J. Rinella, and M. Valliant. 2020. Weed-suppressive bacteria fail to control Bromus tectorum under field conditions. Rangeland Ecology & Management, 73(6), pp.760-765.

Richards, J. H. and Caldwell, M. M., 1987. Hydraulic lift: substantial nocturnal water transport between soil layers by Artemisia tridentata roots. Oecologia, 73, pp.486-489.

Richardson, B. A. and L. Chaney. 2018. Climate-based seed transfer of a widespread shrub: population shifts, restoration strategies, and the trailing edge. Ecological Applications, 28(8), pp.2165-2174.

Riginos, C., T. A. Monaco, K. E. Veblen, K. Gunnell, E. Thacker, D. Dahlgren, and T. Messmer. 2019. Potential for post-fire recovery of Greater Sage-grouse habitat. Ecosphere, 10(11), p.e02870.

Rivas, F. J. 2006. Polycyclic aromatic hydrocarbons sorbed on soils: a short review of chemical oxidation-based treatments. Journal of Hazardous Materials, 138(2), pp.234-251.

Roerick, T. M., J. W. Cain III, and J. V. Gedir. 2019. Forest restoration, wildfire, and habitat selection by female mule deer. Forest Ecology and Management, 447, pp.169-179.

Rosentreter, R., N. L. Shaw, M. L. Pellant, and S. B. Monsen. 2005. Sagegrouse habitat restoration symposium proceedings; 2001 June 4–7; Boise, ID. Proceedings RMRS-P-38. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station

Rouse, J. W., R. H. Haas, J. A. Schnell, and D. W. Deering. 1974. Monitoring Vegetation Systems in the Great Plains with ERTS in Proceedings, Third Earth Resources Technology Satellite-1 Symposium, Greenbelt: NASA SP-351, 3010-317.

Sankey, J. B., M. J. Germino, and N. F. Glenn. 2012. Dust supply varies with sagebrush microsites and time since burning in experimental erosion events, J. Geophys. Res., 117, G01013, doi:10.1029/2011JG001724.

Sankey, J. B., N. F. Glenn, M. J. Germino, A. I. N. Gironella, and G. D. Thackray. 2010. Relationships of aeolian erosion and deposition with LiDAR-derived landscape surface roughness following wildfire. Geomorphology 119:135-145.

Sankey, T. T., C. Moffet, and K. Weber. 2008. Postfire recovery of sagebrush communities: assessment using SPOT-5 and very large-scale aerial imagery. Rangeland Ecology & Management, 61(6), pp. 598-604.

Sauer, J. R. and W. A. Link. 2011. Analysis of the North American breeding bird survey using hierarchical models. The Auk, 128(1), pp.87-98.

Schuyler, E. M., C. A. Hagen, C. R. Anthony, L. J. Foster, and K. M. Dugger. 2022. Temporal mismatch in space use by a sagebrush obligate species after large-scale wildfire. Ecosphere, 13(9), p.e4179.

Schuman, G. E., D. T. Booth, and J. R. Cokrell. 1998. Cultural methods for establishing Wyoming big sagebrush on mined lands. Journal of Range Management 51:223-230.

Shive, J. P., A. D. Forman, A. Bayless-Edwards, K. Aho, K. N. Kaser, J. R. Hafla, and K. T. Edwards. 2019. Vegetation Community Classification and Mapping of the Idaho National Laboratory Site 2019. VSF-ID-ESER-LAND-064, Environmental Surveillance, Education, and Research Program, Idaho Falls, ID.

Shive, J. P., A. D. Forman, K. Aho, J. R. Hafla, R. D. Blew, and K. T. Edwards. 2011. Vegetation community classification and mapping of the Idaho National Laboratory Site. GSS-ESER-144, Environmental Surveillance, Education, and Research Program Report, Gonzales-Stoller Surveillance LLC, Idaho Falls, ID.

Shriver, R. K., C. M. Andrews, D. S. Pilliod, R. S. Arkle, J. L. Welty, M. J. Germino, M. C. Duniway, D. A. Pyke, and J. B. Bradford. 2018. Adapting management to a changing world: Warm temperatures, dry soil, and interannual variability limit restoration success of a dominant woody shrub in temperate drylands. Global Change Biology, 24(10), pp.4972-4982.

Takatori, S. K., R. Hirnyck. 2019. Idaho Pesticide Applicator Training Manual. University of Idaho Extension. Moscow, ID, January 2019.

Townshend, J. R. G. 1992. Land cover. International Journal of Remote Sensing 13: 1319-1328.

Tyrrell, E. A., P. S. Coates, B. G. Prochazka, B. E. Brussee, S. P. Espinosa, and J. M. Hull. 2023. Wildfire immediately reduces nest and adult survival of greater sage-grouse. Scientific reports, 13(1), p.10970.

United States, 1983. The Endangered Species Act as amended by Public Law 97-304 (the Endangered Species Act amendments of 1982). Washington: U.S. G.P.O.

United States Department of the Agriculture, Natural Resources Conservation Service. 2024. Web Soil Survey, https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.

United States Department of the Interior (DOI) Bureau of Land Management (BLM). 2008. Manual 6840, the Special Status Species Management Manual for the Bureau of Land Management.

Waldron, B. L., K. B. Jensen, A. J. Palazzo, T. J. Cary, J. G. Robins, M. D. Peel, D. G. Ogle, and L. S. John. 2011. 'Recovery', a new western wheatgrass cultivar with improved seedling establishment on rangelands. Journal of plant registrations, 5(3), pp.367-373.

Walters, C. J., and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71: 2060-2068.

Walters, C. J. 1986. Adaptive management of renewable resources. McMillan, New York, NY, USA.

Williams, B. K., and E. D. Brown. 2014. Adaptive management: From more talk to real action. Environmental Management 53: 465-479.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of Interior Technical Guide. Adaptive management Working Group, U.S. Department of Interior, Washington, D.C.

Yonkofski, C. M., D. Appriou, X. Song, J. L. Downs, C. D. Johnson, and V. C. Milbrath. 2018. Water Application for Dust Control in the Central Plateau: Impacts, Alternatives, and Work Strategies (No. PNNL-28061). Pacific Northwest National Laboratory (PNNL), Richland, WA (United States).

Young, J. A., R. A. Evans and D. Palmquist. 1990. Soil surface characteristics and emergence of big sagebrush seedlings. Journal of Range Management 43:358-367.

Zaller, J. G., F. Heigl, L. Ruess, and A. Grabmaier. 2014. Glyphosate herbicide affects belowground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. Scientific reports, 4(1), p.5634.